

Drone Pesticide Application Manual

End-to-End Solution for
Pesticide Application with Drone.

2025

FOREWORDDRONE PESTICIDE
APPLICATION MANUAL

The adoption of drone technology in agriculture marks a significant advancement for farming systems across Asia. Drones offer an opportunity to improve the precision, efficiency, and safety of pesticide application, supporting the goals of sustainable food production and environmental protection.

At the same time, this innovation requires responsible management. Proper training, compliance with regulatory requirements, and a strong sense of stewardship are essential to ensure applications are both safe and effective. It is therefore imperative that all operators and service providers adhere to established safety protocols and best practices.

This manual has been developed to provide clear, practical guidance for farmers, operators, and service providers in the responsible use of drones for pesticide application. It brings together technical know-how, regulatory considerations, and best practices to support safe operations and sustainable outcomes.

By embracing these principles, we can harness the full potential of drone technology – strengthening agricultural productivity, safeguarding communities and ecosystems, and leading the way toward a more sustainable future for farming across Asia.

Ricky Ho

Director – Science & Regulatory Affairs
CropLife Asia

PREFACE



DRONE PESTICIDE
APPLICATION MANUAL

The CLA Drone Pesticide Application Manual 2025 is designed as a comprehensive, one-stop solution for all stakeholders seeking to master the art and science of pesticide application using drones, from initial understanding to certified practice.

This manual offers an end-to-end guide that begins with a fundamental exploration of pesticides, delving into their types, modes of action, formulations, and the critical role they play in modern crop protection. Readers will gain insight into herbicides, insecticides, fungicides, and other agents, learning how to select the right product for specific pests, crops, and conditions. The manual also details the structure and significance of pesticide labels, ensuring users comprehend and comply with the vital information these labels provide for safe and effective use.

Recognizing that safety is paramount, this manual thoroughly addresses the safe handling, storage, and disposal of pesticides. It outlines best practices for minimizing risks to human health and the environment, including the use of personal protective equipment (PPE), first aid protocols, and procedures for dealing with accidental spills or exposure. The manual emphasizes the importance of complying with local and international safety standards, fostering a culture of responsibility among operators and service providers.

At the heart of this manual lies drone-based spraying a sophisticated, technology-driven approach to pesticide application. Detailed guidance is provided on selecting appropriate drone models, calibrating spray systems, and optimizing parameters such as droplet size, flight altitude, and speed. The manual addresses the influence of environmental variables (such as wind speed, humidity, and temperature inversions) on spray efficacy and drift, equipping users to adjust operations for maximum on-target accuracy while protecting sensitive areas.

As the use of drones in agriculture intersects with both aviation and agrochemical regulations, the manual includes up-to-date information on the regulatory framework governing drone pesticide application across multiple regions. It offers step-by-step guidance on obtaining the necessary certifications, including pilot licensing, pesticide applicator credentials, and operational permits.

PREFACE



DRONE PESTICIDE
APPLICATION MANUAL

The manual also outlines the requirements for training, continuing education, and recertification, ensuring that operators remain compliant with evolving legal and technical standards.

By bringing together scientific knowledge, technical expertise, regulatory guidance, and actionable protocols, the CLA Drone Pesticide Application Manual 2025 empowers farmers, service providers, agronomists, and policymakers to harness the full potential of drone technology in crop protection. Whether you are new to drone operations or seeking to refine your practice, this manual serves as your trusted resource for achieving safe, efficient, and compliant pesticide application—every step of the way.

We invite you to explore this manual as your gateway to the future of sustainable agriculture, where technology and stewardship go hand in hand.

Crop Life Asia
Drone Task Force

Kranthi Kumar | Pamela Wang | Rishelle Wang | Varun Goel
Rizki Arneldi Vicki | Rachel Pang | Asad Ali | Shbaita Haytham
Bharanideepan | Putra Candra | Chandrashekhar Kulkarni | Ray
Xie | Charlie Ni.

Table of Sections

Section	Topic	Page
1	Overview of Manual	1
2	Understanding of Pesticides	5
3	Safe Handling of Pesticides	13
4	Basic Requirements of Drones	21
5	Product Efficacy and Feasible Formulations	26
6	Prep to Perfection – Pre-application Knowledge	32
7	Spray Smart – Essentials for Perfect Spray (During Application)	50
8	Post Application Measures	59
9	Skills and Trainings Required for Operators	63
10	Regulatory Framework	71
11	Certification of Operators / Drone Spray Service Providers	99
12	References	126



Overview of Manual

This manual, developed by the Crop Life Asia, provides a comprehensive guide for individuals and organizations involved in the application of pesticides using drones often referred as unmanned aerial vehicles (UAVs). It aims to ensure the effective, safe, and sustainable use of drones in agricultural practices while emphasizing the critical need for training, stewardship, and adherence to regulatory standards. The manual focuses on the following 5 key areas

1. Pesticides Knowledge

A foundational understanding of pesticides is essential for their effective and responsible use.

- **Types and Characteristics:** Overview of pesticides, including insecticides, herbicides, and fungicides, and their targeted functions.
- **Efficacy and Compatibility:** Selecting the right pesticides for specific crops and evaluating compatibility with drone spray technology.
- **Safety and Environmental Standards:** Adhering to legal requirements for handling, storage, and application.

2. Understanding Drones

provides insights into drones as powerful tools for modern agricultural practices:

- **Components and Capabilities:** Understanding drone structures, navigation systems, and pesticide delivery mechanisms.
- **Precision and Versatility:** Leveraging drones for variable-rate application and site-specific crop management.
- **Operational Guidelines:** Step-by-step protocols for pre-flight checks, calibrations, and efficient operations.
- **Maintenance:** Best practices for upkeep and troubleshooting to ensure longevity and reliability.

3. Safety and Environmental

Mastery of drone application technology is key to effective pest control. This section includes:

- **Nozzle Selection and Calibration:** Ensuring even distribution and minimizing drift with appropriate equipment settings.
- **Droplet Dynamics:** Understanding droplet size, deposition patterns, and coverage to optimize pesticide efficacy.
- **Flight and Spray Planning:** Guidelines for mapping spray zones, adjusting for weather conditions, and executing efficient spray.

4. Stewardship Topics While Handling Drones

Safe and responsible use of drones is essential for long-term sustainability. This section addresses:

- **Environmental Protection:** Strategies to mitigate impacts on non-target organisms and ecosystems.
- **Operator safety:** Precautions and PPE recommendations while mixing and loading and cleaning.
- **Incident Management:** Procedures for addressing spills, malfunctions, or regulatory non-compliance.
- **Disposal:** process of handling and disposal of the chemicals

5. Training and Certification of Drone Spray Service Providers and Drone operators

Proper education and certification are fundamental for safety, compliance, and efficiency.

Key topics include:

- **Enhancing Accountability:** How certification ensures compliance, reduces liability, and enhances credibility.
- **Government-Mandated Standards:** Overview of certification requirements for DRONE operators engaged in pesticide application.
- **Training Programs:** Comprehensive modules covering DRONE operations, pesticide handling, and safety measures.
- **Certification:** Certification based on proper training and testing knowledge after training.
- **Recertification Professional Development:** Ensuring operators stay updated with advancements in technology and regulatory updates.

Drones in Agriculture

Drones, or unmanned aerial vehicles, have emerged as transformative tools in pest control by enabling precise and efficient application of pesticides, Drones can target specific areas while minimizing wastage:

Applications in to Control pest

1. **Precise Application:** Precisely spraying pesticides on pest-infested areas without affecting surrounding crops.
2. **Rapid Deployment:** Covering large fields quickly, saving time compared to manual methods.
3. **Remote Accessibility:** Reaching areas that are difficult or unsafe for ground-based equipment.
4. **Granule spreading, Monitoring and Mapping:** Identifying pest populations with sensors and providing data for integrated pest management (IPM)

Importance of Drone operators professionalization, certification

The agricultural sector has been revolutionized by the introduction of drones, as tools for precision farming. Among the many applications of drones, pesticide spraying is one of the most promising innovations. However, as this technology becomes mainstream, the role of professionalization and certification for drone operators and spray service providers cannot be overstated. Ensuring that drone operators possess the requisite knowledge, skills, and ethical commitment is vital for maximizing efficiency, safeguarding public health, and fostering trust in this evolving industry. This document provides framework from other countries on training and certification of the Drone Spray Service Providers and operators.

5. Benefits of Drone Application

Enhanced Precision

- Reduces over-application and minimizes pesticide drift, in comparison with aerial application.
- Targets specific areas to maximize effectiveness.

Efficiency and Speed

- Covers vast fields rapidly, improving operational timelines.
- Allows multiple flights per day for large-scale applications.

Cost-Effectiveness

- Saves labor costs, water and reduces pesticide wastage.
- Optimizes fuel usage compared to traditional machinery.

Environmental Protection

- Reduces the risk of pesticide contamination of non-target areas.
- Promotes sustainable farming practices.

Improved Safety

- Limits human exposure to harmful chemicals during application.
- Minimizes risks associated with manual handling of pesticides.
- Multifunctional Drones provide farmers with more convenient/efficient solutions to their problems.

Scope

Scope of drones specified in this manual include Drones, multi-rotor. Specifically, the best application practices in this document are based mainly on the knowledge, study and commercial adoption experiences on drone models like DJI drones like T10, T20, T30, T40, T20P, T50, T25; XAG drones like P20, XP2020, V40, P100pro and P100; EAvision drones like EA-30XP; YAMAHA and other major drone models in India., prevalent in Asia. The parameters set out in this document are based on an analysis of DJI and XAG's recommendations, CropLife Asia member companies' internal data and commercial adoption application experiences in China. Parameters should be updated periodically depending on main representative UASs in the market. Readers should therefore ensure that this training toolbox is adapted or supplemented by other country-specific needs and conditions, as relevant.

Objectives:

- I. To serve as a comprehensive reference document for national government agencies, drone operators, and other stakeholders involved in drone-based pesticide application.
- II. Provide detailed instructions on the safe handling, storage, and application of pesticides during spray by drones.
- III. Offer guidance and knowledge on drone Application technology like optimizing drone flight paths, spray patterns etc.,
- IV. Minimize risks to operators, the public, and the environment by promoting robust safety protocols.

6. Scope of Drone Manual

The purpose of this Drone manual is to provide comprehensive guidelines for the understanding, safe handling of pesticides, operation of Drones for pesticides, knowledge on maintenance of Drones, and effective spray requirements associated with the use of Drones in pesticide application. It aims to equip operators, spray service providers with the knowledge necessary to maximize efficiency, safety, stewardship best practices and compliance with regulatory standards. This manual is intended for both beginner and experienced Drone operators/spray service providers.



Crop Protection products

Crop protection chemicals, commonly known as pesticides a group of substances designed to protect crops from various pests, diseases, and other threats that can reduce yield and quality. These chemicals play a crucial role in modern agriculture, enabling farmers to sustain food production and meet the demands of growing populations.

1. **Herbicides:**
 - Target **weeds** that compete with crops for nutrients, water, light, and space.
 - Examples: Glyphosate, Atrazine.
2. **Insecticides:**
 - Used to kill or repel **insects** that feed on plants, spread diseases, or damage crops.
 - Examples: Pyrethroids, Neonicotinoids.
3. **Fungicides:**
 - Combat **fungal infections** like rusts, mildews, and blights that harm crops and reduce quality.
 - Examples: Mancozeb, Chlorothalonil.
4. **Rodenticides:**
 - These chemicals are used to control **rodents**, such as rats and mice, that consume or contaminate crops and stored grains.
 - Common active ingredients: Brodifacoum, Zinc phosphide.
5. **Acaricides:**
 - Specifically formulated to kill **mites and ticks** that affect plant health and productivity.
 - Examples: Abamectin, Bifenazate.
6. **Molluscicides:**
 - Target **slugs and snails**, which often damage seedlings, fruits, and crops like lettuce and wheat.
 - Examples: Metaldehyde, Iron phosphate.
7. **Nematicides:**
 - Used against **nematodes**—microscopic parasitic worms that damage roots and hinder nutrient absorption.
 - Examples: Fluopyram, Fenamiphos.
8. **Growth Regulators:**
 - Chemicals that alter the growth processes of plants to improve yields or manage harvest timings.
 - Examples: Gibberellic acid, Ethephon.

Classification by formulation

Formulation means the combination of various ingredients designed to render the product useful and effective for the purpose claimed and for the envisaged mode of application.

Components

- Active ingredient - the component with activity against pests
- Inert ingredients - components which have no activity against pests

Type of formulation

Emulsifiable Concentrates (EC)

- Liquid formulations where the active ingredient is dissolved in a petroleum solvent, or, more recently, safer alternatives.
- The formulation is diluted with water to form a suspension for application.
- Usually contains 25 to 75 percent of active ingredient.
- ECs are among the most common pesticide formulations.

Wettable Powders (WP)

- Dry formulations of fine, insoluble powders. The active ingredient is combined with an inert carrier such as clay or talc, together with wetting and / or dispersing agents.
- The formulation is diluted with water to form a suspension for application.
- Usually contains more than 50 percent active ingredient.
- WPs are among the most common pesticide formulations.

Suspension Concentrate (SC)

- Used for active ingredients that are not soluble in the more common solvents.
- They are mixed on a carrier, such as clay, and formulated with a liquid to form a thick, paste-like suspension.
- The formulation is diluted with water to form a suspension for application.
- Combine the benefits of both ECs and WPs.

Seed Dressings (DS, ES, FS, LS, PS, SS, WS)

- Dry or liquid formulations for application to seeds prior to planting.
- Dry formulations usually require no further dilution (SS formulations require dilution with water).
- Liquid formulations usually, but not always, require dilution with water.
- Seed may be available that is already dressed with a pesticide (PS formulations)

***DS**- Dry Seed Treatment, **ES**- Emulsion for seed treatment, **FS**-Flowable Concentrate, **LS**-Liquid Seed Dressing, **PS**- Powder for Slurry treatments, **WS**-Water Soluble powder.

Granules (G)

- Dry formulation of relatively large and heavy particles of an inert material.
- The active ingredient may be coated on the outside or absorbed into the particles.
- Applied without any further dilution.
- Usually contains 1 to 15 percent of active ingredient.
- Most commonly used for soil application to control weeds, nematodes, and soil-living insects.

Baits (B)

- An active ingredient mixed with food or other attractant material.
- The bait may be sold pre-mixed, or pesticide and bait material mixed by the user.
- Pests are killed by eating the pesticide contained in the bait, either in a single dose or over time.

- The concentration of active material is low, usually less than 5 percent.
- Commonly used in indoor situations but may be used in agriculture.

Fumigants (F)

- Pesticides that form poisonous gases.
- Maybe a liquid under high pressure that changes to a gas when released, or a volatile liquid, or a solid that releases a gas under high humidity.
- Used for structural pest control, food and grain storage, soil sterilization, and greenhouses

Formulation types applicable for UAS use

- Pesticide formulations (and their dilution stability) and adjuvants (on surface tension) also affect spray droplet deposition, efficacy, and drift.
- Ultra-low volume (ULV) formulations applied through ULV nozzles are the obvious choice if available. This helps to address the limited flight time for UAVs and to make the application more efficient. In reality, there will be instances where regulations are not so prescriptive, and it is therefore important that the nozzles used are appropriate to the formulations.
- For more information on formulations applicable to drones, refer the formulation section in the application technology section.

Understanding of Pest (Insect, Disease and Weed)

What is a pest?

A pest is any organism that:

- Competes with humans, domestic animals or desirable plants for food or water.
- Injures humans, animals, desirable plants, structures, or possessions.
- Spreads disease to humans, animals, or plants. - Annoys humans or animals

A pest can be broadly defined as: Any organism which adversely affects man, his crops, his livestock, or anything he considers to be of value

The types of pests include:

- **Insects:** aphids, beetles, caterpillars, ants, mosquitoes, cockroaches, etc. Insect-like organisms: mites, spiders, ticks, etc.
- **Weeds:** any plant growing where it is not wanted.
- **Micro-organisms that cause disease:** bacteria, fungi, viruses, etc.
- **Parasitic weeds:** Orobanche (broomrape), Striga (witchweed), Cuscuta (dodder), etc.
- **Molluscs:** slugs, snails, etc.
- **Rodents:** rats, mice, etc.
- **Nematodes:** root-knot nematode, etc.

Insects and their damage

The animal groups of the greatest importance as agricultural pests are (in order of economic importance) insects, mites, nematodes and gastropod mollusks. Insects are responsible for two major forms of damage to crops:

- First, there is the direct injury they cause to the plants as they feed on the tissues; a reduction in leaf surface available for photosynthesis, distortion of growing shoots, a diminution of the plant's growth and vigour, and the wilting of shoots and branches caused by the insects' tunneling activities.

- Secondly there is the indirect damage, where the insects do little direct harm, but either transmit or allow entry of fungal, bacterial or viral infections.

Although some insects are polyphagous, many are restricted to one specific crop, or group of crops. In many cases, it is the larva that feeds on the plant, building up a nutritional store that will be used by the short-lived adult; sawfly and lepidopteran larvae feed mainly on the aerial portions of plants while beetle larvae tend to live underground, feeding on roots, or tunnel into the stem or under the bark. The true bugs, Hemiptera, have piercing and sucking mouth parts and live by sucking sap from plants. These include aphids, whiteflies, and scale insects. Apart from weakening the plant, they encourage the growth of sooty mold on the honeydew the insects produce, which cuts out the light and reduces photosynthesis, stunting the plant's growth. They often transmit serious viral diseases between plants.

Disease and their damage

- Disease could be caused by fungi, bacteria, virus, nematodes, etc.
- Different fungi can attack different plants and plant organs, so fungal infections cause an enormous range of disease symptoms, such as color and shape changes, rotting, wounds, and wilting. Color changes can appear as leaf yellowing and can be accompanied by changes in leaf shape.
- Cell death causes parts of the plant to decompose and turns plant tissues into a dark color; this can appear as spots on leaves, or rotten spots on fruits. It usually caused 70% damage in veggies and fruits. Example: downy mildew.
- We can only reduce the damage by decreasing the spread of the disease to neighboring, healthy organs and plants. This means that prevention is the most effective way to manage plant diseases. To prevent fungal diseases, several methods can be used: the cultivation of fungus-resistant crop varieties, the use of appropriate farming practices, and the use of fungicides, which are chemical substances able to kill fungi.

Weeds and their damage

- The noxious incidence of undesirable plants, also known as weeds, is one of the major constraints to world agricultural production. Weeds are plants that under certain conditions cause economic and social harm to the farmers.
- In the agro-ecological context, weeds are a product of the inter-specific selection brought about by humans since they began cropping, which affected the soil and the whole habitat.
- The process of selection is continuous and depends on the practices adopted by the farmer.
- The present use of chemical herbicides has caused important changes of weed flora in cropping areas, including those of prevailing species as well as biotypes of other species becoming resistant to the commonly used chemical herbicides.

The damage caused by weeds is seen in various ways and seriously affects various agricultural processes. Weeds cause problems due to:

- competition with crops for nutrients, water and light
- the release of root exudates and foliar leachates toxic to crops
- the creation of a favorable habitat for the proliferation of other pests (arthropods, mites, pathogens, and others), serving as hosts for them
- interference with the normal harvesting process and contamination of produce

Major pest that can be controlled by pesticides

1. Insect

- Beetles, Caterpillars, Ants, Mosquitoes, Cockroaches, Mites, Nematodes, Arthropod mollusks, Sawfly, Lepidopteran (Spodoptera, fall armyworm, etc.), Hemiptera(aphids, whiteflies, scale insect)

2. Disease

- Disease caused from fungi Ascomycetes sp, Basidiomycetes sp, Deuteromycetes, and Oomycetes sp class. Such as Alternaria, pseudomonas, Pyricularia, etc.
- Plant disease can't be controlled by pesticides because of nutrient deficiency, drought, etc.

3. Weed

- Grasses (*Echinochloa* sp, etc.), broadleaf (*Boreria* sp, etc.), fern (*Axonopus* sp, etc.), Sedges (*Cyperus* sp, etc.)

Pesticide Label

The pesticide label provides crucial information that protects both the user and the environment. It serves as a guide to ensure the correct and safe usage of the product, minimizing the risks associated with pesticide application. Understanding the label helps in applying the right amount of pesticide at the right time and place, thereby preventing overuse or misuse, which can lead to contamination and resistance in pests.

Components of a Pesticide Label

A pesticide label is meticulously designed to provide all necessary information for safe handling and application. The key components include:

1. Product Identifier

The product identifier includes the brand name and the common name of the active ingredient. This information is crucial for recognizing the product and understanding its primary function.

2. Ingredients Statement

This section lists the active and inert ingredients along with their respective percentages. It helps users identify the chemical composition and assess the potential hazards.

3. Signal Words

Signal words like "Caution," "Warning," or "Danger" indicate the toxicity level of the product. They serve as immediate alerts to the user about the potential risk associated with the pesticide.

4. Precautionary Statements

Precautionary statements provide information on potential health risks and necessary protective measures. This section typically includes advice on personal protective equipment (PPE), first aid instructions, and environmental precautions.

5. Directions for Use

This section is perhaps the most vital, as it includes detailed instructions on how to apply the pesticide correctly. It specifies the target pests, application methods, rates, timing, and any restrictions to ensure safe and effective use.

6. Storage and Disposal Instructions

Proper storage and disposal are essential to prevent accidental exposure or environmental contamination. This section provides guidelines on how to store the pesticide safely and dispose of any unused product or container.

7. Manufacturer Information

This includes the name, address, and contact information of the manufacturer, allowing users to reach out for any additional information or in case of emergencies.

The Pesticide Label: The United Nations (UN) Food And Agricultural Organization (FAO) International Code of Conduct for Pesticide Management defines a pesticide label as “the written, printed or graphic matter on, or attached to, the pesticide or the immediate container thereof and also to the outside container or wrapper of the retail package of the pesticide”.

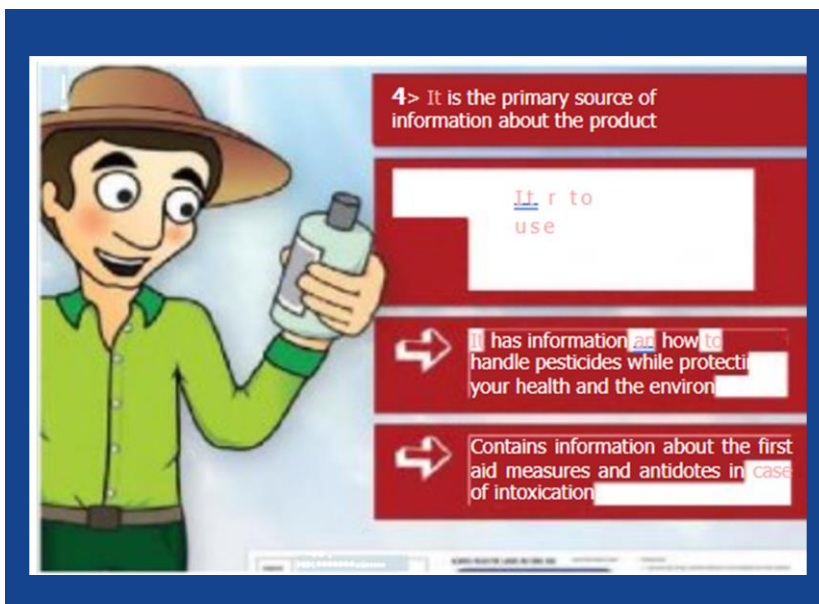
The label is a mandatory part of the product package. Additional information may be provided by means of a safety data sheet and/or a separate or “fold-out” leaflet which accompanies a container, in which cases these leaflets should be referred to on the label.

The label on the container is the primary source of information about pesticides. The label has all the basic information that is needed:

- Product name
- Active ingredient
- Concentration of active ingredient and inert materials
- Crops and pests for which the pesticide is registered
- Dose rates
- Toxicity and hazard warnings
- Safety precautions Pictograms
- Expiry date
- Registration number
- Name of manufacturer/importer
- Pre-harvest interval
- Information on the label is best broken up into smaller, separate sections. Each block of subject matter should have a clearly understood heading.
- Generally, the following subject sections are present on a label (although variations are possible):
- Product identity & Field of use
- Signal word, hazard statement(s), hazard symbol(s)
- Precautionary statements
- Directions for use
- Storage and disposal
- First aid and medical advice
- Advice on dealing with accidental spills

Within each section, the information should be structured in the sequence the user requires

Always read the pesticide label before use



Pictograms



Hazard Statements and Band Color

WHO Class (1)	Label		
	Hazard statement	Symbol	Band Colour (2)
Ia Extremely Hazardous	Very Toxic		VRed
Ib Highly Hazardous	Toxic		TRed
II Moderately Hazardous	Harmful		HYellow
III Slightly Hazardous	Caution	None	Blue
Products unlikely to present a hazard in normal use	Caution	None	Green

(1) The hazard warning on the label refers to the formulation, not the active ingredient.
 (2) This is the most commonly used colour scheme, but it may differ in some countries.

Purpose of the pesticide label and compliance

- Labels are the principal, and sometimes the only, contact between the manufacturer/supplier and the user of the product. They convey essential use recommendations and safety information.
- The label is the main information source explaining the identity and directions of use of the pesticide, i.e. for what purpose as well as where, when, and how it may be used. It may also state who is allowed to use the pesticide. In addition, the label informs the user about the hazards of the pesticide, and risks of its use, which should help the user to assess the actual risk of handling and applying the product under specific local conditions.
- The label is thus an important tool to protect human health and the environment. In many countries, pesticide labels are legal documents in that they are required by law to be put on a pesticide package.
- Generally, the (minimum) content and format of the label is defined by law. In such cases, all pesticide labels, and any modifications or variations, need to be approved by the responsible authority.
- As a result, pesticide labels are enforceable, and it will be a violation to use a pesticide product in a manner inconsistent with its labelling

Measures to prevent violations of the usage standards

Follow six right concepts for the application of pesticides:

1. **Right on target:** The pesticide used must be based on the type of pest that attacks. Before using pesticides, the first step that must be taken is to make observations to find out the type of pest that attacks. The next step is to choose the type of pesticide that fits the pest.
2. **Right pesticide:** One type of pesticide is not necessarily recommended to control all types of pests on all types of plants. Therefore, it is necessary to choose the type of pesticide that is recommended to control a type of pest on a type of plant.
3. **Right time:** Pesticide efficacy will be maximized when applied at the right time, for example by paying attention to weather conditions, thresholds, pest stadia (larvae or imago).
4. **Right dose:** The dosage or concentration of the formulation must be appropriate, namely in accordance with the recommendations because it is known to be effective in controlling the pest in a type of plant. The use of inappropriate dosages or concentrations of formulations will affect the efficacy of pesticides and leave residues on crop yields that can be harmful to consumers.
5. **Right way:** In general, the use of pesticides is applied by spraying. However, not all types of pests can be controlled by spraying. In certain types of pests and certain plants, pesticide application can be done by drenching, soaking, fogging, injection, etc.
6. **Right quality:** Appropriate quality means that the pesticides used must be of good quality. For this reason, pesticides that are registered and permitted by the Pesticide Commission are selected. Do not use pesticides that are not registered, expired, damaged or suspected to be fake because their efficacy is doubtful and can even interfere with plant growth.



Safe and proper use of agricultural chemicals

Agricultural chemicals, commonly referred to as crop protection products/Pesticides, play a pivotal role in contemporary agriculture. They are instrumental in managing weeds, pests, and diseases, thereby ensuring enhanced crop yields and quality. Nevertheless, their safe and proper utilization is paramount to safeguarding human health, the environment, and the efficacy of the products. This document delineates comprehensive guidelines for the purchasing, transportation, application, and disposal of agricultural chemicals in a safe and responsible manner.

Purchase or Procurement of Crop Protection Products

Selection of Appropriate Products

The selection of suitable agricultural chemicals commences with the identification of the specific requirements of your crops and the pests or diseases to be controlled. It is imperative to choose products that are registered and approved by relevant regulatory authorities, ensuring that they have undergone rigorous testing for safety and efficacy.

Reviewing Labels and Safety Data Sheets

Prior to procurement, it is essential to meticulously review the product labels and safety data sheets (SDS). These documents provide critical information regarding the chemical composition, usage instructions, safety precautions, and first aid measures. A thorough understanding of this information facilitates informed decision-making and preparation for safe handling.

Safe Transportation of Agricultural Chemicals Packaging and Containment

During the transportation of agricultural chemicals, it is essential to ensure that they remain in their original, labeled containers. These containers are specifically designed to prevent leaks and spills. Additionally, the chemicals should be kept in an upright position and securely fastened to prevent movement during transit.

Considerations for the Transport Vehicle

Utilize a vehicle equipped with a well-ventilated and separate cargo area for the transportation of chemicals, while transporting in bulk quantity. Avoid carrying chemicals in the passenger compartment to mitigate the risk of exposure in the event of a spill.

Emergency Preparedness

Preparation for emergencies is crucial; therefore, a spill response plan should be in place. Familiarize yourself with the procedures to follow in the event of a spill or leak, including containment and cleanup protocols. Ensure that the necessary equipment and materials are readily available to manage a spill effectively.

Personal Care/Hygiene and Safety

Personal Protective Equipment (PPE)

The use of appropriate personal protective equipment (PPE) is critical when handling agricultural chemicals. This includes gloves, goggles, respirators, and protective clothing. Always adhere to the manufacturer's recommendations for PPE, ensuring that it fits properly and is in good condition. Wear safety helmet when flying the drone.

Hygiene Practices

Adopt good hygiene practices when working with chemicals. Thoroughly wash your hands and face with soap and water after handling chemicals and before eating, drinking, or smoking. Change out of contaminated clothing and wash it separately from regular laundry.

Medical and First Aid

Be aware of the symptoms of chemical exposure and seek medical attention immediately if any adverse effects are experienced. Keep a first aid kit readily available and familiarize yourself with the first aid measures outlined in the product's SDS.

Safe Application of Agricultural Chemicals

Application Guidelines

Adhere to the application guidelines provided by the manufacturer to ensure the effective and safe use of agricultural chemicals. This includes following the recommended application rates, timing, and methods. Avoid applying chemicals during windy conditions to prevent drift and contamination of non-target areas.

Environmental Considerations

Be cognizant of the environmental impact of chemical use. Avoid applying chemicals near water sources, sensitive habitats, and areas with beneficial insects. Implement integrated pest management (IPM) practices to reduce reliance on chemicals and promote sustainable farming.

Record Keeping

Maintain detailed records of chemical use, including the product name, application date, rate, and area treated. This information aids in monitoring the effectiveness of the treatments and ensures compliance with regulatory requirements.

Safe Disposal of Agricultural Chemicals

Proper Disposal of Containers

Ensure that empty chemical containers are triple-rinsed and punctured to prevent reuse. Follow local regulations for the disposal of rinsed containers, as they may be accepted at designated recycling centers or disposal facilities.

Disposal of Unused Chemicals

Never dispose of unused chemicals by pouring them down the drain or dumping them on the ground. Contact local waste management authorities for guidance on the proper disposal of hazardous materials. Participate in community collection programs or return unused chemicals to the supplier if possible.

Environmental Protection

Implement measures to protect the environment when disposing of agricultural chemicals. Avoid contamination of soil, water, and air by adhering to best practices and regulations. Educate others in the community about the importance of safe chemical disposal.

Responsibilities of pesticide users

Pesticide users have a responsibility to ensure that their actions do not harm others, their property, themselves, or the environment. This responsibility includes managing the effects of drift, runoff, or residues. Users should also: comply with applicable legislation and familiarize themselves with the relevant safety information for the products they intend to use.

Basic of safety use

- Authenticity
- Read the label
- Personal protection equipment (PPE), worn and washed separately
- Equipment correctly calibrated
- Storage and transport
- Store pesticides in a locked cabinet or secure area, away from food, feed, or PPE
- Separate pesticides from passengers, groceries, or animal feed, and secure the containers to prevent spills during transport.
- Measure and mix pesticides in a well-ventilated area away from children, pets, toys, and food.
- Proper disposal
- Stored and transported in a container.
- All PPE should be removed, put into a container, and hands washed before getting into any vehicle to prevent contamination with pesticide residues.
- No mobile phones during application and wearing PPE.

Safe use for UAS application

Be aware of other situations that might result in exposure to pesticides on the job. Protect yourself not only during mixing, loading, and application, but also during spill clean-up, repairing and maintaining equipment, and when transporting, storing, or disposing of

pesticide containers that are open or have pesticides on their outer surface. Use PPE to prevent exposure.

Equipment (UAS)

- UAS in good condition (including sufficient battery level, undamaged propellers, fixed screws, etc.)
- SOPs and emergency tool kit for emergency situations
- Follow instructions of the UAS manufacturer

Application

- Do not eat, drink, and smoke
- Choose appropriate application techniques and equipment that will minimize exposure of personnel who may have to enter the treated areas, e.g. for maintenance work.
- Carry chemicals in their original packages in spill-proof containers during transport and while awaiting use.
- Avoid direct exposure of the containers to sunlight to prevent/minimize evaporation.
- It is recommended that you do not make spray applications alone and inform the farmers, growers, and beekeepers before the application
- Put up notices around the treated area giving information about re-entry interval (R.E. I.).
- Refer to label and leaflet for first aid information to assist the doctor in the events of accidental contamination.

Disposal

- Remaining liquid should be disposed of properly.
- Pick up and properly dispose of used containers and other items prior to leaving field.
- Rinse spraying equipment thoroughly (at least 3 times) after the application of each mixture- additional guidance are needed since rinse the whole machine and spray system are important. Follow manufacturers recommendation on the other maintenance, repair and storage.
- Drone cleaning: The drone surfaces, spray lines, tank and associated mixing equipment should be cleaned timely after application. Rinse the tank correctly, fully rinse the whole spray system and machine. Adding detergent to water to soak the spray system for 1-2 hours and then rinse the system at least 3 times.
- Use two tanks for drone, one use for herbicide application, another one use for other pesticides, PGR, and fertilizer's application.
- Dispose of rinsing liquid by spraying on discard areas. Refer to the UAS manufacturer guidelines for rinsing if any.
- Refer to the "FAO guidance on aerial application of pesticides" [y2766e00.pdf](#) for relevant sentences

Pesticides residues and safety assessment

What is pesticide residue?

“Any substance or mixture of substances in food for man or animals resulting from the use of a pesticide and includes any specified derivatives, such as degradation and conversion products, metabolites, reaction products, and impurities that are considered to be of toxicological significance.” – WHO definition

Toxicity assessment of pesticides residues

Although well known for their effectiveness, their impact on soil and environment, and the presence of residue in food products are matters of concern. The presence of pesticides residue cause the interruption in export and import. Agricultural produce has faced rejections and even bans in markets due to presence of higher levels of chemical residues than approved levels. The Organization for Economic Cooperation and Development (OECD) Pesticides Assessment and Testing Assessment of the toxicity of pesticide residues generally comprises:

- acute studies, short-term feeding studies, long-term feeding studies,
- biochemical studies,
- studies on specific effects, e.g., carcinogenicity, reproduction, teratogenicity, and, for some compounds, neurotoxicity, are usually necessary.

ADI and ARfD

- The **toxicological reference values** used in dietary risk assessment are the Acceptable Daily Intake (ADI) and the Acute Reference Dose (ARfD).
- ADI - estimate of the amount of a pesticide in food or drinking water that can be ingested daily over a lifetime without appreciable health risk to the consumer, on the basis of all known facts at the time of the evaluation. It is expressed in milligrams of the pesticide per kilogram of body weight.
- ARfD - estimate of the amount of a pesticide in food or drinking water that can be ingested over a period of 24 hours without appreciable health risk to the consumer, on the basis of all the known facts at the time of the evaluation. It is also expressed in milligrams of the pesticide per kilogram of body weight.
- Dietary risk assessment | Pesticide Registration Toolkit | Food and Agriculture Organization of the United Nations (fao.org)

Pesticide residues standards and limit

What are the maximum residue limits (MRLs)?

A Maximum residue limit (MRL) is the maximum concentration of a pesticide residue (expressed as mg/kg), to be legally permitted in or in food commodities and animal feeds. MRLs are based on Good Agricultural Practice (GAP) data and foods derived from commodities that comply with the respective MRLs are intended to be toxicologically acceptable. (FAO)

3.3.2. What is pesticide registration withholding limit?

The amounts of residues found in food must be safe for consumers and must be as low as possible.

International resources

1. Codex Alimentarius

The main principal international source of MRLs is the Codex Alimentarius. MRLs are set by the Codex Committee on Pesticide Residues (CCPR), based on recommendations made by the FAO/WHO Joint Meeting on Pesticide Residues (JMPR). MRLs can be found in the Codex pesticides in food online database. The database can be searched by pesticide common name or class as well as by commodity name of code

2. Global MRL Database

The United States Department of Agriculture (USDA) used to maintain an international database of MRLs. This database is now managed by Bryant Christie Inc., as the Global MRL database. A (free) registration is required to access this database. The free subscription only provides access to the U.S. MRLs.

3. European Union

The European Commission sets its MRLs applicable in the EU (referred to as maximum residue levels), which are not always the same as Codex MRLs.

Safety storage

- Keep out of reach of children and pets
- Store in the closed, original container
- Store in a cool, well-ventilated area away from direct sunlight, heat or open flame
- Never store pesticides together with food, water and feed

If there's any leakage in the field : Liquid leakage

- The spill should not be hosed down as this merely disperses the pesticide over a wider area.
- A supply of absorbent sawdust, sand, or dry soil should be kept in a container in the store.
- Nitrile rubber protective gloves and face masks should be worn.
- Sawdust, sand, or dry soil should be scattered over the area of the spill and left for a few minutes to soak up the chemical.
- The sawdust, sand, or dry soil containing absorbed spilled chemicals should be swept or shoveled up and placed in a marked container for disposal.

Solid spill

- Use absorbent materials such as sawdust, sand, or dry soil to absorb and remove chemicals from the fields, as sweep-up by non-absorbent material may cause dust further.
- Use tools such as shovels to remove contaminated soil in the field.
- Contaminated/absorbed materials need to be kept in a specific container for proper disposal later.

First aid response and management

- Hold eyes open and rinse slowly and gently with water for at least 15-20 minutes.
- Remove contact lenses (if present) after the first 5 minutes, then continue rinsing.

If swallowed

- Have the person sip a certain amount of water if possible.
- Do not induce vomiting unless told to do so by a doctor or medical professionals.
- Do not give anything by mouth to an unconscious person.

If on skin or clothing

- Take off contaminated clothing immediately.
- Rinse the skin with water for at least 15-20 minutes.

If inhaled

- Open doors and windows
- Move the person to fresh air.
- If the person is not breathing, giving artificial respiration is recommended.



Basic Requirements of Drone's

The use of drones in agriculture has transformed crop management, particularly in the precise application of pesticides. This guide provides an in-depth overview tailored to operators and drone spray service providers, on topics like drone equipment and maintenance, selection of drones, understanding spray equipment and nozzles, insurance considerations, pilot licensing and certifications, troubleshooting knowledge, and necessary registrations.

Drone Equipment and Maintenance

Types of Drone Equipment

Agricultural drones generally fall into two categories: fixed-wing drones and multi-rotor drones. Fixed-wing drones are suitable for extensive areas and extended flight durations, while multi-rotor drones offer superior maneuverability and precision, making them ideal for targeted pesticide applications.

Equipment and Maintenance

Regular maintenance is crucial for ensuring the durability and effectiveness of your drone. Key maintenance practices include:

- **Pre-flight Checks:** Examine the drone for visible damage, verify battery levels, ensure all components are securely attached, and test control systems.
- **Post-flight Checks:** Clean the drone to remove pesticide residues, inspect for wear and tear, and recharge batteries promptly.
- **Scheduled Maintenance:** Adhere to the manufacturer's recommendations for periodic maintenance, including firmware updates, motor inspections, and component replacements.

Proper maintenance of drones and spraying equipment ensures longevity, safety, and efficient operation.

Equipment Maintenance:

- Regularly inspect drone components such as propellers, motors, batteries, and GPS systems.
- Ensure proper cleaning of pesticide tanks, nozzles, and lines after each use to prevent clogging and contamination.
- Update firmware and software regularly for smooth operation and compatibility with new features.
- Maintain a logbook for tracking maintenance schedules, inspections, and repairs.

Spare Parts and Tools:

- Stock spare parts like propellers, batteries, and nozzles.

Keep essential tools

Selection of Drones for Pesticide Spray

Understanding Your Needs

Choosing the right drone for pesticide spraying involves considering factors such as the size of the treatment area, crop type, and specific pesticide requirements.

Key Features to Consider

When selecting a drone, evaluate the following features:

- **Payload Capacity:** Verify that the drone can carry sufficient pesticide liquid for efficient spraying without frequent refills.
- **Flight Time:** Opt for drones with longer flight times to reduce the frequency of battery changes, enhancing operational efficiency.
- **Spray System:** Look for drones equipped with advanced spraying systems that provide uniform distribution and adjustable flow rates.
- **GPS and Navigation Systems:** Ensure the drone has high-precision GPS and reliable navigation systems for accurate and consistent application.

Agricultural Drones

- The drone shall comply with the local related technical specification of quality evaluation for agricultural drones. It is recommended to use a precise navigation, obstacle avoidance and flight control system equipped with RTK centimeter-level positioning for route planning, terrain tracing flight, and real-time monitoring of drone.
- Registration of drone is a must, and all flight activities must strictly abide by the aviation laws and regulations of relevant countries and industries.
- Flight permits are needed.
- All local laws and regulations precede the above requirements.

Understanding Drone Spraying Equipment and Nozzles

Spraying Equipment

The spraying system includes tanks, pumps, hoses, and nozzles, each playing a critical role in achieving effective pesticide application.

Nozzles for Effective Spray

The selection of nozzles significantly affects the efficacy of pesticide application. Key considerations include:

- **Droplet Size:** Smaller droplets offer better coverage but are prone to drift, while larger droplets reduce drift but may not cover the area as thoroughly. Select a nozzle that balances coverage and drift control- Recommendation- Generally coarse to very coarse is recommended.
- **Spray Pattern:** Nozzles produce various spray patterns, such as fan or cone shapes; choose a pattern that suits your crops and application needs
- **Flow Rate:** Ensure the nozzle's flow rate aligns with the drone's capabilities and pesticide requirements. Use flow meters and variable rate technology (VRT) for efficient pesticide application.

Troubleshooting Knowledge

Operators must have basic troubleshooting skills to handle technical issues.

Common Problems:

- **GNSS Issues:** Resolve navigation errors by recalibrating or checking satellite connectivity.
- **Battery Failures:** Replace or recharge batteries and monitor battery health regularly.
- **Spraying System Malfunctions:** Check nozzles for blockages, ensure proper flow rates, and clean filters.
- **Connectivity Issues:** Re-pair controllers or replace antennas if signal loss occurs.

On-Site Repairs:

- Carry essential tools for repairing minor issues like loose connections or damaged propellers.
- Familiarize yourself with error codes and troubleshooting guides provided by the manufacturer. For topics that are not covered, please follow drone manufacturer guidance.

Operator

- Operators include pilots, safety officers and other application assistants. Operators should have a license issued by the state or related institutions and must accept professional training to master the basic rules of drones and the basic knowledge of crop protection. Besides operator, a safety officer or a vision observer is necessary. The knowledge of pesticide toxicity, PPE, correct knowledge of apply and store pesticides, pests and such like basic knowledge should be grasped before application.

- At least one of the operators must have received emergency training and be qualified as a first aider, the operating team must be equipped with a first-aid kit and receive corresponding emergency training. Before applying pesticides, it is necessary to master it.
- A helmet is needed for all operators.
- Related certification and documentation should be carried out with operators.
-

Insurance Considerations

Insurance coverage protects against potential risks and liabilities.

Equipment Insurance:

- Covers damage or theft of drones and spraying equipment.
- May include coverage for spare parts and accessories.

Operator Insurance:

- Provides protection against operator injuries during drone operation.
- May include coverage for health risks associated with pesticide exposure.

Bystander Insurance:

- Covers accidental injuries or property damage caused to third parties during drone operations.

Pilot License and Certifications

To ensure safe and legal operation, drone operators must meet licensing and certification requirements.

Pilot License:

- Obtain a Remote Pilot License (RPL) or equivalent certification as per national aviation authority requirements.
- Undergo training on drone operation, safety protocols, and emergency procedures.

Specialized Certifications:

- Certifications for agricultural drone operations, including pesticide handling and application techniques.
- Additional certifications for operating drones with advanced features like thermal imaging and multispectral sensors.

Drone Pilot License vs drone spray operator certification

A **Drone Pilot License** is an official authorization provided by a national aviation authority that allows an individual to legally operate a drone within specified conditions, Grants legal permission to operate a drone for specific uses (e.g., commercial, agricultural, or recreational). Ensures the operator understands and complies with national airspace regulations.

A **Certification of Drone Operator** is a credential that validates the professional competency of an operator to perform specialized tasks using drones like deep understanding of pesticides and how handle, spray pesticides using drones. Training, certification and recertification focuses on expertise in a particular domain (e.g., agriculture pesticide spraying)

Registration Requirements for Drone's

Drone registration is essential for compliance with government regulations.

National Aviation Authority Requirements:

- Register drones with the relevant aviation authority (e.g., FAA in the USA, DGCA in India).
- Provide details like drone make, model, and serial number during registration.

Identification Markings:

- Label drones with unique registration numbers for identification.
- Use tamper-proof labels or digital registration systems as mandated.

Permits and Approvals:

- Obtain specific permits for agricultural applications, such as aerial pesticide spraying.
- Adhere to altitude and area restrictions as specified by local regulations.

Renewal and Updates:

- Renew registrations periodically as per authority requirements.
- Update details in case of modifications to the drone or its usage



Product Efficacy and Feasible Formulations

Product Efficacy

The efficacy of products and the choice of formulations are critical for optimizing the performance of drone-based agricultural spraying. It ensures that the intended results, such as pest control, disease management, or nutrient delivery, are achieved with precision and minimal wastage. Focusing on the efficacy and feasible formulations for drone spraying is crucial for optimizing performance, reducing environmental risks, and achieving targeted results.

Proper application timing for pest

The application timing should be decided scientifically and properly. Following labels, local pesticide manufacturers and local government's forecast and guidance would be a good choice. For example, preventive application is always the 1st priority application timing for fungicide and earlier infestation stage of insects always the good time for insecticide application.

Droplet Size and Spray Quality

- Droplet Size Optimization: Ensures effective coverage while reducing drift.
- Nozzle Selection: Fine nozzles for fungicides, medium nozzles for herbicides, and coarse nozzles for insecticides.
- Spray Uniformity: Achieved through proper calibration of nozzles and drone speed

Weather and Environmental Considerations

- Wind Speed and Direction: Select formulations with drift-reducing properties in windy conditions.
- Temperature and Humidity: Formulations must maintain efficacy in various environmental conditions.
- Residue Management: Focus on formulations with minimal residue impact on soil and water

Pesticides and Formulations

- Refer to local laws and regulations and use pesticide safely and effectively. Pesticides should be registered and must follow local registration regulation laws.

Feasible Formulations

The choice of pesticides and their formulations is crucial in drone applications. Different pesticides and formulations have varying levels of efficacy, safety, and environmental impact.

Types of Pesticides

- Insecticides: Used to control insect pests that damage crops.
- Herbicides: Used to manage unwanted vegetation that competes with crops for nutrients, water, and light.
- Fungicides: Used to prevent and control fungal diseases that affect crop health and yield..

Formulations

Pesticides are available in various formulations, including liquid, granular, and powder forms. Liquid formulations are often preferred for drone applications due to their ease of mixing, uniform coverage, and compatibility with drone spray systems. Granular and powder formulations may require specialized equipment and application techniques to ensure uniform distribution.

Compatibility

Ensure that the chosen pesticide is compatible with drone spray systems. Some formulations may require specific nozzles or equipment settings to achieve optimal results. For example, micronized nozzles may be necessary for ultra-low-volume (ULV) applications, while hydraulic nozzles may be used for conventional volume applications.

Refer to local laws and regulations and use pesticide safely and effectively. Pesticides should be registered and must follow local registration regulation laws.

Choose feasible formulations on UAS application.

Qualified formulations should have:

- Good physical and chemical stability also at low water volumes. No oil/water separation, flocculation, precipitation and decomposition in the spray tank.
- Good physical compatibility.
- Excellent interface characteristics. Low evaporation and drift. Good dispersion, wetting, spreading and deposition on the crop.
- So, necessary study before using is important. Lots of studies have been conducted to validate the formulations feasibility on UAS application. Large areas of commercial adoption also shows some key learnings.

Below are the key findings and learnings:

- A. In Japan and Korea: most registered formulations are liquid formulations, WDG and GR. For example, 1212 products are registered for on UAS applications by April 2023 in Japan. Most registered formulations are liquid formulations, WDG and GR.
- B. Corteva tested EC, EW, ME, OD, SC, CS, CE, WDG, Bait formulations in the 306 trials. Liquid formulations are the most tested formulations. There are 214 trials in which we tested liquid formulations. They tested solid formulations in the remaining 92 trials. All these formulations showed very good technical feasibility on UAS application.

Table- Corteva tested formulations

Tested formulations by category				
Category Formulations		Total		
Fungicide	CS	1		
	ME	13		
	SC	48		
Fungicide Total		62		
Herbicide	EC	25		
	EC+OD	9		
	EW	24		
	OD	16		
	SC	21		
	WDG	41		
	Herbicide Total	136		
Insecticide	Bait	6		
	CE	4		
	SC	53		
	WDG	45		
	Insecticide Total	108		

Formulation Tested	
Formulation	Number
EC	25
Bait	6
CE	4
CS	1
EC+OD	9
EW	24
ME	13
OD	16
SC	122
WDG	86
Total	306

- C. Based on summarization on 33 published papers of China, scientists tested SC, WG, EC, ULV, SP, ME, WP, AS, SL formulations. All formulations showed good feasibility for UAS application. Most of the tested formulations are liquid formulations such as SC. Among the 33 examples, there are 6 solid products and 27 liquid products.
- D. Dr. Jun Zhang studies the formulation feasibility of the UAS application and gives us a general summary as summarized below.

Formulation Feasibility on UAS Detail requirement of UAS Application	
ULV	++++ can be directly used on UAS
AS	+++ Stability: Qualified after 20 times dilution
EW	+++ Stability: Qualified after 200 times dilution
SLX	+++ Stability: Qualified after 20 times dilution
ME	++ Stability: Qualified after 200 times dilution
SC	Wet Sieving test (75um) $\geq$ 98%, Suspensibility ++ $\geq$ 80%
OD	++ Wet Sieving test (75um) $\geq$ 98%

EC	Stability: Qualified after 200 times dilution, water ++ content $\leq 0.5\%$, the solvent must not be highly corrosive
WDG	++ Suspensibility $\geq 60\%$, wet timing $\leq 2m$
WDT	++ Suspensibility $\geq 60\%$, water content $\leq 3\%$
SLX	Degree of fineness ≥ 80 mesh sieve, wet timing + $\leq 2m$, water content $\leq 3\%$, wet sieving $\geq 98\%$.
WP	Degree of fineness ≥ 325 mesh sieve, diameter + $\leq 5\mu m$, wet timing $\leq 2m$, suspensibility $\geq 60\%$.
Micro encapsule	- Not suitable on UAS application
DP	- Not suitable on UAS application
FU - Not suitable on UAS application * The more +, the better formulation feasibility.	

Source : Jun Zhang, Pesticide and Formulation selection for pesticide application by UAS, China.

Choose feasible formulations on UAS application

Based on above studies, here are some general conclusions:

- Liquid formulations are better suited for applications with UAS than solid formulations.
- Use WP, SLX formulations with caution since they have a higher risk to block hydraulic nozzles.
- Formulations containing emulsifiers are likely to drift. Prudence is needed when such formulations are used for UAS application. For example, EC formulation is easier to evaporate, and drift compared with other formulations like SC, SL. Water-based formulations (like SC) can provide better anti evaporation attributes.
- Physical compatibility for the tested product with other representative tank mixing partners under low water volume should be tested at the very beginning.
- Centrifugal nozzle and hydraulic energy nozzle are two commonly used nozzles equipped on current drones. Centrifugal nozzle dominates the Chinese market now and it is suspected to be the future trend.
- Based on current experiences:
- Generally, both centrifugal and hydraulic energy nozzle can perform very well when using suitable formulations with drone applications, like ME, and SC formulations.
- However, hydraulic energy nozzles are easier blocked when spraying WP formulation compared with centrifugal nozzles. So, when spraying WP formulations, a centrifugal nozzle drone is recommended.
- Sometimes, centrifugal nozzle will also meet some problems when spray poor quality of WP and EC formulation.

- Therefore, nozzle blocking, and physical compatibility test are strongly suggested for test products in WP and EC formulation.

Adjuvants and Their Importance

Adjuvants are substances added to pesticide formulations to enhance their effectiveness. They play a crucial role in drone applications by improving spray characteristics and pesticide performance.

Types of Adjuvants

- **Surfactants:** Reduce surface tension, allowing better spreading and wetting of plant surfaces. Examples include non-ionic surfactants such as polysorbates and alkylphenol ethoxylates.
- **Drift Retardants:** Reduce pesticide drift, ensuring more precise application. Examples include polymer-based drift retardants such as polyacrylamide and hydroxypropyl guar.
- **Penetrants:** Enhance the absorption and penetration of pesticides into plant tissues. Examples include organosilicone-based penetrants and methylated seed oils.

Benefits

Adjuvants can improve the efficacy of pesticides, reduce the required application rates, and minimize environmental impact. They also ensure better adhesion and retention of pesticides on plant surfaces, leading to enhanced pest and disease control.

Application Considerations

When using adjuvants in drone applications, it is important to follow the manufacturer's recommendations for mixing and application rates. Compatibility with the chosen pesticide and drone equipment should also be considered. For instance, some adjuvants may cause clogging or damage to drone nozzles if not properly diluted.

Adjuvant is useful but needs to be tested before using and it needs to be used correctly. From 2016 to 2022, Corteva tested 8 adjuvants in 140 trials. They tested Maifei, Wetceit, Sliwet Target, Inferno, DropMax, L1700 and Silwet 806 in most of these trials. In most cases, pesticides with adjuvant and without adjuvant showed similar performance especially for products with good systemic activity or products with build-in adjuvants.

In some rare cases, they found adjuvant improve product performance; In some rare cases, they found adjuvant increase the phytotoxicity of product; In some rare cases, they found product performance decreased due to tank mixing using with some adjuvant. In some rare cases, they found adjuvant improve product performance. Below give you an example how adjuvant improve performance of product.

Wheat herbicide tank mixing with different adjuvants by drone .Application (remark: in the table, wheat herbicide replaces Quelex)



Source: Corteva, Spring Wheat, 45DAA



Prep to perfection- Pre application knowledge

Application by drones, is influenced by a numerous of factors. Understanding these elements is crucial for optimizing Drone performance and ensuring successful operations. This section delves into the critical aspects of Drone application, emphasizing environmental surveys and considerations, wind effects, hot and dry weather conditions, and surface temperature inversions (Smith, 2021). Environmental conditions and spray parameters play a significant role in ensuring accurate application, reducing wastage, and minimizing adverse effects on non-target areas

Proper application timing for pest

The application timing should be decided scientifically and properly. Following labels, local pesticide manufacturers and local government's forecast and guidance would be a good choice. For example, preventive application is always the 1st priority application timing for fungicide and earlier infestation stage of insects always the good time for insecticide application.

Droplet Size and Spray Quality

- Droplet Size Optimization: Ensures effective coverage while reducing drift.
- Nozzle Selection: Fine nozzles for fungicides, medium nozzles for herbicides, and coarse nozzles for insecticides.
- Spray Uniformity: Achieved through proper calibration of nozzles and drone speed

Weather and Environmental Considerations

- Wind Speed and Direction: Select formulations with drift-reducing properties in windy conditions.
- Temperature and Humidity: Formulations must maintain efficacy in various environmental conditions.
- Residue Management: Focus on formulations with minimal residue impact on soil and water

Pesticides and Formulations

- Refer to local laws and regulations and use pesticide safely and effectively. Pesticides should be registered and must follow local registration regulation laws.

ENVIRONMENTAL VARIABLES AND EFFECTS ON OFF-TARGET MOVEMENT

The interaction of equipment and weather-related parameters is a key factor in a successful spray application using drones. The applicator is responsible for considering all of these variables when making application decisions. The applicator must be familiar with advisories, and/or statutory mandates around environmental parameters, such as wind or proximity to water, that reduce the potential for off-site movement to sensitive areas. It is critical to spray during optimal environmental conditions to achieve acceptable on-target accuracy and reduce drift. Wind, temperature, relative humidity, and surface temperature inversions (thermal inversion) greatly influence drift. Conducting a thorough environmental survey is fundamental before deploying Drones. This process involves the assessment of geographical, meteorological, and infrastructural aspects of the area of operation. Key considerations include (Jones & Williams, 2020):

- Geographical Features: Terrain type, elevation, and the presence of obstacles such as trees, buildings, and power lines.
- Weather Patterns: Historical and real-time data on temperature, humidity, wind speed, and precipitation.
- Airspace Regulations: Understanding local airspace regulations and restrictions to ensure compliance.
- Electromagnetic Interference: Identifying potential sources of interference that could affect DRONE communication and navigation systems

Wind

Wind is one of the most critical environmental factors affecting DRONE performance. High wind speeds can destabilize DRONES, making them difficult to control and increasing the risk of crashes. Operators must consider (Jones & Williams, 2020):

- Wind Speed: DRONES have specific wind speed limits; operating beyond these limits can compromise stability and control.
- Wind Gusts: Sudden changes in wind speed (gusts) can cause abrupt movements, requiring rapid adjustments by the DRONE's control system.
- Wind Direction: Headwinds and tailwinds affect DRONE speed and battery consumption. Crosswinds can complicate navigation and positioning.

Drift potential increases at wind speeds of less than 3 mph (5 kph, 1.4 m/s) (due to variable direction and inversion potential) or more than 10 mph (16 kph, 4.4 m/s). However, many factors, including droplet size and application height, determine drift potential at any given wind speed. If high wind speeds are expected, compensate with larger droplet size, higher water volume and addition of a drift reducing agent. Most Drone spray systems use nozzles that produce droplet sizes with a Volume Median Diameter (VMD, droplet size at which 50% of the spray volume is in droplets larger than the VMD and 50% of the volume is in droplets smaller than the VMD) in the “very fine” to “fine” categories (See Table 1 for the standards used for droplet size classification). Droplets smaller than 150 µm have high drift potential (Grisso et al., 2013), thus wind is a key factor to consider when applying pesticides using UASS. Under high wind conditions, in addition to utilizing larger droplet size, not spraying directly over the downwind edge of the field i.e., moving the spray swath upwind (1/2 to full swath offset) can also reduce overall drift potential. Risk of exposure to operators and bystanders, plus aquatic and sensitive areas can be reduced by avoiding applications

when wind is blowing toward the sensitive area and not spraying when wind approaches or exceeds 10 mph (16 kph) or in gusty wind conditions (defined as wind speeds above 18 mph-30 kph-8 m/s for 20 seconds or less). Always follow buffer zones restrictions as per the product label and the federal/regional regulations.

High wind may also alter the flight dynamics of the Drone specifications should also be considered. If the Drone is not stable, it can alter the spray pattern, compromising the on-target spray, and more importantly it can also be unsafe if the Drone itself is not properly controlled. The World Meteorological Organization has set the international standard height for wind measurement devices at 10 meters (33 feet) above ground, with no obstructions at or above this level. Since Drones typically release the spray at altitudes higher than 1.5 meters, it is important that wind speeds are measured per international standard or as high as feasible if standard measurements are not available.

Table . Droplet size classification based on ISO 25358.2018 and ASABE S572.3

Size Classification	Symbol	VMD Range (Microns*)
Extremely Fine	XF	<60
Very Fine	VF	61-105
Fine	F	106-235
Medium	M	236-340
Coarse	C	341-403
Very Coarse	VC	404-502
Extremely Coarse	XC	503-665
Ultra-Course	UC	>665

*Estimated from sample reference graph in ASABE/ ANSI/ ASAE Standard S572.3

Hot and Dry (Low Relative Humidity) Weather Conditions

Hot and dry weather conditions, characterized by low relative humidity, can affect Drone performance in several ways (Smith, 2021):

- **Battery Performance:** High temperatures can reduce battery efficiency and lifespan, leading to shorter flight times.
- **Overheating:** Drone electronics and motors are susceptible to overheating in hot conditions, which can result in component failure or reduced performance.
- **Aerodynamic Efficiency:** Low humidity can affect air density, potentially impacting the lift and thrust generated by the Drone

Applications made at low percent relative humidity (RH) and high temperatures have greater risk of poor spray coverage and increased drift due to increased evaporation. This is because as a droplet dries, its size is reduced making it likely to drift further. Under those conditions, increase the droplet size and use higher application volumes (2-5 times more water may be required). Coarser droplets will take longer to evaporate, increasing the chance that they will reach the target. Air induction or low drift nozzles should also be considered under those conditions. If possible, time the application during the evening or when temperatures are cooler and relative humidity may have increased, however be aware of the potential for thermal inversions as these can also increase drift. See Figure 1 for guidance on acceptable spray conditions at various temperature and relative humidity combinations. Using certain types of adjuvants, such as oils, drift reduction adjuvants, and others can also help reduce the rate of evaporation of the spray droplet. Consult local

experts for adjuvant selection and the product label to make sure there are no restrictions to adding adjuvants in the tank mix.

Figure General Guidance to temperature and % RH ranges for pesticide applications*

Temperature	°F	32	41	50	59	68	77	86	95	104
	°C	0	5	10	15	20	25	30	35	40
% Relative Humidity	100									
	90									
	80									
	70									
	60									
	50									
	40									
	30									
	20									
	10									

	Unsuitable for spraying, very rapid or very slow evaporation of all droplets
	Marginal spraying conditions
	Marginal to good spraying conditions
	Preferred spraying conditions

* Adapted by the UAPASTF from Graeme Tepper, the grains research and development corporation (grdc.co.au), originally from Nufarm's spraywise decisions chart, 2012
<https://www.hort360.com.au/wordpress/uploads/Pesticide/Application/Spray%20nozzle%20guide%202012.pdf>. Additional information can be found at [Effect of Major Variables on Drift Distances of Spray Droplets | Ohioline \(osu.edu\)](#) and [Practical tips for spraying - GRDC](#)

Surface temperature inversions (thermal inversion)

Surface temperature inversions, also known as thermal inversions, occur when a layer of warm air traps cooler air near the ground. This phenomenon can have several implications for drone operations (Brown, 2019):

- **Stability and Turbulence:** Temperature inversions can create layers of stable and unstable air, leading to turbulent conditions that affect drone stability.
- **Sensor Performance:** Drone sensors, such as infrared cameras, may be affected by the temperature gradient, reducing their effectiveness in detecting and interpreting thermal signatures.
- **Aerosol Concentration:** Inversions can trap pollutants and aerosols close to the ground, potentially interfering with Drone sensors and affecting data quality

Do not spray pesticides when there is a surface temperature inversion (thermal inversion, Figure 2) since the potential for off-target movement is high. A temperature inversion occurs when warm air is trapped between cooler air higher in the atmosphere and dense cooler air close to the ground. This typically happens at the end of the day when solar intensity is

reduced and can last until sunrise the next day. Surface inversions restrict vertical air mixing, which causes small, suspended spray droplets to remain close to the ground and move laterally in a concentrated cloud. This of course causes additional drift which can lead to off-target deposition.

Conditions associated with surface temperature inversions are:

- Low cloud cover (25% or less)
- Light and variable winds (0-3 mph, 0-4.8 kph, 0-1.3 m/s)
- Dry soil surface

Low elevation areas (cool air can sink and collect easier)

- Things to look for that indicate a surface temperature inversion may be present:
- Mist, fog, dew or frost present
- Smoke or dust hanging in the air and moving horizontally close to the surface
- Ability to hear sounds from longer distances
- Smells are more distinct (indicating chemical particles movement in trapped warm air layer)

How to identify thermal inversion conditions

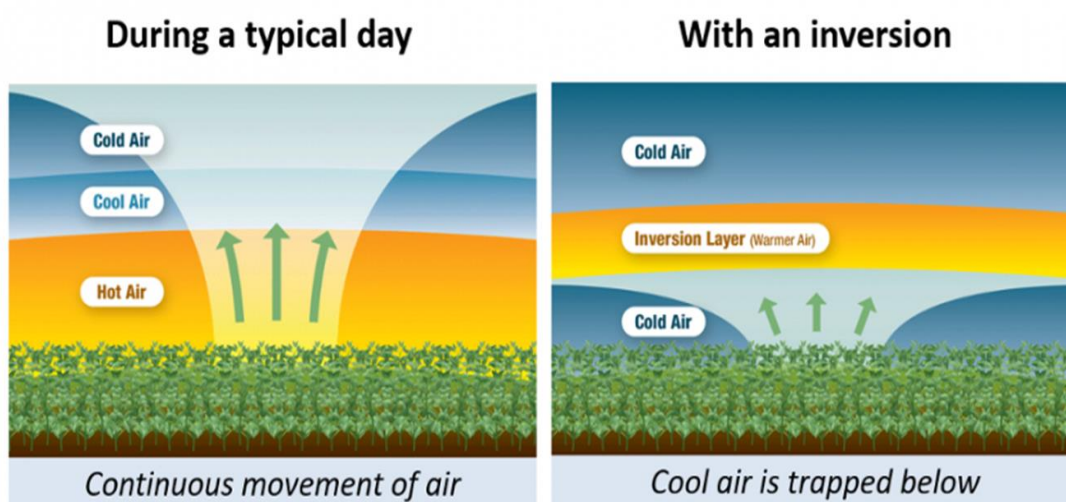


Illustration taken from: [Be on the Watch for Temperature Inversions | Integrated Crop Management \(iastate.edu\)](http://iastate.edu)

Adjusting Spray Parameters to the Environment and Sensitive Areas

The Need for Adjusting Spray Parameters

Environmental Conditions

Environmental factors such as wind speed, temperature, humidity, and the presence of thermal inversions can greatly impact the distribution and efficacy of pesticide sprays. For instance, high wind speeds can cause spray drift, leading to uneven application and potential harm to non-target areas (Smith, 2021). Similarly, hot and dry conditions can cause rapid evaporation of the spray droplets, reducing their effectiveness and increasing the chances of drift (Jones & Williams, 2020). Adjusting spray parameters, such as droplet size, spray pressure, and nozzle type, can help mitigate these effects (Yang et al., 2021).

Sensitive Areas

Sensitive areas, including water bodies, residential zones, and wildlife habitats, require special consideration during pesticide application. The drift of pesticides into these areas can cause significant environmental damage, harm to human health, and legal repercussions. By adjusting spray parameters and implementing buffer zones, operators can minimize the risk of contamination and ensure compliance with regulations (Gonzalez-De-Soto et al., 2020).

Follow the product label instructions carefully to make sure an application can be made that meets any restrictions around drift potential to sensitive non-target areas or organisms. Observe any buffer zones listed on the label; a buffer zone is the distance between the treatment area to the closest edge of a sensitive habitat. It is the responsibility of the user to know and apply any regulatory setbacks and buffer zones above and beyond those included on the label (e.g., stricter Provincial/State requirements than Federal requirements).

Minimizing Drift in Drone Pesticide Application while weather is not congenial

Technological Advancements

Recent advancements in drone technology have made it possible to precisely control spray parameters and minimize drift. For example, drones equipped with real-time weather monitoring systems can adjust spray settings based on current environmental conditions. Additionally, the use of GPS technology allows for the creation of precise application maps, ensuring that pesticides are only applied where needed (Brown, 2019). The integration of artificial intelligence (AI) in DRONES has further enhanced their ability to adapt to environmental conditions and minimize drift (Zhang et al., 2019).

Best Practices

Implementing best practices for drone pesticide application is essential to minimize drift. These practices include:

- Conducting pre-flight environmental assessments to determine optimal spray parameters (Khot et al., 2016).
- Using larger droplet sizes to reduce drift potential (Lang et al., 2018).
- Lowering the spray boom to minimize the distance between the nozzles and the target area (Chen et al., 2017).

- Avoiding applications during high wind speeds or thermal inversions (Brown, 2019).
- Implementing buffer zones around sensitive areas (Gonzalez-De-Soto et al., 2020).

Inspection and Calibration as per wind speed

Importance of Wind Speed in DRONE Pesticide Application

Understanding wind speed's impact on DRONE pesticide application is essential for ensuring precision and minimizing unintended consequences. High wind speeds can lead to significant spray drift, causing pesticides to reach non-target areas and potentially harming sensitive ecosystems (Gonzalez-De-Soto et al., 2020).

Various factors influence spray drift during DRONE pesticide application, including wind speed, droplet size, and height. According to Lang, Chen, and Li (2018), reducing droplet size and optimizing spray settings can mitigate drift.

Inspection Procedures

Regular inspection of DRONES is critical for maintaining performance and addressing any potential issues that might arise during operation. Key inspection steps include:

Pre-Flight Environmental Assessment

Performing a thorough environmental assessment before flight is essential for understanding the prevailing wind conditions. Khot, Panigrahi, and Scharf (2016) emphasize the importance of assessing wind speed, direction, and other environmental factors to adjust DRONE settings accordingly.

Wind Speed Measurement

Accurate measurement of wind speed can be achieved using anemometers or weather stations. Real-time wind speed data should be collected at various altitudes to ensure that drones operate under safe and optimal conditions (Yang et al., 2021).

Calibration Procedures

Calibrating drones based on wind speed involves adjusting various parameters to ensure precise pesticide application. Key calibration steps include:

Spray Boom Optimization

Chen, Wang, and Liu (2017) highlight the importance of optimizing spray boom settings to achieve uniform coverage. Calibration of the spray boom height and angle should be adjusted based on wind speed to prevent drift and ensure effective pesticide application.

Droplet Size Adjustment

Adjusting droplet size is crucial for managing spray drift. Lang, Chen, and Li (2018) recommend using larger droplets in high wind conditions to reduce drift potential. Conversely, smaller droplets can be used in low wind conditions for better coverage.

Preparation Work for UAS

Before the application, the UAS should be inspected and calibrated according to the requirements of the UAS manufacturer and local aviation requirements. Check preflight settings e.g., GPS, compass, LED status, satellite locks, gimbal level, and flight controls. Necessary calibration items of the spray system should include flow rate, compass, flight controller, altimeter, avoidance systems, radar, inertial measurement unit (IMU), and effective spray swath. Firmware needs to be updated to the newest version. For details, please follow UAS manufacturer's recommendation.

Flight route and obstacle avoidance plan

A rational application plan should consider optimal track space, orientation of flight lines, terrain, obstacles, no-fly areas, buffer zones, application height, and prevailing wind direction to avoid spray drift into nontarget or sensitive areas. Most flight control software will allow the operator to align the flight lines to optimize the spray application over the selected area before flight. It is recommended to select the automatic control mode with terrain tracing model. Set appropriate boundary of each border depending on actual situation.



Prior to application, a test flight should be conducted to validate whether the flight parameters are appropriate by observing wind field and its disturbance to crop canopy, and the droplets density and size on water sensitive paper in different locations of crop canopy. Droplet distribution and penetration or spray quality is strongly recommended to be tested for any new crop/pest by using water sensitive paper or other cards at very beginning.

Proper flight parameter setting

Water volume should be adjusted appropriately according to the actual situation and work efficiency to ensure the uniform coverage and effective sedimentation of droplets on target. Generally, water volume is 15 - 45 L /ha for row crops and vegetables. And it is 75 – 300 L

/ha for fruit trees. Use relatively higher water volume and coarse droplet size for herbicide application. Use higher water volume and fine droplet size for fruit tree application. In general, the more water is used, the better the control effect is. While, more water volume, does not mean better efficacy all the time; The feasible water volume is a range: below the minimum water volume or higher than the maximum water volume will impact the control efficacy. With the advancement of technology, it is worth to try lower water volume such as lower than 8 L/Ha.

Flight line spacing should be selected according to the characteristics of different UAS aircraft, nozzle type and operating parameters, crop type, pests, products, etc. Or follow the recommendations of the manufacturer. It is advisable that the deposition density of droplets on the edge of the spray belt be no less than 15 /cm² to 30 /cm² when droplet size is within the range of 80-200 µm VMD, without missing or duplicating application. (for more information, please check Standard for quality evaluation of pesticide application by crop protection UAS (CCPIA, China)).

Application altitude (flight height): it shall be 1.5-4 m from the crop canopy relative to the operating height or follow the recommendation of UAS manufacturers. With low crop or vegetation, flight too close would create more drift as there is 'bounce' from the ground.

Operating speed should be less than or equal to 7 m/s or you can follow the recommendation of UAS manufacturers. It should fly at a uniform speed and avoid going too fast or too slow. If the pests are located at the base of the crop, application speed should be appropriately reduced, application pressure can be increased, and fine droplet size can be chosen to ensure the good coverage of droplet at the middle and lower part of the plant and the backside of leaves. If the application speed is too high, the vortex will be aggravated in the tail of the UAS and the loss of droplets will be increased, creating greater spray drift. The determination of flight parameters for multi-rotor DRONES can be calculated and verified using the following formula (*based on UAS application standards of CCPIA China*):

$$V = Q \times 10000 \text{ divided by } q \times D \times 60$$

In the formula: q -- Water volume per hectare, L/hm²; Q -Total flow rate of nozzle, L/min; V -- Operating/flight speed, m/s; D -- spray width, m.

Pump, nozzle type, droplet size

Droplet size: American Society of Agriculture and Biological Engineers (ASABE) categories of Fine or Very Fine (<150 microns in diameter) are listed as having a potential drift risk. Doubling the droplet diameter will increase the volume applied by x8 [2 cubed].

Color Codes for Droplet Size

Category	Symbol	Color Code	Approx. VMD Range (microns)
Extremely Fine	XF	Purple	<60
Very Fine	VF	Red	60-145
Fine	F	Orange	145-225
Medium	M	Yellow	226-325
Coarse	C	Blue	326-400
Very Coarse	VC	Green	401-500
Extremely Coarse	EC	White	501-650
Ultra Coarse	UC	Black	>650

There are two major types of nozzles on UAS: Hydraulic nozzle and rotating centrifugal nozzle. Rotating centrifugal nozzle is suspected to be future trend. For hydraulic nozzle: The pressure of hydraulic nozzle is to spray under 2-4 bar pressure. T30, T10 such drones from DJI equipped with hydraulic nozzles.

- **Pros:** low cost, strong penetrating power of spray mixture under pressure and low drift, low evaporation under draught area.
- **Cons:** uneven atomization, large differences among droplet size, easy blocking the nozzle, pressure is not a constant value. Easily broken and needs frequent replacing.

For rotating centrifugal nozzle, the working principle of rotary atomizer is by centrifugal force that creates different droplet sizes according to rotational speed. Drones from XAG, EAVISION, and some drones from DJI are all equipped with rotary atomizers.

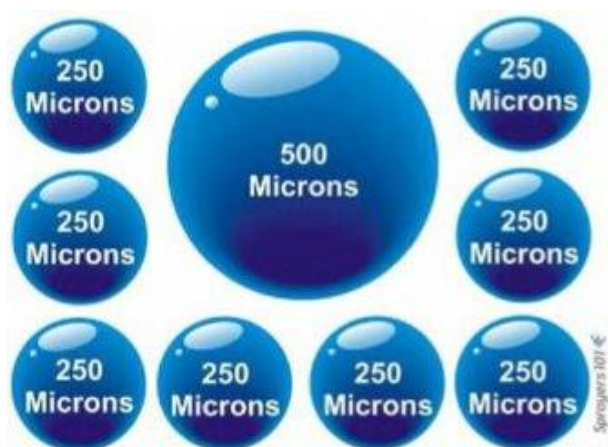
- **Pros:** Even atomization, fewer differences among droplet size and better atomization, better applicability to different formulations, No pollution of pump body and simple maintenance, adjustable droplet size.
- **Cons:** High cost, parts of the centrifugal nozzle are not stable. For motor-driven boards with carbon brushes, the service life is short, and the changing frequency is high. Easier to drift when using small droplets on long-stalked crops or crops with thick canopies like fruit trees

Proper pressure of hydraulic nozzle. In general, the spraying volume of the nozzle is proportional to the size of the spraying pressure and the orifice of the nozzle, and the spraying pressure changes in inverse proportion to the spray droplet diameter. Use higher pressure for fungicide and insecticide application and use lower pressure to do the herbicide application which can be helpful to alleviate drift risk. The application team should regularly check the working state of the nozzles and pump.

Nozzle and droplet size should be selected depending on actual needs and situation. For example, to avoid drift, you can use medium or coarse droplet size to do herbicide application, like coarser than VMD 150 or 200 μm . For the centrifugal nozzle, you can adjust the atomizer speed to realize different droplet sizes. For hydraulic nozzles, you can choose

anti-drift nozzles such as AIXR, AI, TF, and TT rather than XR nozzles. But fine or very fine droplets can better reach the lower part of the crop and the back side of leaves. Fine or very fine droplet sizes are needed for thick canopy applications like fruit tree applications. The droplet size of the centrifugal nozzle can be adjusted, it can realize very fine or fine droplet sizes like T40 with droplet sizes ranging from 50µm to 300 µm. So, you can choose a very fine droplet size such as 50µm by using T40.

- **The one-to-eight rule of droplet size**



The one-to-eight rule: Every time the median diameter of spray is doubled, there are eight times fewer droplets. Conversely, every time the median diameter of the spray is halved, there are eight times more.
(Source: sprayer 101.)

How to choose the proper parameters

- Flight parameters are highly dependent on DRONE models, weather conditions, crops, pests, pesticides, and others (like nozzle type). Corteva found that their products showed very good performance when used according to recommendations by manufacturers and appropriate weather conditions in 306 field trials.

- The table below summarizes key requirements for important application parameters for UAS applications.

Parameter requirement for row crops compared with fruit trees

Crop type	Row crops and low canopy crops	Fruit trees and high canopy crops
General guidance	1. Usually, more water volume and fine droplet size are needed for thick and tall canopy crops such as trees compared with row crops such as rice. 2. Fine or very fine droplet size can penetrate the inner side of the canopy and back side of leaves with the help of the wind field and the “bounce back” effect between the downwash wind field and ground. 3. But high-water volume ≠ better efficacy all the time. Do not increase water volume arbitrarily, since higher water volume may not bring higher efficacy all the time. 4. Higher payload UAS such as payload higher than 20 L/Tank are suggested to be used on fruit trees and high-canopy crops. The higher payload can produce a strong downwash wind field. 5. Criss-cross double application by double water volume is suggested for some difficult control scenario. Two applications: the first application is perpendicular to the second flight application in the same area. Do Not use this application method on herbicides.	
Water volume (L/ha)	Generally, it is 10 - 45 L/ha for row crops and vegetables.	Generally, it is 75 - 300 L/ha for fruit trees.
Flight line spacing (m)	Flight line spacing is recommended to be 2.5 - 5.5 Based on DJI recommendation, Spray meters for orchard. Flight line spacing for width or flight line spacing is around 3 orchards should be narrower compared with - 10 meters for row crops and row crops to ensure better droplet distribution vegetables. and coverage in the canopy.	
Flight altitude (m above canopy)	Generally, it is 1.8 - 3 meter for row crops and vegetables. The heavier the payload, the higher flight altitude.	Generally, it is 1.8 - 5 meters above the canopy crops and vegetables. The heavier the payload, the higher flight altitude.
Flight speed (m/s)	Generally, it is 1.5-3 .5 m/s for orchard Application speed is recommended to be application. Application speed is much slower for 3.5 - 7 m/s for row crops and orchard application compared with it is on row vegetables. crops and vegetables.	
Droplet size (VMD/μm)	Fine or very fine (60 - 225 μm) for fungicide and insecticide; Medium or coarse droplet size (226 - 400 μm) for herbicide.	Extremely fine or very fine (<145μm). Suggested doing the application during the night to manage drift and evaporation. Pay attention to drift and evaporation.

Major impact factors	Suggestions for major parameters			Remark
	General Application Scenario Water Droplet suggestions volume size	Flight speed	Flight altitude line above spacing crop canopy	
Different crops	Crop canopy is big, tall More conservative Increase Decrease and dense, like tree parameter setting	Decrease	Decrease Increase	Usually, more water volume and fine droplet size needed for thick and tall canopy crops such as
	Crop canopy is small and Less conservative Decrease Increase sparse, like wheat parameter setting	Increase	Increase Decrease trees compared with row crops	such as rice. Fine or very fine droplet size can penetrate the
Growth stage of crop	Later growth stage, crop More conservative canopy is big, tall and Increase NA parameter setting dense	Decrease	Decrease Increase	inner side of the canopy and back side of leaves with the help of the wind field and "bounce back" effect between the downwash
	Earlier growth stage, Less conservative crop canopy is small and Decrease parameter setting NA sparse canopy	Increase	Increase Decrease	wind field and ground. But high-water volume ≠ better efficacy all the time. 5. Criss-cross double application by double water volume are suggested for some difficult control scenario. Two applications: the first application is perpendicular to the second flight application in the

Major impact factors	Suggestions for major parameters			Remark
	General Application Scenario Water Droplet suggestions volume size	Flight speed	Flight altitude line above spacing crop canopy	
				same area. Do not use this method on herbicide application.
Infested position of pests	Mainly distributed at More conservative lower part or inner side Increase parameter setting NA of crop canopy	Decrease	Decrease Decrease	Theoretically, disease and insect management needs very fine or
	Mainly distributed at Less conservative upper part or surface of Decrease parameter setting NA crop canopy	Increase	Increase Increase	extremely fine droplet size; weeds management needs relative medium and coarse droplet size.
Infestation level of pests	More conservative High severity Increase NA parameter setting	Decrease	Decrease NA	Preventive and integrated
	Less conservative Low severity Decrease NA parameter setting	Increase	Increase NA	application, but not late application under high pest pressure.
Different pesticides	Herbicide NA Increase Increase Fungicide and insecticide NA Decrease Decrease More conservative Contact pesticides Increase NA parameter setting Less conservative Systemic pesticides Decrease NA	NA NA NA NA	NA Decrease NA NA NA NA NA NA	Be careful of drift. Uniform application and avoid of missing and duplicate applications. Wind speed <2m/s. Preventive and broadcast application is strongly

Major impact factors	Suggestions for major parameters			Remark
	General Application Scenario Water Droplet suggestions volume size	Flight speed	Flight altitude line above spacing crop canopy	
	parameter setting			recommended. Wind speed: <3m/s. Good coverage is needed. Coverage can be improved by the systemic movement of pesticides in the crops to some extent.
Weather	Higher wind speed and More conservative temperature, low relative Increase parameter setting Increase humidity	Decrease	Decrease Decrease	Pay attention to drift and evaporation.
	Lower wind speed, Less conservative Decrease Decrease feasible temperature, parameter setting high relative humidity	Increase	Increase Increase	45

How to choose the proper parameters

- Appendix A summarizes flight parameters recommended by DJI, EAvision, XAG, YAMAHA, and other major UAS manufacturers. These parameters give you more specific guidance on how to use UAS for pesticide applications.

Recommended parameters of drone manufacturers

- Please be noted that these operating parameters of drone are based on DJI drones like T10, T20, T30, T40, T20P, T50, T25, T60, T25P, MG-1P, MG-1S; XAG drones like P20, P30, XP2020, V40, P100pro and P100; EAvision drones like EA-16X, EA-20XE, EA-20X, EA-30X, EA-30XP, EA-J100; YAMAHA and other major drone models in India. This is just a general recommendation; parameters need to be adjusted depending on the detailed situation. The parameters in this section are based on DJI, EAvision, and XAG's published data, private communication, CropLife Asia member companies' internal data, and commercial adoption application experiences in major countries. Parameters will be updated periodically depending on the main representative UAS in the market by drone manufacturers.

Basic Requirements for Operators before application

Drone spray service providers or operators play a crucial role in efficient pesticide application by ensuring efficient, safe, and environmentally responsible application of pesticides, herbicides. To operate legally and effectively, they must meet specific regulatory, technical, and operational requirements. Before they start application, operators must have knowledge on the basic requirements

1. Regulatory and Legal Compliance

Adhering to national and international regulations is essential for drone spray operators.

Licensing and Certification

- **Drone Pilot License:** Operators must hold a Remote Pilot License (RPL) or equivalent certification from the relevant aviation authority (e.g., FAA in the U.S., DGCA in India, EASA in Europe).
- **Pesticide Application Certification:** Operators must be trained and certified to handle and apply agricultural chemicals legally and safely.
- **Operational Permits:** Specific authorization may be required for commercial agricultural spraying.

Drone and Operator Registration

- **Drone Registration:** DRONES must be registered with aviation authorities and comply with weight and operational restrictions.
- **Operator Registration:** Businesses providing drone spraying services may need to be registered with agricultural or environmental regulatory bodies.

Insurance Coverage

- **Equipment Insurance:** Covers damage or theft of drones and spraying systems.
- **Liability Insurance:** Protects against damages caused to people, property, or the environment.
- **Operator and Bystander Insurance:** Ensures safety coverage for operators and nearby individuals.

2. Equipment and Technical Standards

Drone spray operators must use reliable, high-quality DRONES and spraying systems that meet agricultural standards.

Drone Selection

- **Payload Capacity:** Should support sufficient pesticide/fertilizer volume for efficient application.
- **Flight Time and Battery Life:** Must allow for extended operation with minimal downtime.

- GPS and Automation: Precision flight planning and auto-navigation for accurate spraying.

Spraying Equipment

- Nozzle Types: Selection of drift-reducing, pressure-controlled, and adjustable nozzles.
- Flow Control Systems: Ensuring even and accurate liquid dispersion.
- Tank Size and Agitation Systems: Adequate for efficient mixing and preventing chemical settling.

3. Environmental and Safety Considerations

To minimize risks and environmental impact, drone spray providers must adhere to safety protocols.

Environmental Monitoring

- Weather Conditions: Avoid spraying in high winds, extreme heat, or temperature inversions.
- Drift Control: Use nozzles and adjuvants to minimize pesticide drift.
- Sensitive Areas: Maintain buffer zones near water bodies, residential areas, and ecological zones.

Safety and PPE for Operators

- Protective Gear: Gloves, goggles, respirators, and full-body protective suits.
- Emergency Procedures: Training in handling pesticide spills, drone malfunctions, and accidental exposure.

4. Operational and Maintenance Standards

Regular maintenance and professional management are critical for operational efficiency.

Drone Maintenance

- Pre-Flight Checks: Inspection of batteries, propellers, GPS systems, and spray nozzles.
- Routine Servicing: Cleaning nozzles, calibrating spray flow, and updating firmware/software.

Troubleshooting and Repairs

- On-Site Repairs: Ability to fix common issues such as clogged nozzles or motor failures.
- Remote Diagnostics: Access to real-time DRONE telemetry for quick issue resolution.

5. Training and Skill Development

A well-trained drone operator ensures efficiency and compliance with safety and environmental standards.

Technical Training

- Flight Operations: Hands-on training on drone navigation and automation.
- Spray Calibration and Application Techniques: Adjusting flow rates, spray height, and droplet size.
- Pesticide- training on safe handling of pesticides, spray and disposal of pesticides

Regulatory Training

- Legal and Environmental Compliance: Understanding pesticide regulations and Drone flight laws.
- Data Collection and Reporting: Logging flight data, spray records, and environmental impact assessments.



Spray Smart-Essentials for perfect spray (During application)

This section of the manual is dedicated to guiding users through the intricacies of operating effectively for pesticide spraying, ensuring both efficiency and safety

Mixing, Loading, and Spraying Techniques

A critical component of successful pesticide application is the proper mixing and loading of formulations. This section covers the initial mixing and loading processes, emphasizing the importance of adhering to recommended guidelines to ensure that the right concentrations are achieved. Proper mixing not only enhances the efficacy of the pesticide but also ensures safe handling and application.

Once the DRONE is loaded, the focus shifts to the actual spraying process. Users will learn about the nuances of applying pesticides using DRONE technology, including considerations for flight parameters and environmental conditions that can influence application success. The concept of Effective Swath Width (ESW) and spray coverage will be discussed, providing insights into how to optimize the application for maximum impact while reducing waste and drift.

Subsequent mixing and loading procedures will also be addressed, highlighting the importance of maintaining consistency and accuracy throughout the application process. This ensures that the benefits of the initial mixing are sustained throughout the operation.

Risk Management

To support safe and effective pesticide application, this section will introduce recommended risk management methods. Users will be guided on how to assess flight and environmental parameters, ensuring that all factors are considered before and during the application. Additionally, the feasibility of different formulations will be discussed, helping operators select the most appropriate products for their specific needs.

Operation of Drones

The pilot is responsible for considering all flight-related factors when making decisions. Application should follow designated flying routes and obstacle avoidance plans. It is recommended to use automatic application mode with terrain tracing. Avoid the use of manual control mode. The application status of the should be monitored in real time. Inspection of important parts of the aircraft shall be carried out after each landing to ensure continuous normal application. Forbidden to approach the agricultural when the blades still rotating, always keep safe distance.

Ensure uniform application and avoid of streaked, missing, uneven, overlapped or wrong application. Edge sweeping should be carried out to ensure that fields are covered with chemicals. For areas or edges where the drone missed due to irregular blocks of field or other reasons, application should be conducted separately. Cautiously plan the application during hovering and turning of .

If the nozzle becomes blocked during application, stop spraying and return aircraft to take off area to clean nozzle. Aircraft flight control should allow DRONE to return to same location where spraying was interrupted. Obstacle avoidance system should be turned on throughout the application. Report and record any incident accordingly. In case of In case of aircraft crash, signal interference, technical problems during flight etc.

Basic criteria for pesticides loading and mixing

Using proper method to dilute, to tank mixing or to prepare pesticide solution. General understanding of chemicals which you used is necessary for any good drone application practice. Such as, tank mixing requirement for each pesticide, fertilizer or plant growth regulator and adjuvant, pH value of above chemicals, tank mixing solution stability under extreme weather conditions such as when the temperature is higher than 35°C, whether the products you used are qualified or not?



Tank mixing with pesticide with potassium dihydrogen

Mixing and loading of pesticides- basic criteria

To ensure safely and effectively tank mixing using of pesticide by Drone application, there are several good practices you can follow:

1. Always check label and MSDS of the products to ensure you have better understanding of the used chemicals. Observe the most restrictive of the labeling limitations and precautions of all products used in the mixtures.
2. It is always recommended to do physical compatibility study before using chemicals on drone application if possible. Consistent and stable mixture is the precondition.

Order	Formulation
1	Solid fertilizer
2	Water soluble bags(WSB);
3	Water soluble granules (SG);
4	Water dispersible granules (WG) (DF, PX/XP);
5	Wettable powders (WP);
6	Suspension concentrates (SC);
7	Water soluble concentrates;
8	Oil based suspension concentrates (SE)
9	Oil dispersion(OD)
10	Emulsifiable concentrates (EC);
11	Surfactants, oils, adjuvants;
12	Soluble fertilizers;
13	Drift retardants.

For example, big companies do such kind of tests for their pesticides by tank mixing

using with representative tank mixing partners in the market. Such test is simple and cheap and would be executable for service providers and pilots.

3. Water quality is critical to the performance of pesticides. There are four main water quality indicators related to pesticide performance: pH, hardness, cleanliness and turbidity¹. In general, clean water with small hardness and neutral pH are suggested to be used. Such as pond water or ditch water rather than deep well water.
 - Water hardness is caused by positively charged minerals and cations which can bind to some herbicides (glyphosate is the best-known example, also 2,4-D amine) and reducing its performance¹.
 - Water with pH values between 4 and 7 are considered acceptable. But some pesticides like herbicides and copper fungicides have specific pH needs to dissolve properly. Label directions are important, sometimes calling for specific adjuvants. Some pesticides, particularly insecticides, can break down rapidly in higher pH water.
 - Cleanliness/turbidity. Water may contain suspended solids such as clay. Some chemicals are sensitive to this, as they are readily adsorbed to soil particles, and so turbid water can reduce their effectiveness.



Sources of water

4) Proper tank mixing order and procedure are very important to ensure good tank mixing compatibility of pesticides, plant growth regulator, foliar fertilizer, and adjuvants.

- A small test of tank mixing compatibility should be conducted if needed. It is recommended to premix a small quantity of a jar mix and observe for any adverse changes, such as settling out, flocculation (compatibility jar test), before adding the remaining amount of water. Avoid tank mixing of very concentrated spray mixtures.
- Please make sure the mixtures on-hand are mixed evenly and sufficiently before adding the next chemical.
- Pesticides need to be used immediately after tank mixing. Do not leave the pesticide solution overnight.
- When an application must be postponed, normal agitation is required to re-suspend any material that may have settled before application can be performed.

- Proper tank mixing sequence. Fill 1/4-1/3 water in nursery tank and shake evenly. Follow below order to add different kind of formulations (see the table).



Several pesticides tank mixing using on rice Untreated check caused tip burning of rice leaves. Source: Corteva trials

Mixing/Loading and Applying Using :

As with all pesticide applications, safety measures, including what to do in the case of accident response, should always be followed according to the specific product label instructions to adequately protect operators and bystanders. In many ways, the process to use a for pesticide applications is fairly similar to currently approved methods, but there are also several areas in which processes differ. Mixers/loaders and applicators must follow PPE requirements stated on the pesticide product label.

The overall process in using a DRONES can be summarized in 3 parts:

- Initial mixing and loading
- Spraying
- Subsequent mixing and loading

Initial Mixing and Loading

A common practice with mechanized sprayers in certain regions is the use of nurse tanks. Nurse tanks are large volume containers of spray solution mixed onsite for the purpose of filling and refilling spray equipment. Nurse tanks increase filling and refilling efficiency of a spray rig/apparatus as the number of times the pesticide product is measured, dispensed, and handled can be minimized.

Similar to the mixing process of other spray tanks, the operator would fill a nurse tank and/or mixing container half-full of clean water. For smaller amounts, a container with a wide mouth opening and cap is preferred. Next, the pesticide container is opened, and the appropriate amount of pesticide needed for that tank load is measured (either by weight or volume) and then added into the nurse tank. It is often considered a good practice to use a drip tray to capture spillage. After closing the pesticide container, the measuring container and drip tray are rinsed with clean water, and then the rinsate is poured into the nurse tank. Finally, the mixed solution/suspension is carefully dispensed into the spray tank opening of

the drone by pouring or preferably by pumping the required volume through a closed system.

It is important to consider that in this step, the mixer/loader may potentially come into contact with both the concentrated product and diluted spray solution. Wearing labelled PPE, such as gloves and a full layer of clothing, is vital. When mixing in the nurse tank or drone tank, the first interaction would be with concentrated product. When loading from the nurse tank into the drone tank, the handler would potentially come into contact with the diluted spray solution.

Additionally, it is important to conduct the mixing/loading steps in a location away from ditches and water sources to avoid contaminating surface or groundwater. And non-participants should be excluded from the site of spray operation before application begins.

Spraying

After the product is mixed and loaded into the drone, the product is ready to be applied. Unlike in manned aerial application systems, this process typically takes place from a distance. After choosing an appropriate position for take-off and landing, the certified drone operator would deploy the drone to the proper altitude and proceed to the application site. While spraying, the operator and spotters must keep visual line of sight with the drone. The operator and bystanders should attempt to remain upwind of the application site, although, in some field terrains (e.g., hills, slopes, etc.), this might require the applicator to venture along the side of the field or be in a position downwind of the drone spray zone. If this is the case, suitable protective measures (e.g., additional PPE) may be required. Care should also be taken to avoid exposure of incidental bystanders during the application process. Avoid entering the sprayed area shortly after the application without proper PPE or as directed by product label.

Subsequent Mixing and Loading

After the drone senses depletion of payload and automatically returns to filling station/area, the drone is ready to be refilled from the nurse tank. Multiple sets of batteries are also used so newly charged batteries are replaced while depleted sets are being charged. This process could occur many times in a single day and will depend on the size and efficiency of the drone platform.

As indicated in the initial mixing/loading description, at this point the mixer/loader could potentially come into contact with either concentrated product or diluted solution and use of labelled PPE is essential. As many handlers would use a nurse tank to refill the drone tank, the greatest potential exposure from this activity would be from the diluted solution. In situations where the nurse tank is not used, mixer/loaders would be handling more concentrated product. As noted below, these different interactions should be considered when assessing exposure.

Recommended risk management method

Identify all areas that should not be sprayed. These should be geographically fenced in flight control software so that sprays are automatically turned off when DRONE enters these areas. And farmers should be notified.

Flight parameter

- Appropriate flight parameters like decreased flight altitude, reduced flight speed, or increased water volume under high-risk application scenarios.
- Use Autonomous control mode all the time to avoid duplicate, wrong, and missing applications.
- Using coarse or coarser droplet size ($> 300 \mu\text{m}$ VMD). Use a centrifugal nozzle to adjust the droplet size to medium or coarse; Or use an anti-drift hydraulic nozzle such as AIXR, AI, TF, TT rather than XR nozzles.
- Hydraulic energy nozzles are easier blocked when sprayed WP formulation compared with centrifugal nozzle; Nozzle blocking, and physical compatibility tests are strongly suggested for products in WP and EC formulations, especially for with hydraulic nozzle.
- Rinse the spray system and the whole machine correctly and timely.
- Use two tanks for DRONE, one for herbicide application, and another one for others.

Environmental parameter

- Meteorological information such as wind speed shall be monitored in real-time during application. When the meteorological conditions are not favorable for spraying, the application should be stopped immediately.
- Avoid applying pesticides when wind speed is greater than 3 m/s. Avoid applying herbicide when wind speed is greater than 2m/s. If wind conditions are gusting, avoid flight during such conditions.
- Do not apply pesticide when temperature is higher than 35°C and relative humidity lower than 55%.
- Choose the most appropriate time of day to fly. In general, early morning, late afternoon, or night is the ideal choice. The application should also be avoided when there is strong temperature inversion.
- Application during the night can help to alleviate drift and evaporation.
- Application, when there is dew on the leaf, would be good for herbicide application.
- Very well water management is needed for rice paddy application according to the detailed pesticide requirement. Keeping high soil moisture while application will be helpful to improve herbicide performance on up-land crops.
- Conduct a good environmental survey.
- Pay special attention to sensitive nearby crops. In sensitive cases, at least a 300-meter width buffer zone is suggested to be set. Or avoid doing application when there are sensitive aquatic lives, plants, and such lives nearby.

- At least 15 buffer zones are suggested for other common application scenarios.
- Pay special attention to the application of nonselective herbicides.

Effective Swath Width (ESW)

A drone manufacturer may provide you with a theoretical swath width, sometimes expressed as a range (4 to 9 meters, for example). It is important to define the ESW by measuring spray deposition along the swath and checking for spray distribution variability. This is essential to obtain good calibration and to determine the application rate. Total swath width is defined as the spray footprint of the drone (the linear distance, perpendicular to the direction of travel that spray deposits during a single spray pass). EWS will be a fraction of the total swath, and an overlap is used to reduce deposition variability. Swath width of a drone is impacted by several factors, including, but not limited to:

- nozzle type
- spray pressure and droplet size
- nozzle position and orientation (under rotor or on a boom),
- spray release height
- flight speed
- rotor downwash
- size of the drone, and
- environmental conditions

Changes in the spray setup will affect swath; it is important then to determine ESW for different application strategies for an effective product application. There are multiple ways to determine EWS, however this process can be complicated and may require specialized equipment and professional help. One way to calculate EWS is by spraying over media (water sensitive cards, kromekote paper, mylar cards, paper receipt tape etc., are some of the most used samplers) distributed across the flight pass at known distances. While water only can produce stains on water sensitive cards, a dye (FD&C Blue, Rhodamine, Pyranine etc.) can be added to the spray to help stain other samplers for better visualization. Use a digital camera or scanner to capture individual images of the cards and computer programs to extract coverage data of individual cards. Mobile/smart phone applications such as DropLeaf, DropScan, **Dropflight** and SnapCard are also available to read coverage data. Once the coverage information is obtained and expressed as a function of distance to the centerline, the effective swath width can be determined by calculating the coefficient of variation (CV) of multiple swaths. The CV shows the extent of variability in relation to the mean of the spray coverage in this case. After measurements are collected and coverage is expressed as a function of distance, an ESW is selected and an average coverage (mean), and standard deviation are calculated. CV is calculated by dividing the standard deviation by the average and multiplying by 100. CV is expressed as a percentage (%). Typically, ESW is the largest swath in which the CV is

equal to 25% or lower. See Figures 5 and 6 for more details. ISO/CD 23117-2 provides more information on how to determine a drone effective swath, and additional resources can also be found from experts in this field including but not limited to: <https://sprayers101.com/calibrate-drone/>, <https://www.applicationinsightllc.com/products/swath-gobbler>, <https://www.astm.org/stp162720190132.html>,

Spray Coverage

Variability in spray coverage within swath contributes to lack of pest control (low/no spray present) or possible crop damage (too much spray present). Variability can happen due to several reasons, including but not limited to equipment setup (wrong/faulty nozzle used, swath being too wide, speed too slow), bad operational design (flying too high or too low), or weather conditions during operation (strong, variable winds). Because the drone discussed in this BMP document use rotors that push spray downwards, and its ESW is generally larger than the overall spray equipment width, they naturally produce sprays that are more variable than sprays produced by other equipment such as a ground sprayer. Therefore it is critical to understand the factors affecting variability, to calibrate the equipment, and to pay attention to signs that may point to a higher-than-normal variability in spray deposits during the application.

Feasible Formulation for drone application

Adjuvant can reduce drift potential but must be tested and used correctly. Adjuvant can be used scientifically on herbicide applications, fine or very fine droplet size applications, windy and dry days, and such risky application scenarios.

Granule application could be a good option for herbicide application to avoid of drift such as Japan's ready-to-use rice herbicide on rice.

Among liquid formulations, SC and SL have less drift. Formulations containing emulsifiers (like EC) are likely to drift. It is recommended to select SC and SL to prevent drift compared with EC such as oil-based formulations.



Post Application Measures

This section of the Pesticide Application Manual focuses on critical safety and compliance measures necessary for effective pesticide application. It outlines essential practices, protocols, and assessments that operators must follow to ensure safe handling, application, and post-application procedures. By adhering to these guidelines, operators can minimize risks to themselves, the environment, and the surrounding community.

Warning Boards

Operators must display warning boards in the application area to inform personnel and the public about pesticide use. These boards should clearly indicate the type of pesticide being applied, the date and time of application, and any necessary safety precautions. Proper signage helps prevent accidental exposure and ensures that everyone in the vicinity is aware of the ongoing activities.

Disposal

Proper disposal of pesticide containers and residues is crucial to prevent environmental contamination. Operators should follow local regulations for disposal, ensuring that empty containers are rinsed and disposed of in designated waste facilities. It is essential to document disposal methods and locations to maintain compliance with environmental guidelines.

Operator Clean Off

After completing pesticide application, operators must thoroughly clean off any pesticide residues from their equipment and protective gear. This process includes washing hands, face, and any exposed skin, as well as cleaning tools and equipment used during the application. Maintaining personal hygiene is vital to prevent pesticide exposure and ensure operator safety.

Records

Maintaining accurate records of pesticide applications is essential for compliance and future reference. Operators should document details such as the type of pesticide used, application rates, weather conditions, and the area treated. These records should be kept for a specified duration, as required by local regulations, and should be readily accessible for inspection.

Equipment and Maintenance

Proper management does not end when the drone completes its spraying run. The after-application phase is critical to ensure environmental safety, regulatory compliance, and sustained effectiveness of the treatment. It covers the installation of warning boards to alert neighbors and workers, safe disposal of leftover mix and containers, thorough operator clean-off procedures, and meticulous record-keeping of spray details. It also explains how to conduct an efficacy check and field survey, assess spray quality, and follow an after-application checklist to verify that all steps are completed.

Cleaning, Maintenance, and Handling

After each use, the application equipment must be cleaned and decontaminated internally (i.e., spray tank) and externally due to the possibility of residues remaining both within and on the outside of the drone. At the end of each day's spraying, the spraying system should be flushed through with a suitable cleaning agent; either water and detergent for water-based sprays or suitable solvent for oil-based sprays. It is important to note that cleaning could be product-specific (for example, recommendation of cleaning agents and proper PPE), and/or drone manufacturer-specific (due to things like sensitivity of electrical equipment) and therefore checking any specific product and/or drone local guidance may be necessary.

Cleaning a drone after use would be similar to cleaning a backpack and other small tank sprayers and typically would follow a triple-rinse procedure. Ideally, the drone spray tank is removed (if model used does not have a fixed tank), filled one-quarter the way with clean water, the lid is replaced, and the tank is shaken to ensure coverage of all interior walls and then dispensed into the appropriate treatment or disposal area. This procedure would be followed for a total of 3 rinses (rinse may include specific cleaning agent, as described above) before being left to air dry. It is better to rinse three or four times with small volumes rather than once with a full tank. Cleaning and maintenance of spray nozzles, pumps, and tubes would be treated similar to those procedures followed with backpacks and other small tank application methods. On drone with fixed tanks, a similar triple rinse procedure can be followed, and the rinsate can be sprayed out in an appropriate area for disposal. Do not power wash drone exterior as water can be forced into electronic parts causing malfunction.

Tank cleaning is important, as even very small quantities of residues in a tank can contaminate subsequent spray mixtures resulting in unintended effects such as potential crop damage. Residues could also affect tank mix compatibility or the safety profile of a subsequent product. Care should be taken with herbicides, with some labels containing explicit instructions on tank cleaning.

Care must be taken after working with wettable powders, as residues can accumulate in the spray lines and filter housing. The pesticide product itself or material shed from damaged seals can deposit and build-up in un-purged areas impairing proper atomizer operation. PPE, as indicated on product label or those mandated by regional regulations, should be worn appropriately and disposed of or thoroughly cleaned after use, dried and stored in a well-ventilated area, away from other materials and in a way that is safe for people and the environment.

Warning boards and lines: Signs should be erected to indicate the area has been sprayed indicating the type of chemicals, application time, safety interval, etc.

Equipment maintenance, repair and storage:

Follow the manufacturer's recommendation on the other maintenance, repair, and storage.

Waste disposal: Refer to Safe use of pesticides. Any spray residues or tank washing should be disposed of according to local regulations and guidelines provided on the product label.

Operator: Refer to Safe use of pesticides. After application, personnel involved in spray mixing and filling should remove PPE and wash clothing, hands, face, and body.

Records: All data management should fully comply with local laws and regulations. Records of spray application should be made to include details of date, time, area treated, coordinates, products applied, application parameters, environmental conditions, and so on. These details should be completed on the day of application

Incident Management

In drone pesticide operations, incident management is a critical safeguard to address any unexpected events such as spills, drift beyond target areas, equipment malfunctions, or operator exposure. Clear records must be in place to immediately record and mitigate the incident, notify relevant authorities or supervisors, and document the details in an incident report.

Control efficacy check

Double-check the flight route and flow data after the application. If significant missing areas are found, the possible risks should be assessed, and timely remedial measures should be taken.

Efficacy survey: After the application, control efficacy should be investigated and tracked, feedback from farmers should be collected, and corresponding efficacy records should be made. During the investigation, select the middle part of the application plot and investigate according to the visual assessment method: five-point assessment method, checkerboard method, or zigzag method.

Flight hazards and Incident reporting

Refer to Safe use of pesticides. Where possible, application assistants should be present at the application site to communicate with the operator and anyone on the ground who might be at risk during the application and to escort them from the area. Emergency plans should be in place for catastrophic events such as aircraft engine or landing gear failure leading to a forced landing or crash.

Any loss or damage on drone and any damage to property outside of the drone should be reported according to appropriate authorities and the company's policies. A dry powder extinguisher should be prepared during operation.

Spray quality requirement

Where possible, spray quality should be evaluated for any new products used by UAS application or any products which have never been used by UAS before. In general, the distribution uniformity of droplets (coefficient of variation) should be within the range of $\leq 45\%$ - 65% . The droplet density should be at least larger than ≥ 15 or 20 or 30 droplet / cm^2 .

Refer to the chart below (*China NY/T 3213 Guidelines*) for Plant Protection UAS spray quality assessment.

Table. drone qualification requirements

#	Items			Quality requirement index	
				Water volume per hectare q (L/ha)	
				7.5<q<=15	15<q<45
1	Deviation of spray volume			<=5%	
2	Droplet deposition density (Droplet/cm2)	Insecticide	Systemic	>=15	>=20
			Non-systemic	>=20	>=30
		Fungicide	Systemic	>=15	>=20
			Non-systemic	>=20	>=30
3	Uniformity of droplet distribution (Coefficient of Variation)			<=65%	<=45%



Skills and trainings required for operators

Proper training for drone operators is crucial for the safe and effective application of pesticides. To ensure the safe and effective use of drones for pesticide application, it is essential that operators undergo comprehensive training. This training will equip them with the necessary skills and knowledge to operate drones safely, comply with regulations, and apply pesticides effectively.

Training Requirements for Drone Operators

Basic Understanding of Drone Technology: Operators should have a foundational knowledge of drone components, functions, and maintenance.

Pesticide Application Knowledge: Training must include information on pesticide types, application rates, and safety precautions.

Regulatory Compliance: Operators should be familiar with local, state, and federal regulations regarding pesticide application and drone usage.

Pilot License

Certification Requirement: Operators must obtain a Remote Pilot Certificate from the Federal Aviation Administration (FAA) or the relevant authority in their jurisdiction. This certification demonstrates that the pilot has passed the necessary knowledge tests and understands airspace regulations.

Renewal and Continuing Education: Pilots are required to renew their certification periodically and engage in continuing education to stay updated on new regulations, technologies, and best practices in drone operation and pesticide application.

Drone Flying Skills

Hands-On Flight Training: Operators should undergo practical training sessions that include the following

Basic flight maneuvers: Take-off, landing, hovering, and navigating.

Emergency procedures: Handling malfunctions and executing safe landings.

Precision flying: Skills for accurate pesticide application, including understanding wind conditions and terrain.

The rapid integration of drones into agriculture, particularly for pesticide application, has transformed crop protection practices across the Asia-Pacific (APAC) region. Drone-based pesticide application promises efficiency, precision, and reduced operator exposure compared to traditional methods. However, to realize these benefits safely and sustainably, pesticide application drone operators must be rigorously trained, licensed, and certified. This chapter outlines the essential skills and training requirements, the process of obtaining a pilot license, and the specific certification needs that encompass knowledge of pesticides and responsible application. Country-specific examples from APAC illustrate how these standards are applied in practice.

Agricultural drone operations typically involve flying at low altitudes over crops, often in repetitive patterns, and sometimes carrying heavy payloads (liquid tanks for spraying). Efficiency and precision are critical: for example, when spraying pesticides or fertilizers, the drone needs to maintain a consistent height and speed to ensure even coverage and avoid damaging the crops or missing spots. Training programs for agricultural drone pilots therefore focus on a few key areas: flight precision, agronomic knowledge, and safety (both operational and chemical safety).

Firstly, pilots learn how to plan and execute flight paths for crop spraying or mapping. This includes using specialized mission planning software where the pilot inputs field boundaries, and the software generates optimal flight lines (a “lawnmower” pattern) for coverage. Trainees are taught how to adjust parameters like swath width, flight speed, and nozzle flow rate depending on the product being sprayed and the wind conditions. Flying a heavy spray drone (which might weigh 15–25 kg when loaded) is quite different from flying a small camera drone – the inertia is greater and the spray drone may have a more limited flight time (often under 15 minutes when loaded). Thus, training emphasizes power management (e.g., knowing when to trigger return for refill before the tank runs completely dry, to avoid the drone spraying air or running out of battery mid-field) and terrain following (as fields may have undulating terrain, some spray drones have radar altimeters to keep constant height above crops, which the pilot must understand and monitor). Pilots also practice handling the drone in manual mode above fields in case the automated system needs override – for instance, if one nozzle clogs and the drone needs to be paused and brought back.

In APAC, China is a leader in agricultural drone usage and training. By 2020, tens of thousands of pesticide spraying drones (many produced by DJI’s agricultural division) were in use by Chinese farmers and agri-service providers. The government, recognizing the need for skilled operators to fully realize the benefits, has supported training programs specifically for rural youth and farmers. As noted earlier, private drone manufacturers in China provide targeted training programs for pesticide application, and these have become the dominant channel for certifying agri-drone pilots[7]. These courses often last 1–2 weeks, combining theory (safe mixing and handling of agrochemicals, understanding droplet sizes and spray drift, etc.) with field practice (actually operating the drone over farms). They culminate in a practical test where the trainee must demonstrate the ability to uniformly spray a

given plot and handle the equipment. The Chinese government strongly backs these training initiatives, seeing them as crucial for modernizing agriculture; there are even subsidy programs that help farmers purchase drones only if they get trained and licensed to use them[8].

Japan has a long history of remotely piloted aircraft in agriculture (dating back to Yamaha R-MAX helicopters for rice field spraying since the 1990s). Today's multi-rotor ag drones in Japan require the operator to have not just a drone pilot certification but also a separate pesticide applicator license. In fact, many APAC jurisdictions require dual qualifications: one for operating the drone itself, and another for handling and applying agricultural chemicals. A 2020 overview of Asia-Pacific regulations noted that countries like Japan, Korea, the Philippines, and Taiwan all mandate two separate licenses – a drone pilot license plus a traditional Pest Control Operator (PCO) or equivalent license – for those engaging in drone-based spraying[34][21]. This ensures that the person understands both aviation safety and agricultural chemical safety. Taiwan, for example, has government-linked agricultural institutes working with universities to train drone operators, and while the aviation authority issues the drone licenses, the agricultural authority ensures they also meet pesticide applicator requirements[35].

Given this dual aspect, agricultural drone training programs often involve partnerships between aviation bodies and agricultural departments. A recent example comes from the Philippines: In 2024, the Philippine Department of Agriculture's Fertilizer and Pesticide Authority (DA-FPA) signed an agreement with the International Rice Research Institute (IRRI) to develop training materials and guidelines for farm drone use[36]. The goal was to train not just pilots but even policy makers on safe and effective agricultural drone practices, aligning with the "Drones for Rice" initiative to standardize drone use in rice farming[36]. This collaboration led to updated regulations: the DA-FPA issued guidelines (Memorandum Circular 2024-025) specifically on the use of Remotely Piloted Aircraft Systems for pesticide spraying, and tasked its divisions to create similar protocols for fertilizer application via drones[37]. By involving agricultural scientists and regulators in the training design, the program ensures that pilots learn how to avoid issues like over-application of chemicals or drift that could harm adjacent fields. An official at DA-FPA noted that "this training will help craft implementing guidelines in monitoring drone activities in agriculture", underlining how training pilots and developing regulations go hand-in-hand[38]. IRRI's technical experts contribute knowledge on agronomy so that the drone operations truly meet farming needs (e.g., the best time of day to spray to avoid strong winds, or how to calibrate the drone for different crop heights)[39].

A drone flies low over a rice paddy in Asia, illustrating the use of UAVs in agriculture. Precision and safety are paramount when operating agricultural drones. Specialized training programs teach pilots to maintain steady altitude and speed for uniform spraying, to handle chemicals safely, and to coordinate with farmers and regulators[38][37].

Skills unique to agricultural drone pilots include

Understanding Crop and Pest Conditions

A good ag drone operator has basic agronomic knowledge. They can identify the sections of a field that need treatment (sometimes using drone-collected multispectral imagery to spot stress in crops) and understand the treatment prescription (e.g., which pesticide and rate). Some training courses for ag drone pilots, such as those in Malaysia and Vietnam supported by CropLife Asia, include modules on crop scouting and pest identification so that pilots can add value beyond just flying the drone.

Mission Planning for Coverage

Agricultural fields can be large, and efficient coverage is crucial. Pilots learn how to break a large field into manageable sectors for sequential missions and to optimize turn-around time (refilling and recharging quickly between sorties). This involves logistical skills – planning where the refill station or water source will be, how to minimize downtime, etc. In large farm operations in China, it's common for a team of operators to work in relay: one monitors the drone in flight, another prepares the next battery and chemical load. Training for such teamwork and coordination is often emphasized by manufacturers like DJI when they certify service providers.

Maintenance and Calibration

Agricultural conditions (dust, exposure to corrosive liquids) can be harsh on drones. Pilots are trained in daily maintenance tasks like cleaning nozzles, checking pumps and hoses for leaks, calibrating spray flow (often using a test to measure flow rate and ensure even spraying), and updating any firmware. They also must calibrate the drone's compass and terrain radar if flying close to crops to ensure accurate height-keeping. These technical skills are vital to avoid mishaps such as uneven spraying or equipment failure mid-flight. Some of these topics appear in the CropLife Asia recommendations (2020) which suggest that training curricula for UAV sprayer operators should include equipment maintenance and safe handling of concentrates, although the detailed recommendations are beyond our scope here.

Operational Safety and Chemical Safety

Agricultural drone pilots must protect themselves and others from chemical exposure. Training includes use of personal protective equipment (PPE) like masks and gloves when mixing and loading pesticides into the drone's tank. Pilots are taught to observe buffer zones – e.g., not spraying near water bodies or sensitive habitats, or maintaining a downwind buffer so that drift doesn't affect bystanders. They also learn emergency procedures specific to spraying: for example, if a drone malfunctions and crashes, containing a spill of pesticide and reporting it. Given many farms are in rural areas, safety training also touches on things like not startling livestock with drones and coordinating with farm workers in the fields during

operations. Japan's longstanding practice has formalized many of these safety points under the Japan Agricultural Aviation Association (JAAA) guidelines.

Regulatory Compliance in Agriculture

In addition to general drone flight rules, ag drone operators have to comply with agriculture-specific regulations. This may include obtaining spraying permits for each job, keeping records of chemicals applied (for traceability in food production), and respecting no-spray buffer zones near residential areas. Training programs ensure pilots know the paperwork and procedures. For instance, in Thailand, an operator might have to notify local authorities before a large-scale drone spraying activity; in India, current rules prohibit drone spraying without explicit permission, so pilots are trained on how to apply for and adhere to those permissions. In many APAC countries, night spraying is prohibited, so operations must be done in daylight – timing and planning are part of training.

Efficient Drone Flying Skills for Spraying Operations

Efficient pesticide application relies on a pilot's ability to maximize coverage while minimizing chemical use and drift. Training should emphasize:

- **Flight Path Optimization:** Setting correct swath width and overlap using mission planning software.
- **Altitude & Speed Control:** Maintaining consistent height over varying crop canopies and adjusting speed for uniform coverage.
- **Battery & Payload Management:** Planning missions to reduce downtime from battery changes and refills.
- **Emergency Handling:** Manual control skills in case of GPS loss, unexpected obstacles, or equipment malfunction.

Research Insight: A study on agricultural drone spraying in China found that operators with formal simulator training achieved 20–30% better spray uniformity and reduced off-target drift compared to untrained pilots (Li et al., 2023, *Precision Agriculture Journal*).

Training Requirements for Pesticide Application Drone Operators

Operating a drone for pesticide application demands a blend of aviation knowledge, agronomic expertise, and operational discipline. Training programs must cover:

1. Core Drone Operation Skills

- **Flight Basics:** Take-off, landing, hovering, flight path planning, obstacle avoidance.

- **Maintenance & Troubleshooting:** Routine inspections, propeller balancing, battery management, sensor calibration.
- **Autonomous Modes:** Using GPS waypoint navigation and software for grid spraying patterns.

2. Pesticide Application Knowledge

- **Pesticide Types and Formulations:** Understanding emulsifiable concentrates (EC), suspension concentrates (SC), wettable powders (WP), etc.
- **Calibration and Nozzle Selection:** Droplet size, spray quality, and drift management.
- **Safe Handling & PPE:** Proper mixing, loading, cleaning, and storage; required personal protective equipment.

3. Regulatory Compliance & Environmental Awareness

- **Local Aviation Regulations:** Airspace classification, no-fly zones, altitude restrictions.
- **Environmental Stewardship:** Buffer zones near water bodies or sensitive habitats, weather considerations (wind speed, inversions).

Obtaining a Pilot License for Drone Operators from Civil Aviation authority

In APAC, most countries require pesticide application drone operators to hold a **Remote Pilot License** or equivalent before engaging in commercial spray operations. Licensing generally involves:

- **Minimum Training Hours:** For example, China requires 44–100 hours depending on operational complexity.
- **Theoretical Examination:** Covers air law, meteorology, flight principles, and safety management.
- **Practical Flight Test:** Demonstrates operational proficiency under an examiner's supervision.

Example: In **Japan**, operators undergo training approved by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and often also by agricultural agencies. Pilots learn to fly multi-rotor UAVs specifically for spraying and must pass a practical test. In **India**, the Directorate General of Civil Aviation (DGCA) mandates training at a Remote Pilot Training Organization (RPTO) and issues a Remote Pilot Certificate upon successful written and practical assessments.

Certification of Pesticide Application Drone Operators

Beyond a flight license, operators applying pesticides must demonstrate competency in safe chemical use. Certification programs typically include:

- **Pesticide Knowledge Modules:** Crop protection principles, label comprehension, and residue standards.
- **Integrated Proficiency Tests:** Written exams on pesticide regulations and practical tests on calibration, spraying technique, and emergency spill response.
- **Periodic Recertification:** Many jurisdictions require renewal every 3–5 years with updated training on new formulations and regulations.

Example: In **China**, drone operators often attend manufacturer-led programs (e.g., DJI Academy) that integrate pesticide application training. Certification is issued after both theory and field tests. **Japan** mandates that operators hold both a drone pilot license and a pesticide applicator permit. **Philippines** through its Department of Agriculture and Fertilizer and Pesticide Authority (DA-FPA) now requires drone service providers to undergo accredited training covering both drone operations and pesticide safety.

The certification and skill development of pesticide application drone operators is essential for modern, sustainable agriculture. APAC countries lead the way with structured licensing, training, and certification programs that integrate flight competence and pesticide safety knowledge. By adhering to these standards, operators ensure precise application, protect the environment, and comply with evolving regulations. As drone technology advances, continuous education and recertification will remain cornerstones of responsible pesticide application.

APAC governments and private sector are actively expanding these training opportunities. There are success stories of upskilling farmers with drones: a case in point is a program in Indonesia where hundreds of young farmers were trained to use drones for seeding and fertilizing, boosting yields and reducing manual labor. Another is the “Asia Pacific Young Farmers Drone Camp” organized by agricultural cooperatives, where youths from across ASEAN received hands-on drone training and even competed in Agri-Drones Olympiads to test their skills. Such programs often involve partnerships with universities and drone companies to ensure both the theoretical and practical components are robust.

In conclusion, agricultural drone operators in APAC are becoming an essential part of modern farming, but their effectiveness hinges on specialized training. By learning to operate drones with agronomic precision and adhering to stringent safety protocols, these pilots help achieve the promise of drones in agriculture: higher productivity with lower environmental impact. The investments by APAC governments and organizations in training – from China’s manufacturer-led licensing to the Philippines’ policy-driven training development – indicate a strong commitment to cultivating a skilled workforce of agri-drone pilots[38][37].

APAC Country Examples

Country	Licensing Body	Certification Requirements	Notes
China	CAAC & AOPA China	Training (44–100 hrs), written & practical exams, pesticide handling modules	Manufacturer-led academies widely recognized.
Japan	MLIT & MAFF	Pilot license plus pesticide applicator permit, standardized manuals	Long history with agricultural UAVs.
India	DGCA & State Ag Depts	Remote Pilot Certificate via RPTO, safe pesticide use training	Digital platform for license issuance.
Philippines	CAAP & DA-FPA	UAV Operator Permit plus pesticide safety certification	Updated 2024 guidelines integrate pesticide modules.
Vietnam	Civil Aviation Authority & MARD	Drone license and chemical application training	Partnerships with universities and cooperatives.

Global Context: In the EU, pilots operating spraying drones must comply with EASA’s Specific Category operations and hold national pesticide applicator certifications. In **Brazil**, agricultural UAV pilots undergo MAPA-recognized training and periodic recertification every 2 years, reflecting Latin America’s strong emphasis on stewardship

References (selected): The information in this chapter was drawn from a range of up-to-date sources, including regulatory documents, academic studies, and industry news. Key references include Asia-Pacific regulatory guidance from ICAO and national authorities^{[1][3][23]}, peer-reviewed research on drone pilot competencies and training effectiveness^{[27][29][30][25]}, and case studies of training programs in agricultural applications^{[7][38]}, among others. These citations are embedded in the text to direct readers to detailed evidence and further reading on each topic discussed.

[1] [2] [22] Asia-Pacific Region Adopts Reference Materials for the Regulation of Air Taxis and Drones | Global Airspace Radar

<https://globalairspace radar.com/news/asia-pacific-region-adopts-reference-materials-for-the-regulation-of-air-taxis-and-drones/>

[3] [4] [5] [10] [11] [15] [23] XPP-PDF Support Utility

<https://www.mayerbrown.com/-/media/files/news/2015/06/the-regulation-of-drones-in-the-asiapacific-region/files/bloomberg-bna-world-data-protection-report/fileattachment/bloomberg-bna-world-data-protection-report.pdf>

[6] [7] [8] [9] [18] [19] [20] [21] [34] [35] croplifevietnam.org

<https://croplifevietnam.org/wp-content/uploads/2021/06/CropLife-Asia-UAV-operator-training-and-certification-guidance-December-2020.pdf>

[12] [PDF] The Drone Rules, 2021 - PIB

<https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232932501.pdf>

[13] Drone Registration in India | Drone Rule 2021 - Aleph INDIA

<https://alephindia.in/drone-registration-in-india.php>

[14] Ministry of Civil Aviation notifies liberalised Drone Rules, 2021

<https://egovernance.vikaspedia.in/viewcontent/e-governance/digital-india/unmanned-aircraft-system/ministry-of-civil-aviation-notifies-liberalised-drone-rules-2021?lgn=en>

[16] [17] [31] Japan's revised drone laws to permit BVLOS flights over people come into effect - Unmanned airspace

<https://www.unmannedairspace.info/emerging-regulations/japanese-revised-drone-laws-to-permit-bvlos-flights-over-people-come-into-effect/>

[24] DGCA Rules for Drone Pilot Training in India | DGCA UAV Regulations

<https://indianinstituteofdrones.com/DGCA/>

[25] [26] [32] [40] [41] Use of Simulation for Pre-Training of Drone Pilots

<https://www.mdpi.com/2504-446X/8/11/640>

[27] [28] [29] Enhancing Drone Operator Competency within the Construction Industry: Assessing Training Needs and Roadmap for Skill Development

<https://www.mdpi.com/2075-5309/14/4/1153>

[30] [33] electronic library - Key Competences and Training of Civil Drone Pilots

<https://elib.dlr.de/145126/>

[36] [37] [38] [39] IRRI and DA-FPA ink MOA on farm drone training material development - CGIAR

<https://www.cgiar.org/news-events/news/irri-and-da-fpa-ink-moa-on-farm-drone-training-material-development/>



Regulatory Framework

The regulatory framework governing drone pesticide application is crucial for ensuring safety, compliance, and effective pest management. This section outlines the current trends in drone laws and regulations, along with recommendations for developing a Standard Operating Procedure (SOP) and establishing a certification process for drone pesticide spray service providers.

Recommendations for Building a national Standard Operating Procedure (SOP)

- **Define Objectives:** Clearly outline the goals of the SOP, including safety, compliance, and operational efficiency.
- **Outline Procedures:** Document step-by-step procedures for drone operation, pesticide application, and maintenance. Include pre-flight checks, flight planning, and post-application protocols.
- **Training Requirements:** Specify the necessary training and certification for operators, including initial training and ongoing education.
- **Safety Guidelines:** Incorporate safety measures to protect operators, bystanders, and the environment. This includes guidelines for handling pesticides and emergency procedures.
- **Documentation and Reporting:** Establish a system for documenting pesticide applications, including records of the types and amounts of pesticides used, flight logs, and any incidents or accidents.

Setting Up a Certification Process for Drone Pesticide Spray Service Providers

- **Eligibility Criteria:** Define the qualifications required for service providers, including certification as a remote pilot and completion of pesticide application training.
- **Training Programs:** Develop comprehensive training programs that cover drone operation, pesticide application techniques, and regulatory compliance.
- **Assessment and Evaluation:** Implement a system for evaluating the skills and knowledge of service providers, including written exams and practical assessments.
- **Certification Renewal:** Establish a process for the periodic renewal of certifications, requiring continuing education and re-evaluation to ensure that providers remain compliant with current regulations and best practices.

The Asia-Pacific (APAC) region is experiencing rapid adoption of unmanned aerial vehicles (UAVs) for pesticide application, driven by the need to increase agricultural efficiency, manage labour shortages, and improve precision in crop protection. However, unlike conventional ground sprayers, UAVs intersect two highly regulated domains: **civil aviation** and **agrochemical use**. Understanding the regulatory framework governing these operations is therefore critical for every stakeholder – operators, spray service providers, pesticide manufacturers, extension agencies, and policy makers

Refer to local laws and regulations and use pesticide safely and effectively. Pesticides should be registered and must follow local registration regulation laws.

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
India	Yes. Dedicated Drone Rules 2021 in force (govern all UAV operations) and an official SOP for pesticide/nutrient spraying was issued in 2022[1]. The framework encourages agri-drones (with subsidies) and mandates compliance with safety protocols.	Central Insecticides Board & RC (CIB&RC) – evaluates and approves pesticides for drone use (477 products approved as of 2022)[2][3]. No separate applicator license for drone spraying; operators must follow the SOP and use only approved formulations.	DGCA (Ministry of Civil Aviation) – All drone pilots and drones must be registered via Digital Sky and DGCA-certified (Remote Pilot Certificate)[4]. Pilot training and licensing are handled by DGCA-authorized Flight Training Organizations.
China	Yes. A comprehensive framework is in place. CAAC (Civil Aviation Administration of China) regulations cover UAV registration and operation; pilots of crop-spraying drones must be licensed[5]. In Jan 2024, CAAC and MARA (Ministry of Agriculture & Rural Affairs) jointly issued <i>interim</i>	MARA / NATESC – Oversees safe pesticide use with drones (e.g. training content) and likely manages approval of drone-specific pesticide formulations (China has a large number of approved drone spray products, reflecting its extensive use[2]). Product labels must permit aerial application. There is no separate “applicator license” for farmers; instead,	CAAC – via AOPA-China. Pilots of agricultural UAVs >7 kg are required to obtain a drone pilot license issued by AOPA (under CAAC)[5]. Additional certification under a special “Crop Protection” class is required for spray drone operators[5]. (Note: New 2025 rules strengthen licensing and no-fly zone compliance[9].)

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	<i>regulations for training and management of agricultural UAV operators</i> [6] , standardizing pilot training/certification. China has widely adopted spraying drones (over 120,000 in use by 2021) under these rules.	training certification is emphasized (over 40,000 crop-spray drone pilots trained via AOPA/DJI programs) [7] [8] .	
Japan	Yes. Japan pioneered agri-drones (over 30 years use). MAFF (Ministry of Agriculture, Forestry & Fisheries) established guidelines for pesticide drone use back in the 1990s. A well-established framework exists: drones must meet approval standards, pilots must be licensed and specifically trained for pesticide spraying [10] . In 2019–2022, Japan updated its laws – the Civil Aviation Bureau (JCAB) introduced a formal UAV pilot license and model certification system for drones. Standard protocols (e.g. requiring two-person teams for	MAFF (Japan) – All pesticides must be registered for drone application. Japan has a large catalog of approved drone-spray formulations (e.g. ~1,212 products by 2023) [11] . Labels must explicitly allow UAV spraying [12] . Training in safe handling is required; many operators are certified via Japan Agricultural Aviation Association programs.	JCAB (Ministry of Land, Infrastructure, Transport) – oversees drone flight regulations. Pilot License is mandatory (introduced 2022) for larger drones; operators pass a skills test or training for certification [13] . Japan’s system is rigorous, ensuring pilots are competent on specific drone models. (Earlier, pilots were trained via manufacturer programs like Yamaha’s for mini helicopters.)

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	spraying) are enforced to ensure safety.		
South Korea	Yes (established). South Korea has integrated drones into agriculture for years (including unmanned helicopters). General drone laws (MOLIT's KOCA rules) apply to agri-drones. While no separate ag-specific law, the widespread use – ~30% of pesticide spraying in Korea is done by drones – has led to de facto standards[14]. The government provides guidance and subsidies for drone spraying.	MAFRA/RDA (Ministry of Agriculture) – Coordinates with agencies to ensure safe pesticide use. South Korea has registered ~203 pesticide products for use with drones[2], indicating formal evaluation of formulations. Licensed pesticide applicator requirements similar to ground spraying may apply, but specific “drone applicator” licenses are not reported. Emphasis is on using approved products and adherence to drift mitigation guidelines.	KOCA (Korea Office of Civil Aviation) – Registration and licensing required for larger drones. Commercial drone operators must register, and a pilot license is needed for UAVs ≥12 kg[15][16]. Pilot certification involves training and an exam. (South Korea's civil aviation rules ensure drone pilots understand airspace and safety.)
Taiwan	Partial/In Progress. Taiwan is actively developing its framework. A general UAV operation regulation exists (for registration and basic rules), and an agricultural drone spraying regulation is under construction[17]. As of recent reports, no national SOP has been finalized – authorities recognize	Council of Agriculture (COA) – Responsible for pesticide use oversight. It has been reported that operators must obtain a pesticide spraying permit in addition to a pilot license. COA has trained pesticide spray technicians (300+ certified for traditional spraying) and is now extending training to UAV usage[18][19]. Only pesticides registered under	CAA (Civil Aeronautics Administration) – governs drone flight. Remote Pilot certificates are required for larger drones or commercial use. Taiwan reportedly requires <i>two</i> certificates for agri-drone operators: a CAA drone pilot license and a COA-issued pesticide application license (to ensure competence in

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	the urgent need to standardize drone spraying practices [17] .	Taiwan's system can be used (all agro-pesticides require COA registration). Efforts are underway via TARI (Taiwan Agricultural Research Institute) to develop SOPs and safety standards for drone spraying.	both flight and spraying). This dual certification approach is being implemented as part of the emerging framework.
Vietnam	Yes (new). In January 2023, the Ministry of Agriculture and Rural Development (MARD) issued the first official standards/guidance for pesticide-spraying drones [20] . This document serves as the legal basis for deploying drones in agriculture and is Vietnam's initial policy framework for agri-drones. It covers registration of drones for ag use and operational guidelines. (General drone flight rules are covered by civil aviation regulations, which are being harmonized with the agri-drone guidelines.)	MARD – Vietnam's MARD now oversees registration of pesticide products for drone use [20] . The 2023 standards allow pesticides to be explicitly approved for aerial application via drone. Prior to this, no products were officially labeled for drones. With the new policy, Vietnam can register drone-specific uses on pesticide labels and set training requirements.	CAAV (Civil Aviation Authority of Vietnam) – handles airspace and UAV permits. Currently, MARD is coordinating with CAAV to ensure drone operators in agriculture comply with aviation safety rules. Pilot licensing follows general UAV rules (e.g. weight-based permits). As the MARD standards roll out, expect formal requirements for operators to obtain CAAV approval/permits for agricultural spraying missions (in addition to adhering to MARD's guidelines).
Philippines	In Progress. The Philippines is moving toward an	FPA (Dept. of Agriculture) – Accredits drone	CAAP – regulates all UAV operations. Drone pilots must

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	integrated policy. The Civil Aviation Authority (CAAP) and Department of Agriculture have been working since 2023 to harmonize rules[21]. Amendments to the civil aviation regulations to specifically address agricultural drone use are slated for release. Meanwhile, the Fertilizer and Pesticide Authority (FPA) has issued interim guidelines: it accredits “Drone Spray Operators/Controllers” and has begun approving certain pesticides for drone spraying[22].	pesticide applicators. Operators must secure FPA accreditation as a Drone Controller/Spray Supervisor, which entails training and an exam on safe pesticide use[23][24]. (Notably, a valid CAAP UAV Controller Certificate is a prerequisite[23].) FPA also maintains a list of approved pesticide products for drones[22] (several drone-use pesticides have been conditionally approved, e.g. <i>Prevathon</i> insecticide[25]). Full protocols (application standards, drift management, etc.) are being developed by FPA in collaboration with IRRI and other agencies[26].	follow CAAP’s general drone rules (registration, operational limits) and upcoming specific provisions for ag use. Commercial drone use requires a CAAP license (Remote Pilot License) or controller certificate. CAAP conducted consultations in 2023 and is updating its rules to accommodate agricultural spraying[21]. Until new rules are out, operators need CAAP authorization for any aerial spraying activities (on a case-by-case waiver basis).
Indonesia	No specific ag policy (yet). Drones are subject to general civil aviation regulations (Ministry of Transport’s rules). Spraying drones are allowed but with restrictions – e.g. they must operate at least 500 m away from residential areas[27]. Indonesia	Ministry of Agriculture (anticipated) – At present, Indonesia has no special certification for drone applicators. Pesticides used must comply with existing laws (i.e. be registered for use on crops, though labels may not mention drones). The government is in early stages of considering	DGCA (Directorate General of Civil Aviation) – oversees drones under general UAV rules. Operators must abide by existing drone regulations (e.g. permits for flying in certain zones, maximum altitude etc.). There isn’t a specialized drone pilot license just for

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	currently lacks a dedicated law or detailed guidelines for agricultural drone use; authorities acknowledge the legal framework is “still weak” and that a clear law or regulation is needed[27].	how to regulate drone spraying; likely a collaboration between the ag ministry and aviation authority will define training/certification in the future. For now, any large-scale drone spraying often involves government-supervised pilot projects (no formal license for pesticide application yet).	crop-spraying – operators use standard UAV operator permits. Enforcement of no-fly zones (like the 500 m rule) is the main concern. In summary, no dedicated pilot certification for ag drones is in place beyond the standard UAV operator requirements.
Thailand	No, not specifically. Drones in Thailand are governed by the Air Navigation Act and civil aviation notifications. No specific agricultural drone regulation or SOP exists yet[28]. Farmers are using drones (especially for rice), and the government has been studying the issue, but as of now all agri-drone operations must simply comply with general drone laws (e.g. registration, permits for >25 kg, line-of-sight operation, etc.).	Department of Agriculture (DoA) – Thailand has no dedicated pesticide-by-drone certification. Pesticides are regulated under existing laws (which generally did not envisage drones). Operators are expected to follow label instructions (many labels do not include drone use yet). The DoA has been “developing guidance” together with other agencies[29], but until formal guidelines emerge, there’s no official certification or list of allowed drone pesticides in Thailand. (Most farmers rely on best practices and vendor training.)	CAAT (Civil Aviation Authority of Thailand) – responsible for drone oversight. No special pilot license for agricultural use is required aside from standard drone operator registration. Drones over 2 kg must be registered and those over 25 kg need special permission. Commercial ag-drone service providers typically must obtain a CAAT permit for operating UAVs. In practice, many operators receive informal training (often from drone distributors), but no government-issued “ag drone pilot” license exists yet.

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
Malaysia	Partial. No separate ag-drone law, but integration into existing frameworks. Drones fall under the Civil Aviation Act 1969 and civil aviation regulations. For agriculture, Malaysia's Department of Agriculture (DoA) has introduced an "Agricultural Payload" approval list – a list of pesticides and substances permitted for use by spraying drones[30]. This effectively serves as a policy mechanism to ensure only approved chemicals are used via drones. There is no published national SOP specific to drone spraying, but guidelines exist through DoA directives.	DoA / Pesticide Board – Under the Pesticides Act 1974, aerial application typically requires a licensed Pest Control Operator for spraying services. Malaysia publishes a list of pesticides approved for drone spraying[30], and operators must stick to these. At present, no special "drone applicator" license is mandated; however, companies offering drone-spraying services often need a Pest Control Operator license. The DoA works with the Civil Aviation Authority to ensure safety (e.g. avoiding drift to sensitive areas). Training programs for farmers and technicians are growing (often led by state ag departments).	CAAM (Civil Aviation Authority of Malaysia) – regulates drone pilots. Operators must obtain a UA pilot license or special permit for heavy drone use (drones >20 kg require a Remote Pilot License and an authorization). Commercial operations (including crop spraying) need CAAM permission per CAD 6011 Part II (UAS Agricultural Operations guidelines). In summary, drone pilots must be CAAM-licensed and follow any operational conditions (e.g. altitude limits, daytime only, etc.), in addition to having DoA clearance for the payload.
Bangladesh	In development. Bangladesh currently lacks finalized drone-spraying rules, but efforts are underway. The Ministry of Agriculture and Civil Aviation	Dept. of Agricultural Extension (DAE) – Expected to handle on-field protocol. As of now, no formal pesticide applicator certification for drone use exists. Any drone spraying must adhere to existing pesticide	CAAB (Civil Aviation Authority of Bangladesh) – currently requires all drones to be approved case-by-case. No specific drone pilot license yet (operators need CAAB permission for

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	Authority (CAAB) are jointly developing a regulatory framework for agri-drones[31] – covering licensing, airspace management, and training. No official SOP yet, but pilot projects have demonstrated drones in rice and jute fields. (Bangladesh did issue general drone guidelines in 2020 for hobbyist use, but ag use needs special provisions.)	safety rules and get ad-hoc permission. Bangladesh is likely to introduce a certification or training requirement through DAE once the policy is ready (with support from international partners to build capacity).	any UAV >5 kg or for commercial use). The upcoming framework will likely institute a licensing system for drone pilots in agriculture[31]. Until then, very few operators (mainly government or research projects) are authorized, each under experimental/exemption approvals.
Pakistan	In development. Pakistan approved a <i>National Drone Policy</i> in principle (2022–2023) but it remains in draft awaiting parliamentary approval[32]. The draft policy creates a four-tier classification of drones and mandates federal registration of all UAVs[33]. It also proposes a new Civil Drone Regulatory Authority to oversee drones. Some provincial initiatives have begun – e.g. Punjab’s Agriculture	Department of Plant Protection / Provincial Agri Depts – Presently, no official certification for drone pesticide applicators. The Punjab province’s draft SOP is an internal guideline to ensure safe operations during pilot projects[34]. Eventually, the federal Plant Protection authorities may require operators to be licensed (possibly akin to existing Aircraft Spraying Licenses in manned aviation). Currently, pesticide imports for drones and	CAA (Civil Aviation Authority of Pakistan) – Until the new drone law passes, CAA handles approvals on a case-by-case basis. Importing or operating drones requires special permission due to security regulations. The <i>draft rules</i> will formalize pilot licensing (based on drone weight categories) and mandatory registration[33]. In the interim, no dedicated drone pilot license system exists – the

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	Dept. has formulated SOPs for agri-drone use and conducted pilot programs[34] – but widespread use is limited until national regulations are formalized.	their use are tightly controlled (only a handful of service providers operate under research exemptions).	few agriculture drone operators either operate informally or under experimental permits. Once law is enacted, pilots will need to obtain certification from the proposed Drone Regulatory Authority and CAA.
Australia	Yes. A mature framework combining federal and state regulations. CASA (Civil Aviation Safety Authority) permits agricultural spraying by drones under existing aerial application rules. Operators must obtain a Remote Pilot Licence and an Operator's Certificate (ReOC) for spraying operations. Additionally, each state imposes SOPs and licensing under pesticide laws – e.g. in New South Wales, pilots applying pesticides (and the businesses hiring them) must hold specific qualifications and an EPA pesticide applicator licence under the NSW	State Agriculture/Environment Agencies – handle pesticide applicator licensing. Aerial pesticide application by drone is treated like crop-dusting: operators in most states need an aerial applicator licence or must work under a licensed contractor. For example, NSW's EPA issues licenses for UAV spraying of ag chemicals[35]. States also maintain approved chemical lists or conditions (to prevent drift near sensitive areas). The federal Australian Pesticides and Veterinary Medicines Authority (APVMA) may require that chemical labels permit aerial use; many labels have been updated to include drone application scenarios.	CASA – regulates all drone pilots. Remote Pilot Licence (RePL) is required for drones >25 kg (or <25 kg if for commercial spraying beyond visual line of sight, etc.). Also a Remote Operator's Certificate (ReOC) is required for the company/operation. CASA's Part 137 (Agricultural Operations) and Part 101 UAS rules apply – meaning drone pilots must follow similar standards as manned ag pilots. In summary, an Australian ag-drone pilot typically holds a CASA RePL and a state-issued chemical applicator license[35].

Country	Policy & SOP Status	Pesticide Application Certification (Authority/Mechanism)	Drone Pilot Licensing (Authority)
	Pesticides Act [35] . Similar requirements exist in other states.		
New Zealand	Yes. Since 2019, New Zealand explicitly allows drone spraying under regulated conditions. The CAA (Civil Aviation Authority) created rules for unmanned aerial spraying: operators need to be certified under Part 102 (for higher-risk UAV operations) <i>and</i> comply with aerial agriculture requirements (similar to manned topdressing planes) [36] . Essentially, a drone operator must obtain a Part 102 Operator Certificate that specifically authorizes agricultural spraying.	Ministry for Primary Industries / EPA – New Zealand’s EPA treats drone spraying under existing hazardous substances regulations. Operators must ensure pesticides are approved for aerial use and follow all label rules. While there isn’t a separate “drone applicator” license, the company’s Part 102 certificate for ag operations acts as a certification that they meet safety and efficacy standards. Pilots often undergo training equivalent to manned ag pilots (including knowledge of drift management and weather).	CAA – Drone pilots must either fly under a Part 102 certified operator or, if using smaller drones under 25 kg within basic rules, still follow Part 101. For commercial spray operations, CAA effectively requires a licensed pilot <i>and</i> an approved operation plan. New Zealand’s framework can be seen as case-by-case: companies propose how they’ll meet safety standards, and CAA grants an operating certificate for those agricultural drone activities [36] . This includes pilot competency checks. In practice, specialized training for ag drone pilots is provided by ag aviation schools or the manufacturers, reviewed by CAA during certification.

Certification Frameworks in Asia-Pacific Countries

China

In China, agricultural drone operators are required to be licensed, but the training and certification system is largely driven by industry with government oversight. The Civil Aviation Administration of China (CAAC) mandates drone pilots to have a license, and the Aircraft Owners and Pilots Association (AOPA) is an official training body registered with CAAC[5]. In practice, however, leading drone manufacturers like DJI and XAG have established their own training academies which have become the popular route for aspiring spray service providers[6]. These private academies – often run by the manufacturers in partnership with crop protection organizations – offer courses tailored to pesticide application, including UAV flight control, maintenance, and spraying techniques[7][8]. Operators undergo both classroom theory (e.g. flight regulations, meteorology, pesticide safety) and hands-on flight practice. For example, practical training hours are included for flight maneuvering skills (take-off, landing, route navigation) and for safe pesticide handling (mixing, nozzle calibration, cleaning)[9][10]. Trainees must demonstrate proficiency through written exams and practical flight tests. Notably, since 2024 Chinese regulations explicitly allow drone pilots to be trained and licensed by accredited manufacturers themselves[11]. These manufacturer-issued certificates are expected to gain official recognition, reflecting a public-private model of certification[12][13]. Currently, a drone pilot license in China is separate from any general pesticide applicator license (i.e. a pest control operator license is not integrated)[13]. Instead, the drone training curriculum covers essential pesticide knowledge as a “top-up” for those not already certified in pest control. China’s approach illustrates a flexible framework: strong government support for third-party training, minimum standards set by CAAC, and industry-driven programs that rapidly build capacity for tens of thousands of drone spray operators[6][14]. Periodic re-training is encouraged as drone technology evolves, though formal re-certification intervals are still emerging. Many training academies issue certificates with validity (e.g. 2–3 years) and offer refresher courses to update operators on new models and safety guidelines, helping maintain high competency standards[15][16].

India

India has developed a structured certification system for drone operators in agriculture in recent years, under the oversight of the Directorate General of Civil Aviation (DGCA) in coordination with the agriculture ministry. Any person operating a pesticide-spraying drone (typically in the small or medium category, >2 kg) must hold a **Remote Pilot Certificate (RPC)** issued by a DGCA-approved training organization[17][18]. Farmers or service providers are required to undergo training at an authorized Remote Pilot Training Organisation (RPTO) that covers multirotor flight principles, aviation regulations, maintenance, and safety procedures[19][18]. After completing the course (often about 5 days of theory and hands-on flying practice), candidates must pass a written exam and a practical flight

test. Upon passing, they receive the RPC (which has replaced the earlier “drone pilot license” in India’s liberalized drone rules)[\[20\]](#). The RPC is generally valid for 10 years, after which renewal training or a refresher test is required for re-certification[\[18\]](#).

Importantly, beyond aviation skills, operators are expected to follow agricultural guidelines issued by the Ministry of Agriculture. In 2022, the ministry released Standard Operating Procedures (SOPs) for drone pesticide application, emphasizing safe mixing, drift management, and adherence to approved agrochemical uses[\[21\]\[22\]](#). While India does not (yet) mandate a separate **pesticide applicator license** specifically for drone spraying, the guidance effectively requires pilots to be knowledgeable in pesticide stewardship. Many RPTOs now include basic crop protection modules in their curriculum (e.g. understanding pesticide labels, spray calibration, and PPE usage) so that graduates can spray in compliance with agricultural regulations[\[23\]\[24\]](#). Additionally, special programs have been launched to expand the certified workforce: for instance, the government’s “Kisan Drone” initiative provides subsidies for agri-drones and supports training programs through agricultural universities and Krishi Vigyan Kendras (farm science centers)[\[25\]](#). One notable example is the **Drone Didi** scheme, training rural women to be licensed agri-drone pilots with a focus on crop spraying, thereby building local capacity[\[25\]](#).

Testing of proficiency in India involves DGCA’s standard remote pilot exams (covering air law, navigation, meteorology, etc.) and a practical assessment where candidates must plan and execute a mock spray mission under instructor observation. Those specializing in spraying also receive practical coaching on spray equipment handling and pesticide safety, often in collaboration with the Ministry of Agriculture’s extension officers. India’s framework thus integrates civil aviation training with sector-specific best practices. The issuing authority for the Remote Pilot Certificate is DGCA (via its DigitalSky online platform), and certificates are recorded in a national database[\[19\]\[26\]](#). As of 2022, India eliminated the need for a separate drone pilot license document – the DGCA RPC suffices as proof of competence, simplifying compliance[\[20\]](#). Recurrent training is expected as drone rules update; pilots may be required to undergo refresher courses on new technology or regulations within the 10-year certificate period. Overall, India’s approach underscores formal training (with ~40–50 hours of instruction) and a long certificate validity, coupled with detailed SOPs to guide safe pesticide use.

Japan

Japan has one of the longest-established systems for certifying aerial pesticide applicators, dating back to the use of remote-controlled helicopters in the 1990s. Today, drone (UAV) spray operators in Japan must be licensed, and the framework involves both government regulation and authorized private training bodies[\[27\]\[28\]](#). Historically, the Japan Agricultural Aviation Association (JAAA) was the sole body entrusted by the government to train and license aerial application pilots (for radio-controlled helicopters). The training manual developed by JAAA set a rigorous

standard, covering flight skills and pesticide safety. Since 2019, regulations have evolved: the government opened up pilot training to **private schools** (including manufacturers' academies and other entities), which can be authorized to conduct courses and issue certificates[28]. JAAA remains an important reference (its curriculum is still used as a base for drone training), but licensing is now decentralized to multiple accredited organizations[29].

A Japanese drone spray operator typically undergoes a comprehensive course (often around 10 days or more) that includes classroom lessons on drone technology, aviation law, and agrochemical knowledge, as well as practical flight training on simulators and in fields. For example, Yamaha Motor (which manufactures the FAZER and other crop-spraying unmanned helicopters) runs training centers where pilots log many hours practicing precise navigation and spray operations. The curriculum emphasizes understanding pesticide application guidelines: trainees learn about droplet size and drift, weather conditions, dosing and dilution, and equipment maintenance[8][30]. They also study Japan's Good Agricultural Practice (GAP) and label instructions, since the Ministry of Agriculture, Forestry and Fisheries (MAFF) requires that any aerial application (including by drone) use registered products according to approved conditions[31][32]. After training, pilots must pass a technical exam (including demonstrating flight maneuvers and emergency procedures) and a written test on safety and regulations. Those who pass are certified and can operate drones for crop protection. As of the latest rules, **two separate licenses** are required: one for operating the UAV itself and one as a Pest Control Operator (PCO) for handling pesticides[33]. In practice, many operators already held a PCO license (for manual spraying) and then add a drone operation certification as a "top-up"[34][35]. If an operator does not have a pesticide applicator background, a drone-specific pesticide safety training is provided, although a full PCO license might not be mandated for them in certain cases[36].

Japan's MAFF supervises the accreditation of training facilities to ensure standardized instruction nationwide[37][38]. The regulatory conditions for safe UAV pesticide operations in Japan include vehicle approval, pilot licensing/training, use of registered pesticides, and strict adherence to label usage instructions[37]. Certification and licenses must be regularly renewed; for instance, pilots generally undergo **refresher courses every 3 years** to stay updated on new drone models or revised regulations[37]. MAFF's guidance also calls for routine evaluation of training syllabi and periodic re-testing to uphold high safety standards[15][16]. In summary, Japan's framework is mature and institutionalized: it integrates civil aviation safety (through pilot licensing) with agricultural chemical safety (through product registration and applicator licensing), supported by decades of data showing that UAV spraying can be as efficacious as traditional methods when done by properly trained operators[32][39].

South Korea

South Korea has rapidly adopted agricultural drones and has implemented a certification regime similar in spirit to Japan's. Drone spray operators in Korea are

required to obtain a license, with training and examination typically conducted by **authorized private bodies** under government oversight[40]. The Korean Rural Development Administration (RDA) and the Ministry of Agriculture have collaborated with the civil aviation authority to develop training standards. Private training schools (often run by drone manufacturers or agricultural cooperatives) provide the required courses, and **private accredited entities issue the licenses** to pilots upon successful completion[40]. This indicates that while the government sets the rules, it entrusts certified institutions to train and test pilots – a model akin to China’s and Japan’s recent approach.

A typical training program in Korea covers drone operation theory, maintenance, navigation and map-based flying, as well as pesticide application techniques. Trainees practice under real field conditions, learning to handle Korea’s hilly terrains and patchwork fields safely. They are also taught about pesticide drift, weather impacts, and the importance of using approved chemical doses. The proficiency test usually consists of a written exam and a practical flight test (pilots must demonstrate precise flying along crop rows, consistent altitude for spraying, emergency handling, etc.). Additionally, operators must separately obtain a pesticide applicator qualification: similar to Japan, **two licenses are needed** – one for drone piloting and one as a certified pest control applicator[41][42]. The pest control license may be issued by the local agricultural authority and ensures the operator knows how to safely mix and apply agrochemicals. However, for those whose primary role is drone operation, Korea has explored offering a streamlined pesticide training course instead of the full conventional applicator course (to lower barriers for new tech adopters)[43].

Korea’s system also emphasizes continuous improvement. The RDA periodically updates training content as drone technology evolves (e.g. automation features, larger drone models). Upgrading and retraining of operators is mandated at intervals – pilots are encouraged or required to attend refresher workshops to maintain their skills[44][45]. The issuing authorities for licenses are typically the accredited training schools (license certificates often bear a delegated authority from the government). There is strong government support for private sector involvement; in fact, regulators work closely with third-party trainers to expand training capacity[45][46]. By 2025, South Korea reportedly had thousands of licensed drone applicators, reflecting the success of this partnership model. In summary, South Korea requires formal certification of drone pesticide operators, combining a **Remote Pilot competency certificate and an agricultural chemical applicator certificate**, with a training regime delivered by certified private academies and monitored by government for quality assurance[47][48].

Thailand

Thailand is an example of a country in transition from informal to formal certification frameworks for drone operators. The use of drones for spraying has grown popular among Thai farmers in recent years, initially driven by private companies and farm co-ops offering drone services. As of the mid-2020s, the Thai

government (through the Civil Aviation Authority of Thailand, CAAT) has moved to strengthen pilot licensing requirements. New regulations mandate that **all drone operators obtain a drone aviation certificate from CAAT** by September 1, 2025[49]. This effectively means anyone flying a drone commercially (including for pesticide spraying) must undergo training and pass a CAAT-administered test. Drones above 2 kg already required registration and basic pilot permits, but the updated rules extend a licensing requirement to smaller drones and aim for universal compliance[50]. Operators of very large drones (>25 kg) must even seek special permission from the Transport Minister, but for most farm drones (often ~10–20 kg), a CAAT certificate suffices[51].

Before these regulations, much of the training in Thailand was industry-led. Major drone manufacturers have established training centers in Thailand – for example, DJI partners with local agencies to run a **Drone Academy**, and Chinese firm XAG, along with Thai agribusiness Chia Tai, set up a training and service center that includes a “Drone Academy” for farmers[52][53]. These programs teach farmers how to operate drones for tasks like rice paddy spraying or seeding, covering equipment maintenance and safety. A typical curriculum spans a few days of instruction on drone operation (flight controls, mission planning) and field practice on spraying techniques (maintaining altitude, overlap, avoiding drift). Since many early adopters were tech-savvy farmers, peer learning was common, but now formal testing is being instituted. The CAAT’s new licensing exam likely involves an online theoretical test and a practical demonstration, aligned with ICAO safety standards[54][55].

In parallel, the Ministry of Agriculture is beginning to look at pesticide-related certification. Currently, **no separate pesticide applicator license is explicitly required for drone use in Thailand**, but general pesticide laws still apply (e.g. only registered chemicals can be used, and large-scale custom applicators might need permits). To promote best practices, Thai agricultural agencies have been holding training workshops. For instance, the Department of Agriculture has partnered with universities on pilot training programs in 500 farming communities, including establishing licensing examination centers in rural areas (in collaboration with the private sector) – an initiative aimed at making certification accessible to farmers across the country. These efforts indicate that proficiency testing will include not just piloting skills but also knowledge of safe pesticide application (proper mixing, buffer zones, etc.). Re-testing and renewal requirements are expected to be introduced as the system matures. Given that the rule requiring a CAAT certificate is new, enforcement and periodic renewal (possibly every 2–5 years) will be areas to watch. In summary, **Thailand’s framework is evolving from voluntary training to mandatory certification**, with CAAT ensuring aviation safety compliance and the agriculture ministry encouraging pesticide safety training. By late 2024, Thailand conducted its first government-led drone training courses and issued certificates to dozens of operators, signaling the start of an official certification program[50]

A farmer in Thailand practices operating an agricultural spraying drone. Formal licensing of all drone operators (including those for pesticide application) is being phased in by the Thai

civil aviation authority[56]. Training programs, often run in partnership with industry, teach safe flying and spraying techniques to ensure efficacy and safety in the field.

Vietnam

Vietnam has actively begun integrating drones into agriculture, and while a full-fledged licensing framework is in its infancy, significant steps have been taken toward operator certification. The Ministry of Agriculture and Rural Development (MARD), through its Plant Protection Department, conducted the country's first structured training course on operating drones for pesticide spraying in 2024[57][58]. This pilot program – organized in collaboration with CropLife Vietnam and a private drone company (AgriDrone Vietnam) – trained a group of “trial officers” (research and extension personnel) in both theory and hands-on drone operations. Over two days, participants learned UAV flight skills and safety protocols specific to pesticide application, then practiced flying and spraying on rice fields under supervision[58]. The course concluded with an evaluation, and trainees who met the competency standards were **awarded certificates by the Plant Protection Department**[59]. The Director of the department personally presented these certificates, underlining the ministry's commitment to formal training and its recognition of drone operation as a professional skill[60].

While this initial course targeted agricultural officers (to enable them to later train farmers), it set the template for broader certification. The content covered regulatory guidelines (Vietnam is drafting rules to allow drone spraying on crops under certain conditions), technical know-how (drone mechanics, navigation), and agronomic knowledge (optimal spraying height, droplet size, avoiding sensitive areas). It also highlighted the efficiency benefits: according to CropLife Vietnam, drone spraying can reduce water usage by 90% and cut costs by ~50% compared to traditional knapsack sprayers[61] – facts that are used to encourage adoption, but with the caveat that only properly trained operators can achieve these benefits safely.

Looking ahead, Vietnam is likely to require that any commercial drone spraying service providers be certified. This would entail a process where operators undergo a training course similar to the pilot program, possibly on the order of 3–5 days, covering both aviation and pesticide safety. The **civil aviation authority in Vietnam (CAAV)** already has regulations requiring drone pilots (above certain weights or for commercial use) to register and in some cases obtain permission, but a specific “drone license” for small agricultural UAVs is not yet standard. We can expect CAAV to formalize remote pilot competency requirements in line with ICAO guidelines, which would include an online exam and a practical test[62]. On the agriculture side, the Department of Plant Protection is developing guidelines for drone pesticide use (for example, ensuring drones are only used with officially tested and approved pesticide products, to maintain efficacy and safety[63]). There is also regional cooperation – Vietnam has been learning from neighboring countries and international experts. In fact, the International Rice Research Institute (IRRI) and Vietnam's Fertilizer and Plant Protection Authority have a partnership to create training materials for farm drone operation[64].

In sum, Vietnam's current approach to certification is through **joint training initiatives and gradual institutionalization**. Operators who are early adopters often receive training from private companies (like AgriDrone or DJI's local dealers) – for example, AgriDrone Vietnam offers short courses to farmers when they purchase equipment[65]. But moving forward, official certification will likely involve passing an exam to receive a permit or license from MARD or a designated authority. The recent government-run program indicates that certificates will be issued for completion of approved training, and we can expect re-certification requirements (such as attending an update workshop every few years) once the program scales up. At present, Vietnam does not mandate a standalone pesticide applicator license for drone use – the focus is on building basic capacity and ensuring all drone applicators have at least undergone some formal training in safe operations.

Malaysia

Malaysia's regulatory framework for drone pesticide operators is taking shape through a combination of civil aviation rules and specific provisions for agricultural drone work. All drone operators must hold a **remote pilot certificate** issued under the Civil Aviation Authority of Malaysia (CAAM) regulations[66]. CAAM certifies pilots via approved Remote Pilot Training Organizations, where trainees learn general drone operation and aviation law[66]. In addition to the basic pilot certification, Malaysia has introduced a dedicated certification for agricultural spraying operations: an **Unmanned Aerial Work Certificate (UAWC)** for agricultural UAS operations. In fact, CAAM regulation explicitly states that using a drone for aerial work (like dispensing pesticides) is not allowed without authorization from the Authority[67]. To obtain this, operators must apply for the UAWC under a specific procedure that ensures they meet extra requirements for agriculture. The UAWC functions as an operational license verifying that the drone system and the pilot are qualified for tasks such as crop dusting. It requires demonstrating procedures for safe dispensing of "agricultural payloads" (fertilizers, pesticides, etc.) and often a safety management plan[68].

The **training curriculum** in Malaysia for agri-drone operators typically includes the core CAAM syllabus (flight theory, navigation, drone laws) plus modules on agriculture. The Pesticides Board of Malaysia and other agricultural agencies have input into these modules, covering topics like spray calibration, weather considerations in the tropics (to avoid monsoon winds during spraying), and avoiding contamination of water bodies. Some programs are run in partnership with universities and state agriculture departments. For example, the state of Pahang's Skills Development Centre offers a 5-day Agriculture Drone Pilot course that blends theory with field practice, after which participants receive a certificate recognized by local authorities[69]. Private companies such as AirAsia's Drone Academy (a CAAM-certified RPTO) also train many agricultural drone pilots, indicating a growing ecosystem of training providers[70][71].

Certification testing involves a written exam (based on CAAM's remote pilot knowledge test) and a practical assessment. For the UAWC specifically, operators

might have to submit their drone's specifications, a maintenance log, and pass an audit of their operational procedures[\[72\]\[73\]](#). Issuing authorities: CAAM issues the Remote Pilot Certificate and the UAWC (after vetting by a committee that may include the Department of Agriculture). As such, an agricultural drone service provider in Malaysia would carry two credentials: a personal pilot certification and an operating permit for the service. The UAWC and pilot cert typically require renewal. Malaysia's approach is proactive in ensuring **both pilot competence and proper use of pesticides**. Notably, pilots applying pesticides in Malaysia must also comply with existing pesticide regulations – while there isn't a separate "pesticide applicator license" category for drones, commercial applicators generally need to be registered, and certain states might require the pilot or the employing company to have licensed pesticide applicators on staff. For instance, similar to Australia's model, an operator might need to hold an *EPA (Environmental Protection Agency) license* if local law demands it for any aerial spraying. Indeed, in nearby Singapore and by extension Malaysia, regulations are trending toward requiring companies to have certified pest control professionals if they offer spraying services.

In summary, Malaysia's certification framework can be seen as **integrated but dual-layered**: CAAM handles the flight authorization side (with the UAWC explicitly covering agricultural spraying), and the Ministry of Agriculture ensures training content and practice align with safe pesticide use. Recertification usually entails renewing the UAWC annually or bi-annually and the pilot license every few years, with evidence of continued proficiency. As of 2025, Malaysia is refining these processes, but the fundamentals (trained at an RPTO, special certification for spraying) are in place[\[74\]\[68\]](#).

Indonesia

Indonesia is at an emerging stage of formalizing drone operator certification, with strong involvement from educational institutions and private industry. Currently, anyone using drones for commercial purposes (including agriculture) must follow rules set by the Directorate General of Civil Aviation (DGCA Indonesia). This means registering the drone and, in many cases, obtaining a **drone pilot permit** after passing a basic competency test[\[62\]](#). Indonesia's DGCA has introduced a licensing scheme where operators pass a written exam and a practical flight test administered by DGCA-authorized examiners, to receive a remote pilot certificate[\[62\]](#). The content covers general UAS knowledge, airspace regulations, and safety – not specific to agriculture. However, recognizing the specialized needs of agricultural drone use, there are initiatives to augment this with targeted training.

Notably, partnerships between drone companies and universities are fostering an agricultural drone training pipeline. For example, Terra Drone Indonesia (through its Terra Agri division) signed MoUs with Indonesian universities (like Politeknik CWE, focused on oil palm plantations, and Unsurya Aviation University) to incorporate **practical drone training** into their curricula[\[75\]\[76\]](#). Students and local youths can enroll in these programs, which offer hands-on training in operating spray drones in realistic farm settings – such as practicing pest control in a palm oil

plantation training site[\[77\]\[78\]](#). Those who complete the program undergo a certification training (Terra Drone’s “Terra Academy” curriculum) and can earn an industry-recognized certificate[\[78\]\[79\]](#). This certificate is not a government license per se, but it complements the DGCA pilot permit by proving the holder has agriculture-specific UAV skills. The goal is to cultivate a workforce of **certified agri-drone pilots** ready for hire in Indonesia’s plantations and farms[\[80\]\[81\]](#).

In terms of official requirements, Indonesia’s Ministry of Agriculture is in the process of evaluating drones for crop protection. No separate pesticide applicator license exists yet for drones; however, any entity offering spraying services must abide by general pesticide regulations (i.e. using approved products, keeping spray logs, etc.). The government has run trials (for example, testing drones on rice and palm oil crops) to issue guidelines on efficacy and safety. It is expected that as these trials conclude, Indonesia will formalize guidelines and possibly require that drone spray service providers register or get certified. For now, **certification in Indonesia heavily relies on training and self-regulation**: major plantations that use drones often require their drone operators to have completed a manufacturer’s training course or hold a certificate from a known academy. Testing proficiency is largely internal or via these training programs – e.g. an operator might have to log a certain number of supervised flight hours and pass an exam to be “certified” by a company.

Renewal and recertification are not yet standardized. Operators with a DGCA permit might need to renew it every 2 years (similar to other countries’ practice), which could involve a refresher test. Companies like Terra Drone provide updated training as drone models advance, ensuring pilots stay current. In summary, Indonesia’s approach is **evolutionary**: it has foundational aviation rules for drones and is building the agriculture-specific training layer through innovative academia-industry collaborations. As a result, hundreds of Indonesian operators have already received practical certifications through these programs, preparing the way for a more formal national certification system in the near future[\[76\]\[81\]](#).

Pakistan

The use of drones in Pakistan’s agriculture is nascent, and the regulatory framework is still being developed. Pakistan’s Civil Aviation Authority (PCAA) introduced the **Civil Unmanned Aircraft Systems (UAS) Rules 2020**, and updated “Civil Unmanned Aircraft Rules 2024”, which set out guidelines for drone import, licensing, and operation[\[82\]\[82\]](#). Under these rules, drone operators are supposed to obtain a license from PCAA – which involves security clearances and passing a written exam on aviation regulations. However, practical implementation has faced challenges. For agricultural drones specifically, Pakistan does not yet have a dedicated operator licensing program, but awareness of the need is rising. A recent policy review highlighted that **drone pilots often lack professional competence in key areas** like aviation law, risk management, and operational procedures, and it called for establishing dedicated training centers and pilot certification processes[\[83\]\[84\]](#). In other words, regulators recognize that formal training and

licensing for drone applicators is a “crucial step toward efficient drone deployment” in agriculture[85][84].

At present, any organization wanting to use drones for crop spraying must navigate a complex approval process. This involves obtaining No Objection Certificates (NOCs) from the Ministry of Defense for each drone and operation, which is cumbersome[86][87]. There is a push to streamline this by perhaps granting blanket permissions to accredited service providers or government projects[88][89]. In parallel, private sector and NGOs have started training programs. For example, the **Global Air Drone Academy** and local Pakistani partners have offered short courses to teach youths basic drone piloting, culminating in an exam (analogous to the FAA’s Part 107 exam in the US)[90]. Some Pakistani drone distributors (e.g. Agritrionics or DJI dealers) also provide training to their customers on how to operate spray drones and maintain them[91]. Yet, these are not standardized or government-certified.

We can anticipate that Pakistan will establish a two-tier certification: one, a **remote pilot license** issued by PCAA (with exams on airspace rules, flight operations, etc.), and two, an **agricultural drone operator certificate** possibly issued by the Ministry of National Food Security & Research or provincial agriculture departments, focusing on pesticide use and field safety. The latter might be similar to a pesticide applicator license. Indeed, discussions have been held about requiring drone spraying service companies to employ at least one licensed agronomist or pest control expert to supervise operations. Proficiency testing, when formalized, will likely involve both a theoretical test (covering local crop spraying regulations and safety) and a practical test (demonstrating drone handling and precise spraying). The PCAA’s licensing, once enforced, will require renewal (for example, annually or biennially, with background checks), but until the process is simpler, compliance remains low. In summary, Pakistan’s current focus is on **building capacity and regulatory clarity**. Policymakers have recommended the creation of certified training programs and pilot licenses to address skill deficits[84]. Once these recommendations are implemented, Pakistan will move from an ad-hoc situation (where a few pilots might be “certified” by virtue of some training but not a unified standard) to an official certification framework ensuring all agricultural drone operators are proficient and authorized.

Philippines

The Philippines has embraced drone technology in agriculture in recent years, prompting its regulators to adapt existing licensing systems to drone spraying. By law, drone pilots conducting **aerial work** (which includes pesticide application) must have a license from the Civil Aviation Authority of the Philippines (CAAP). CAAP requires commercial drone operators to obtain a **Remote Pilot License** under its RPAS rules, which entails training at a CAAP-accredited drone school and passing a knowledge test and practical assessment. Therefore, an agricultural drone service provider first needs to be a licensed UAV pilot (with CAAP’s certificate comparable to a private pilot license but for drones).

On the agriculture side, the **Fertilizer and Pesticide Authority (FPA)** under the Department of Agriculture plays a key role. The FPA traditionally licenses Pest Control Operators (PCOs) and pesticide applicators for ground and aerial spraying. Currently, a drone operator who offers crop spraying is expected to either hold a PCO license or work under an entity that has one. In practice, this means two separate certifications: one from CAAP for flying the drone, and one from FPA for handling and spraying pesticides[92][48]. For example, if a cooperative buys a spray drone, they might send a team member to get a CAAP drone pilot license, and also ensure that person (or another team member) has attended FPA's pesticide applicator training to be licensed for pest control operations. The FPA has begun updating its training materials to include drone-specific guidance, acknowledging that drone spraying has unique considerations (altitude, droplet drift patterns, etc.) beyond traditional methods[64]. In 2021, the FPA partnered with the International Rice Research Institute to develop a module on drone spraying in the national pesticide applicator training program[64].

In terms of curriculum: CAAP's drone training covers flight safety, emergency procedures, and Philippine airspace regulations. Some CAAP-approved schools now offer specialized courses for agricultural applications, which include mission planning for field spraying and maintenance of spray equipment. The FPA's pesticide applicator training covers chemical safety, calibration, environmental protection, and is being expanded to cover drone operation scenarios (like avoiding drift to neighboring farms, etc.). **Proficiency testing** for CAAP's license is through exams and a check flight. For the FPA license, an exam on pesticide regulations is required, and sometimes a practical demo (traditionally calibration of a knapsack sprayer; this may be adapted for drones). The integration of the two is ongoing – to streamline, there are proposals that licensed drone pilots be allowed a shortened FPA course or that joint certifications be issued, but as of now the requirements are distinct[92][48].

Philippines is also actively training farmers via its regional crop protection centers. Demonstration programs have shown farmers how to use drones and encouraged them to get certified operators to do the spraying. Re-certification: CAAP's remote pilot license typically needs renewal every few years, which might involve a refresher seminar or re-examination. The FPA's applicator licenses also expire (usually after 1–3 years) and require continuing education for renewal. The Philippines thus ensures that drone spray operators are **dually qualified** – competent in piloting (to avoid crashes or air hazards) and knowledgeable in pesticide use (to avoid misuse or environmental harm)[48]. This dual framework is aligned with the country's general approach to agricultural aviation, as the Philippines had prior experience licensing manned crop dusters and now applies similar rigor to drones.

Global Perspectives and Comparative Overview

While Asia-Pacific countries have been at the forefront of agricultural drone use, other regions have also developed certification and licensing frameworks to address this new technology. Below is a comparative overview of select countries and regions outside APAC, followed by a summary table contrasting key elements of certification frameworks worldwide.

United States

In the United States, the regulatory framework for drone pesticide applicators is governed by both federal aviation laws and state-level pesticide laws. At the federal level, the **Federal Aviation Administration (FAA)** requires any commercial drone pilot to hold a **Part 107 Remote Pilot Certificate** (or a certificated manned pilot license)[\[93\]](#). This involves passing an FAA aeronautical knowledge test covering regulations, airspace, weather, and drone operations. For small drones (under 55 lbs/25 kg) used in farming, Part 107 is the primary requirement. However, many spraying drones exceed 55 lbs with payload, or involve carrying hazardous materials (pesticides), which brings additional FAA rules. Specifically, agricultural aerial application is governed by **FAA Part 137** (the agricultural aircraft operations rule)[\[93\]\[94\]](#). Traditionally Part 137 was for manned crop dusters, but now it applies to drones as well. Drone operators can obtain a Part 137 certificate by demonstrating to the FAA their knowledge of low-altitude aviation, operation manuals, and safety procedures; in practice, most drone companies have to petition the FAA for exemptions to certain rules (since Part 137 assumes a manned aircraft). The FAA has begun streamlining this: by 2024, it approved certain standard exemptions for drone sprayer models, even publishing a list of approved UAVs that can be used for agriculture with fewer hurdles[\[95\]](#). Nonetheless, an American drone pilot who wants to spray must typically: (1) be a Part 107 remote pilot, and (2) obtain a Part 137 operating certificate or be named on someone else's Part 137 certificate with a waiver to use UAVs[\[96\]\[97\]](#). Practical proficiency is verified through FAA inspections or designated examiners – e.g. a pilot might need to perform designated maneuvers and show knowledge of dispersal equipment to an FAA inspector for the Part 137 certification.

Parallel to the aviation requirements, the **Environmental Protection Agency (EPA)** and state agriculture departments regulate pesticide applicators. Every U.S. state requires licensing for individuals who apply restricted-use pesticides or offer pesticide application services. Typically, a drone sprayer would fall under the **“aerial application” category license** (often called Category 11 or similar) which historically covered crop dusters. For instance, states like Mississippi or California require a person operating any aircraft (including drones) for pest control to pass the state's exams on pesticide laws, crop pests, and safety[\[98\]\[99\]](#). Many states have updated their statutes to explicitly mention drones: some, like North Dakota and Ohio, mandate additional permissions for drone pesticide application beyond standard licenses[\[100\]\[101\]](#). In practice, an operator needs to pass a state pesticide

applicator exam and obtain a license (which often must be renewed annually or bi-annually with continuing education). They also must follow all label requirements – e.g. if a pesticide label doesn’t include aerial use, a drone can’t be used unless a specific exemption is granted.

To illustrate, consider a service provider in Iowa: they would study and pass the FAA Part 107 test (airmanship), then apply for an FAA exemption to operate a drone sprayer under Part 137 (providing operations manuals, maintenance schedules, pilot training records to the FAA)[\[94\]](#). Simultaneously, they’d take Iowa’s commercial pesticide applicator exam for the aerial application category and register their business. Only after satisfying **both agencies** can they legally operate. The interplay of these requirements is complex, and efforts are underway to simplify it as drone use expands. The Association of American Pest Control Officials (AAPCO) is coordinating among states to harmonize rules for UAS pesticide applications[\[100\]\[101\]](#).

Recertification in the U.S.: The FAA Part 107 license must be renewed via a recurrent knowledge test every 24 months (recently, the FAA allows an online recurrent training in lieu of a test) to ensure pilots stay up to date. Part 137 certificates also require periodic renewal and ongoing compliance checks. State pesticide licenses typically expire annually or bi-annually; applicators must attend continuing education or re-exam to renew. This ensures that drone operators remain knowledgeable about new regulations, pesticide products, and safety measures. In summary, the U.S. approach demands that **drone operators be certified as pilots and as pesticide applicators**. While no single “integrated” certificate exists yet, both competencies must be present. This dual system aligns with the U.S. regulatory structure where FAA oversees the vehicle and airspace, and EPA/state authorities oversee pesticide use. Notably, U.S. regulators are gradually adapting – the FAA’s steps to list approved drones and issue broad exemptions[\[95\]](#), and states updating laws, indicate a trend towards making compliance more straightforward for drone applicators while maintaining rigorous safety standards.

European Union

In the European Union, drone pesticide application is heavily influenced by overarching EU pesticide regulations and aviation rules, and consequently certification of operators must navigate both. A key consideration is the **EU Directive 2009/128/EC on sustainable pesticide use**, which *prohibits aerial spraying* of pesticides as a general rule, with exceptions only by explicit permit[\[102\]\[103\]](#). Drones, while not explicitly mentioned in the original directive (which talked of planes and helicopters), have been interpreted to fall under “aerial application”[\[102\]](#). Therefore, EU member states can only allow drone spraying under strict derogation conditions (e.g. when ground spraying is impractical, in specific areas like steep vineyards, and using risk mitigation measures). This policy backdrop means that, unlike Asia where drone spraying is broadly embraced, in the EU each operation might require case-by-case approval.

Pilot certification in the EU follows the European Union Aviation Safety Agency (EASA) framework. Drone pilots must obtain a competency certificate according to

the category of operation. For most agricultural drones, which are likely over 25 kg or operated beyond visual line of sight at times, the operations fall under the **‘Specific’ category** of EASA rules. Pilots therefore need to undergo training and examination as determined by their National Aviation Authority for that category – often including a General VLOS Certificate (A1/A3), an additional A2 certificate for certain operations, or a Light UAS Operator Certificate (LUC) if the organization is large[104][105]. Essentially, an operator would take online training (for basic categories) and possibly an approved course for higher risk operations, then pass exams to be certified as a remote pilot. Some countries (e.g. Spain, France) require a practical flight assessment for heavy drones.

On the pesticide side, all EU countries require that professional pesticide users are certified according to the sustainable use directive. This means a farmer or contractor must have attended training on safe pesticide use and obtained a certificate (often valid 3–5 years) to purchase and use certain pesticides. Drone operators would be no exception – they would need this training just like a farmer using a tractor sprayer. In France, for example, a drone operator must have the “certificat phytopharmaceutique” (phytopharmaceutical certificate) which is the standard license for pesticide applicators. What is emerging is that some EU countries are devising specific training for drone use as part of this certification. **France** recently authorized limited drone spraying for “low-risk” substances (like biocontrol agents on steep vineyards and in overseas territories)[106][107]. As part of this, operators must follow guidelines issued by the French Ministry of Agriculture and be both licensed pilots and certified applicators. France’s initial steps (2022–2025) involve pilot projects where operators get temporary permits; they must report outcomes (drift data, efficacy) to authorities. **Italy and Spain** have also run trial programs with drones in orchards and rice fields under close supervision[108][38]. **Switzerland**, while not EU, is notable in Europe for explicitly legislating drone spraying – it authorizes drone pesticide applications given the pilot is licensed and each product is approved for such use[37][109]. Switzerland requires operators to pass a training course recognized by the Federal Office for Agriculture, which includes both drone handling and application science.

EU-wide, EASA’s rules ensure that a drone pilot’s competency is recognized across member states (an EASA remote pilot certificate is valid EU-wide). However, the permission to spray is still national. Therefore, an agricultural drone operator in the EU typically must: (1) be an EASA-certified drone pilot, and (2) have a national pesticide applicator license, and then (3) obtain a special permit for aerial spraying from that country’s authority. The training for item (3) might be an extra briefing or risk assessment submission rather than a standardized course, given these are currently handled case by case. The **UK** (no longer in EU) is noteworthy in that its Health and Safety Executive has begun approving drone spraying under exemptions, and the UK leads an OECD working group exploring standards for drone applications[108]. The trend in Europe is cautiously forward: the upcoming EU regulation updates consider allowing drones as a special case under the aerial spray ban, likely with strict training and technology requirements (e.g. drift reduction nozzles, geofencing). We can expect that formal certification specifically

for “drone applicators” may emerge, perhaps akin to how manned aerial applicators have a separate rating.

In summary, Europe’s current “certification” for drone pesticide operators is fragmented but generally requires **two certifications plus a permit**. Pilots need a drone license (per EASA rules) – usually involving an online course/exam and possibly a practical test for large drones[\[110\]](#). They also need to be certified pesticide users (per the sustainable use directive training, which covers environmental safety, IPM principles, etc.). Then, for the actual drone spraying activity, they need regulatory approval for each campaign or area. Recertification: the drone pilot license has continuity requirements (in some countries, a refresher test if you go to a higher category or if regulations change). The pesticide certificate in the EU often lasts 5 years, after which one must attend update training to renew. Thus, an operator has ongoing education obligations on both fronts. The European approach underscores caution and a high safety bar, which is why as of 2025, drone spraying is still not widespread in the EU, but this may change as more data (from pilot projects in France, Italy, Spain, Hungary, etc.) demonstrates safe use under certified operators[\[108\]](#)[\[111\]](#).

Latin America

Latin American countries are quickly adopting agricultural drones and establishing certification norms, often learning from both the U.S. and Asian experiences. **Brazil**, the largest agriculture producer in the region, has recently updated its regulations to integrate drones. The National Civil Aviation Agency (ANAC) of Brazil amended its rules to simplify drone use: now only **drone registration and a pilot license** are required to begin operations[\[14\]](#). Previously, Brazil had very strict rules (RBAC 94 and 137) requiring special approvals for agricultural drones. The reform means that as long as the drone is registered and the operator holds an ANAC-issued remote pilot license (which involves passing a theory exam and practical demonstration, similar to a private pilot license standard[\[112\]](#)), they can perform aerial spraying. This signals a liberalization – effectively treating small agricultural drones more like standard equipment rather than experimental aircraft. Nonetheless, Brazil’s Ministry of Agriculture is involved in ensuring these pilots know about safe application. It has proposed a “**Class V**” **applicator license** specifically for drone operators, although as of 2024 that was still in draft. Brazilian states, and the large agricultural companies, often organize training for drone operators. For example, Brazil’s agrochemical industry association (SINDAG) in partnership with universities has courses on drone spraying which cover meteorology, application technology, and regulations. Brazil’s Congress was considering a draft law on drone applications to further clarify requirements[\[113\]](#). In the interim, any drone spraying business effectively needs a licensed drone pilot (ANAC license) and must follow existing aerial applicator laws (which include having a responsible agronomist and notifying authorities before spraying).

Argentina has been active in demonstrations of drone spraying on crops like soybeans and corn. The regulatory stance in Argentina is evolving: general drone

use falls under the National Civil Aviation Administration (ANAC Argentina) rules, which currently require special permission for flights beyond visual line of sight or heavier drones. For pesticide use, Argentina's CASAFA (Chamber for Agricultural Health and Fertilizers) has pointed out that **product labels need adjustment**, because recommended spray volumes in Argentina are often higher than what drones can deliver[114][115]. So, while pilots can get a drone operator certificate, the Ministry of Agriculture is cautious until pesticide labels legally include drone application. Argentina is training pilots via pilot programs; some provinces allow drone use by pilots who register and take a short course, but national standards are pending.

Mexico requires drone operators to get authorization from their civil aviation authority (AFAC). In agriculture, Mexico's SAGARPA (Agriculture Secretariat) held a public consultation to include an **official appendix on UAS** in their crop protection regulations[114][116]. This likely will lead to a framework where drone spray service providers must be registered and operators certified. Mexico already mandates that any aerial applicator (manned aircraft) have a license and a permit for each operation; for drones, they have so far issued temporary permits to companies on a case-by-case basis. Training in Mexico is often provided by tech institutes or the distributors of drones (e.g. DJI Mexico) – courses cover how to operate in the field and safe chemical handling.

Several Latin American countries are in **initial stages** of implementing rules[113]. In general, we see a pattern: a **remote pilot license** from the aviation authority + some form of pesticide applicator certification from the agricultural authority. For instance, **Chile** requires commercial drone pilots to pass a test and get a license from DGAC (civil aviation), and SENASA (National Agriculture Service) oversees pesticide use; currently drone spraying in Chile is limited to trials, with training provided by companies under SENASA's oversight. **Colombia** and **Peru** are similar – they have drone regulations for pilots and are developing protocols for pesticide use. Many LATAM nations collaborate through forums on how to safely integrate drones; they often reference standards from Brazil or the US.

Recertification in Latin America will likely mirror existing schemes: pilot licenses typically require periodic medical checks and renewal tests (for aviation), while pesticide applicator licenses (where they exist, e.g. many countries license aerial fumigation pilots similar to the U.S.) require periodic renewal with refresher courses. Brazil, for instance, enforces RBAC 137 which requires aerial applicators to attend an aviation safety course every 3 years; if drones become included fully under RBAC 137, that would extend to them as well[117]. In LATAM, a large emphasis is also on manufacturer training – companies like XAG and DJI have established training centers (e.g. DJI has one in Mexico, XAG in Brazil) where operators get certificates. These are often recognized by local authorities as proof of competence until formal licenses are issued.

To conclude, Latin America is moving swiftly to adopt drones, with regulators balancing innovation and safety by requiring operator certification. Brazil's example of easing entry (just registration and a pilot license)[14] might lead others to follow suit once basic training infrastructure is in place. Industry and government are working hand in hand (e.g.

partnerships to train thousands of new pilots in countries like **Ghana** in Africa as well [\[118\]](#), which parallels LATAM efforts).



Certification of Drone Spray Service Providers

Establishing a robust certification process for drone spray service providers is essential to ensure safe and effective pesticide application. This section outlines the proposed system for certification, including training requirements, proficiency testing, issuance of certificates, and ongoing retraining and upgrading.

Training

Comprehensive Training Program: Develop a structured training program that covers:

- **Drone Operation:** Instruction on flying techniques, maintenance, and troubleshooting.
- **Pesticide Application:** Education on different types of pesticides, application methods, safety protocols, and environmental considerations.
- **Regulatory Compliance:** Training on relevant laws and regulations governing pesticide usage and drone operations, including local, state, and federal guidelines.

Proficiency Test

Assessment of Capabilities: After completing the training program, candidates must undergo a proficiency test that includes:

- **Written Examination:** Testing knowledge of drone operation, pesticide application, and regulatory compliance.
- **Practical Assessment:** Evaluating the candidate's ability to operate the drone and apply pesticides safely and effectively in a controlled environment.

Scoring Criteria: Establish clear scoring criteria for both the written and practical assessments to determine successful candidates

Issuance of Drone Spray Service Certificate

Candidates who successfully pass the proficiency test will be awarded a Spray Service Certificate, which validates their qualifications to operate drones for pesticide application.

Retraining and Upgrading

Establish a process for renewing certifications every [insert duration, e.g., three years], which may include- Additional training sessions, Updated proficiency tests to ensure continued competence

Certification of Agricultural Drone Operators and Drone Spray Service Providers

Key Elements to setup a Certification program:

Across these examples, certain common themes emerge for curricula and proficiency testing of agricultural drone operators:

Comprehensive Training Syllabus:

Operators are trained in three core areas – drone piloting skills, pesticide application knowledge, and regulatory compliance. For instance, programs in Asia cover drone maintenance, flight planning, and troubleshooting, alongside modules on pesticide types, safe mixing and spraying practices, meteorology, and drift mitigation. Many countries have adopted or are adopting Japan's and China's model syllabi as a baseline. We from Crop Life Asia recommend to setup a Drone spray operator or certification system covering sections 1 to 10 of this manual.

Training the operators or service providers for at least 2-3 days using the private public partnership or using the Agricultural ministry or extension ministry routes.

Proficiency Testing

Certification invariably involves both a written exam (testing knowledge of drone operations, navigation rules, and pesticide safety) and a practical flight test where the candidate must demonstrate competent drone flying and correct spraying technique. To ensure high competency, regulators often set minimum passing scores and limit the number of test retake. For example, U.S. states require passing scores (usually ~70% or higher) on pesticide exams, and FAA mandates a 70% score on the Part 107 exam. Japan and China similarly enforce practical skill standards – e.g. China's AOPA flight test requires maneuvers like maintaining a stable spray height over crops and emergency handling, while Japan's test requires precise operation within set parameters, which even a 90-year-old trainee managed to pass after adequate practice.

Issuance of Certificates

Candidates who meet all requirements are issued a Drone Spray Service Certificate or equivalent credentials. This certificate verifies their qualification to operate drones for pesticide application. In China, this is an actual license card from AOPA/CAAC; in Thailand, it's an official ID card from the Agriculture Department; in the U.S., it's two documents (an FAA pilot certificate and a state applicator license). These credentials must often be presented on-demand during operations to inspectors or authorities.

Recertification and Ongoing Training

Because technology and regulations evolve, certification is not one-and-done. Most frameworks include a validity period for licenses and a need for renewal. For example, FAA drone pilot certificates must be refreshed every 24 months with updated training, and many pesticide licenses worldwide require renewal (with continuing education) every 3–5 years. Authorities stress refresher courses and upgrading of skills. China's system compels pilots to log flight hours and undergo a review every two years even though the license is six-year

term. CropLife Asia’s guidelines recommend regular re-training intervals and even periodic re-examination to ensure competency is maintained as drones and formulations advance. In sum, operators are expected to continually update their knowledge – whether through formal re-certification classes or manufacturer training on new drone models and spray technologies.

As agricultural drones become more prevalent for crop spraying, many countries have established certification frameworks to ensure that operators are properly trained to use pesticides safely and effectively. Certification typically involves fulfilling both civil aviation requirements (for drone piloting) and agricultural/pesticide use requirements (for safe pesticide handling). This dual approach helps maintain high standards of flight safety and chemical application safety[1][2]. Regulatory bodies often mandate specific training curricula, proficiency exams, and periodic re-testing or refresher courses for drone spray service providers[3][4]. Table 1 below provides a comparative overview of certification frameworks in key regions, highlighting the roles of aviation and agricultural authorities, training duration, testing methods, and issuing authorities. Table-2 below compares key elements of agricultural drone operator certification across selected countries/regions, highlighting who conducts training, what licenses are required, training duration/ modes, testing methods, issuing authorities, and how re-certification is handled.

In conclusion, certification of agricultural drone operators is becoming a cornerstone of safely scaling up this technology. It ensures operators have the needed skills – from flight navigation to chemical safety – and it provides accountability through licenses and renewals. Continual learning is emphasized via re-certification and refresher trainings, due to fast-evolving drone models and agronomic techniques[44][37]. The examples from APAC countries like India, China, and Japan show robust models that other nations are studying. We can expect further convergence toward international best practices, supported by organizations like the OECD and industry task forces that are developing standardized training guidelines and “best practice” manuals for drone spraying[123][124]. By adhering to these certification frameworks, drone spray service providers can achieve proficiency and earn trust, ultimately enabling drones to contribute safely and effectively to modern sustainable agriculture.

Table 1. Comparison of Drone Spray Operator Certification Frameworks by Country/Region (Training requirements, testing methods, and licensing authorities)

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
China	License Required: Yes. The Civil Aviation Administration of China (CAAC) mandates a UAV pilot license. Training is largely conducted by private academies (often run by major manufacturers like DJI, XAG) accredited by CAAC[5]. For multi-rotor drones, courses last ~18–28 days (VLOS vs. BVLOS levels) and include theory (aviation law, meteorology) and hands-on flight training[6][7]. Testing: Written and practical exams are required. Issuing Authority: Certificates are issued via the Aircraft Owners and Pilots Association of China (AOPA), which is authorized by CAAC[8]. Renewal: CAAC drone pilot licenses are valid for six years with a competency review every two years[9][10].	License Required: <i>No separate PCO license.</i> China does not require a standalone pest control operator license for drone sprayers; instead, pesticide safety is integrated into the drone training. Private drone training programs include modules on pesticide types, safe use, application techniques, and emergency procedures[8]. The government supports these specialized programs to ensure operators can handle agro-chemicals responsibly[11]. Testing: Pesticide knowledge is tested as part of the overall certification exam. Issuing Authority: The same AOPA/authorized schools certify that the operator has pesticide application competency. Renewal: Operators are encouraged to attend periodic retraining as technology evolves[12], but no separate ag license renewal is mandated aside from keeping the drone license valid.
India	License Required: Yes. India's Directorate General of Civil Aviation (DGCA) requires agricultural drone pilots to hold a Remote Pilot Certificate (RPC). Training is provided by DGCA-authorized Remote Pilot	License Required: <i>No separate pesticide applicator license for drone use.</i> Instead, the Ministry of Agriculture & Farmers' Welfare has issued Standard Operating Procedures (SOPs) for safe drone pesticide and

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	Training Organizations (RPTOs)[13], typically through a short course (~5–7 days) covering drone regulations, flight operation, and basic maintenance. Testing: Trainees must pass a written exam on air regulations and a practical flight test to obtain the RPC[13]. Issuing Authority: DGCA issues the Remote Pilot Certificate via its Digital Sky platform upon successful training and examination. Renewal: The RPC is generally subject to renewal or refresher requirements as per DGCA rules (e.g., periodic online tests), aligned with evolving drone rules (Drone Rules 2021 simplified licensing)[14].	nutrient application[15][16]. These SOPs require that drone operators adhere to label instructions, maintain buffer distances, and use approved pesticides. Operators are expected to undergo basic pesticide-handling training (often offered by agricultural universities or state agriculture departments) in addition to their drone pilot training[17][18]. For example, state agricultural universities (e.g. in Telangana) have developed drone spraying training modules and recommendations to supplement pilot training[18]. Testing: There is no separate national exam for pesticide use; however, competency in pesticide application is assessed through adherence to SOP checklists and demonstration of knowledge during training. Issuing Authority: The agricultural ministry does not issue individual applicator licenses to drone pilots; compliance is enforced through guidelines and, for service providers, through project approvals. (E.g., interim approvals list which pesticides can be sprayed by drones[19].) Renewal: Operators are expected to stay updated via periodic training on new SOP updates (for instance, crop-specific drone spray SOPs were released in 2022) but

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
Japan	License Required: Yes. Japan historically managed drone (and RC helicopter) spray pilots via the Japan Agricultural Aviation Association (formerly “Nosui-Kyo”). Since 2019, private training institutions authorized by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) provide training and licensing[20]. A typical course includes ~5 hours of classroom instruction (aviation law, safety, meteorology) and ~10 hours of practical flight training[7]. Trainees then take a government-standardized theoretical and practical exam. Issuing Authority: Certificates (Remote Pilot competency certificates) are issued by the authorized training organizations on behalf of MLIT[7]. As of 2022, Japan introduced unified drone pilot licenses (Class I/II) for different risk categories, enhancing nationwide standards. Renewal: Licenses are generally valid for a few years (the new system has a 3-year renewal cycle for higher-level certificates, according to MLIT guidelines).	formal recertification for pesticide use is not yet implemented beyond the DGCA pilot license renewal. License Required: <i>No separate pesticide applicator license.</i> Agricultural drone operators in Japan are trained in pesticide use as part of their certification, rather than holding a distinct chemical applicator license[21]. The legacy training manual from JAAA covers pesticide types, application methods, droplet control, and safety measures, and new editions of this manual have been released to incorporate drone-specific regulations (2019, 2020)[22]. Testing: The integrated exam includes pesticide application knowledge. Operators must demonstrate safe handling (e.g. mixing, loading, and decontamination procedures) during the practical test. Issuing Authority: The drone pilot license itself signifies pesticide spraying qualification, as overseen by the Japan Agricultural Aviation Association and now private schools using the standardized curriculum[22]. Renewal: Refresher training is strongly encouraged. Many training bodies require pilots to attend update seminars on pesticide technology and safety annually or biennially. (The government also updates guidelines periodically, e.g.,

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
		anti-drift measures, which operators must follow to remain compliant.)
South Korea	License Required: <i>Yes.</i> South Korea regulates drones under its Aviation Safety Act, requiring a license for larger or commercial UAV operations[23][24]. Private training schools accredited by the Korea MOLIT (Ministry of Land, Infrastructure and Transport) offer courses for agricultural drone pilots. The training typically includes both classroom sessions on regulations and flight theory, and practical flight training (exact hours vary; often on the order of 20–30 hours total). Testing: Pilots must pass a written exam and a flight proficiency test to obtain a UAV operator license. Issuing Authority: The Korea Transportation Safety Authority (KOTSA) or MOLIT issues the remote pilot license. Renewal: Licenses must be periodically renewed; continuing education or a refresher exam may be required (the exact interval is set by regulation, e.g., every 3 years).	License Required: <i>No dedicated pesticide license (general safety training required).</i> Korea does not mandate a separate pesticide applicator certification for drone sprayers; however, operators must follow the safety guidelines under the country's pesticide regulations. The government often provides supplementary training on pesticide handling via the Rural Development Administration (RDA) or cooperatives. Testing: The drone pilot exam encompasses some questions on agricultural chemical safety, but there is no stand-alone pesticide exam. Issuing Authority: No separate issuing body for pesticide operation; compliance is monitored via general agricultural safety enforcement. Renewal: Operators are expected to keep up with any new directives on pesticide use (for instance, updates on approved formulations for drones). Refresher courses on safe pesticide application are offered but not formally required for license renewal.
Thailand	License Required: <i>Yes (for larger drones).</i> The Civil Aviation Authority of Thailand (CAAT) requires registration and pilot authorization for drones over 2	License Required: <i>In practice, Yes (certification card).</i> Thailand's Department of Agriculture has implemented an ID card system certifying

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	kg or for commercial use. Aspiring drone spray pilots usually undergo a CAAT-recognized training (some local programs mirror the UK CAA ground school in Thai context^[25]). Training covers drone operations, airspace rules, and safety. Testing: Operators may need to pass a basic written exam to receive a permit for agricultural drone flying. Issuing Authority: CAAT issues operational permissions or licenses for drone pilots (along with an operator registration ID). Renewal: Pilots must renew registrations periodically and maintain records of flights per CAAT's regulations.	trained drone spray service providers^[26]. The Department, in collaboration with universities and industry, published a best-practices guidebook for pesticide spraying by drones^[27]. Operators attend special training seminars (e.g., "Professional Farming Drone under Academic Principle and Laws") covering pesticide spraying techniques, legal compliance, and safety. Testing: Those who complete the training must demonstrate proficiency; upon completion, they are issued an identification card certifying them as qualified operators^[28]. Issuing Authority: The Ministry of Agriculture (Dept. of Agriculture) issues the certification cards for drone applicators. Renewal: Currently, the card serves as proof of training; operators are encouraged to update their training as new techniques or regulations arise. The program is evolving, so renewal or retraining intervals may be instituted as the framework matures.
Vietnam	License Required: <i>Partial (developing)</i>. Vietnam is in the process of formalizing drone regulations. The Ministry of Defense currently oversees drone permits, requiring an approval (NOC) for each operation – a cumbersome	License Required: <i>No formal pesticide license yet</i>. The Fertilizer and Pesticide Authority (FPA) of Vietnam is not a separate entity (Vietnam's plant protection regulations fall under the Ministry of Agriculture and

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	process[29][30]. There is no nationwide civilian drone pilot license yet as of 2024, but steps are being taken to establish one[31]. In the interim, Vietnam's first Drone Academy (launched 2020 at HCMUT) offers a one-month UAV pilot training course for the public[32], following DJI's Unmanned Aerial Systems Training Center (UTC) curriculum. Trainees (high-school age and up) learn drone operation basics and local regulations. Testing: The academy conducts a theory and practical test; graduates receive a certificate of completion[33]. Issuing Authority: This academy-issued certificate currently has <i>no legal weight</i> in government licensing[34] – it is a private credential showing one has been trained to UTC/DJI standards while Vietnam develops its own license system. Renewal: Not applicable yet (no official license); the focus is on scaling up training and awaiting formal regulatory licensing.	Rural Development). In practice, drone service companies partner with government projects to ensure safety. For instance, pilot programs and training of government officials on drone spraying have been conducted (e.g., for rice crop protection)[35][36]. Testing: There is no standardized pesticide application exam for drone operators. Operators are trained on safe pesticide use through workshops often supported by international stakeholders (e.g., CropLife Asia and academic institutions). Issuing Authority: No separate certification is issued by an agricultural authority yet. However, any large-scale drone spraying activity must be approved by provincial agricultural departments, which effectively ensures only trained operators participate. Renewal: As the regulatory framework is under development, Vietnam is expected to introduce formal guidelines requiring certification and periodic retraining once the legal structure (possibly through the Ministry of Agriculture or Defense) is in place[37][38].
Malaysia	License Required: Yes. Malaysia's Civil Aviation Authority (CAAM) treats agricultural drones as remote aircraft requiring a permit.	License Required: Yes (<i>for commercial applicators</i>). Under Malaysia's Pesticides Act, any commercial application of pesticides (including drone

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	Operators should obtain a Remote Pilot Certificate (RPC) by training at a CAAM-approved RPTO (Remote Pilot Training Organisation)[39]. Training typically spans ~5 days and covers drone theory, regulations (Civil Aviation Regulations 2016), and practical flying. Testing: After training, candidates take a written knowledge test and a practical flight test under CAAM supervision[40]. Issuing Authority: CAAM issues the RPC and an operator's certificate (depending on weight category and operation, an authorisation under CAD 6011 might be required for heavy spray drones). Renewal: RPC holders must renew their certification at intervals set by CAAM (often two years), including demonstrating continued competency or undergoing refresher courses.	spraying services) typically requires a licensed Pest Control Operator (PCO). Several drone training academies have therefore become registered PCOs or work with certified pesticide operators[41][42]. Training: Drone Academy programs (e.g., DJI Academy Malaysia, Drone Academy Asia) integrate pesticide safety training (mixing, calibration, PPE, environmental precautions) into their courses[42]. Testing: Operators may need to pass a PCO exam or at least be trained by a PCO to legally offer spraying services. In practice, many drone service companies ensure at least one team member holds a PCO license who oversees pesticide handling. Issuing Authority: The Pesticides Board (under the Department of Agriculture) issues PCO licenses. Some states or local authorities also register drone spray service providers. Renewal: PCO licenses in Malaysia must be renewed periodically (usually every 1–2 years) with evidence of training or continuing education. Drone operators must maintain both their aviation RPC and their status as licensed pesticide applicators to continue operations legally.
Pakistan	License Required: <i>No (framework</i>	License Required: <i>No</i>

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	<i>in development</i>). Currently, Pakistan requires an import and operation No Objection Certificate (NOC) from the Ministry of Defense for any drone usage[29][43]. There is <i>no dedicated drone pilot licensing system</i> yet, which poses challenges for timely agricultural use. Recognizing this gap, policy think-tanks have recommended establishing a drone pilot licensing and training program domestically[37][38]. Plans are underway to streamline drone approvals and create training centers, but as of 2025, aspiring agri-drone pilots rely on ad-hoc training (e.g., manufacturer training, or courses abroad) and must obtain case-by-case military clearance to fly. Testing: No standardized exam exists; operational permission is the main hurdle. Issuing Authority: The Civil Aviation Authority (CAA) and Defense Ministry are expected to collaborate on future drone pilot certifications, but none are issued yet.	<i>(framework in development)</i>. Pakistan does not yet have a formal pesticide applicator certification for drone spraying. However, any aerial pesticide spraying (manned or unmanned) traditionally fell under the Agricultural Pesticide rules which required that pilots be appropriately qualified. In absence of a specific drone spraying license, pilot competency and safe use guidelines are being drafted as part of broader drone regulation reforms[38]. Training: Some private companies and universities (e.g., NAVTTC – National Vocational & Technical Training Commission – have developed curricula for drone applications in agriculture[44]) are beginning to train operators in both drone operations and crop protection. Testing: Until regulations formalize, no official exam. Issuing Authority: The Department of Plant Protection or provincial agriculture departments may in the future require registration of drone service providers, but currently oversight is minimal beyond import permissions. Renewal: N/A – Pakistan’s focus is first on introducing an initial certification regime; re-certification norms will follow once a baseline licensing system exists.

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
Indonesia	License Required: <i>Yes.</i> Indonesia's Directorate General of Civil Aviation (DGCA) requires certification for drones above certain weight or for commercial missions. Operators must pass a DGCA-administered theory exam and practical flight test to earn a drone pilot license[40]. Training is available through programs like Terra Drone Indonesia's Terra Academy, which partners with local universities to run drone pilot certification courses[45][46]. The courses cover multi-rotor operation, mission planning, and Indonesian air regulations. Testing: DGCA examiners conduct or supervise the written and flight tests. Issuing Authority: DGCA issues a Remote Pilot License or an equivalent certificate of competency. Renewal: Typically required every 2 years; pilots must log flight hours and perhaps take a refresher to renew their license (in line with DGCA regulations and any future ASEAN standards harmonization).	License Required: <i>No separate license yet.</i> Indonesia currently allows drone pesticide spraying under general aerial spraying regulations (which historically cover manned crop dusters). Aerial application of pesticides is legal if the product label permits it[47], and the applicator follows safety rules. Training: The Ministry of Agriculture has been collaborating with tech firms (e.g., partnerships like Terra Drone Agri with universities) to train personnel in proper spray techniques and calibration. Testing: No distinct exam; operators must abide by pesticide laws (which require, for example, not exceeding labeled rates and preventing drift). Issuing Authority: While no specific drone spraying license is issued, the Ministry of Agriculture may require service providers to register. (For example, large plantation companies using drones might need to report to the Plantation Crop Protection offices). Renewal: Not applicable as a formal license – but as Indonesia develops more detailed protocols, it may introduce certifications with renewal (especially if guided by emerging ASEAN policy trends).
Philippines	License Required: <i>Yes.</i> The Civil Aviation Authority of the	License Required: <i>Yes (per new 2024 rules).</i> The Fertilizer

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	Philippines (CAAP) regulates drone use. Commercial drone operators (including for agriculture) must secure a CAAP UAV Controller Certificate or an authorization under CAAP's drone rules. Pilots undergo training on Philippine airspace rules and drone operations (often through CAAP-approved training organizations or manufacturer courses) and must register their drones. Testing: CAAP requires a written exam for UAV controllers. Practical flight demonstrations may also be required for heavier or beyond-visual-line operations. Issuing Authority: CAAP issues licenses/authorizations for drone pilots and drone operations (e.g., UAV Operator Permit). Renewal: Licenses are typically valid for 1 year and must be renewed, with pilots submitting logbooks and possibly undergoing check rides as required by CAAP.	and Pesticide Authority (FPA) released Memorandum Circular No. 25 (2024) which lays out Enhanced Rules for pesticide application by drones[48]. Under these rules, all drone spraying service providers, pilots, technicians, and even end-users must comply with standardized protocols and likely need to undergo FPA-approved training[49][50]. FPA is developing training materials (in partnership with IRRI and others) to ensure pilots know about droplet sizes, drift management, and emergency measures[51][52]. Testing: The FPA's rules call for certification of operators, which implies a test or assessment, though details are being finalized. We can expect a written or online exam on pesticide laws and a practical assessment of spraying technique. Issuing Authority: The FPA, in coordination with the Department of Agriculture, will issue Drone Pesticide Applicator Certificates or endorsements to those who pass. Already, lists of drones and pesticides approved for drone use are maintained by FPA[53][54]. Renewal: The 2024 regulations will require periodic re-certification or refresher courses – FPA has indicated that regular monitoring and an

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
		information campaign (caravan) will keep operators up-to-date[55]. Likely, certifications will need renewal every 2–3 years, with proof of continued compliance.
European Union (General)	License Required: Yes. Under EU Aviation Safety Agency (EASA) rules, any drone used for aerial spraying would fall under the ‘Specific’ category of operations (since it is neither low-risk “open” nor routine). Operators must obtain a Specific Operations Risk Assessment (SORA) approval or follow a pre-defined risk standard scenario if available. Pilot Competency: Remote pilots must at minimum have the general EU Drone Certificate (which involves online training and an exam for open category), and for specific category, they often need additional practical training and to be declared competent by the operator or an entity. Some EU countries (e.g. France) require pilots of spraying drones to hold a Télépilote Certificate (the French remote pilot license) and undergo extra training in aerial application techniques[56]. Testing: EU’s basic drone license involves an online exam (40 questions) for the Open category, and a further theory exam and practical assessment for the Specific category in many cases (handled by national aviation authorities or approved	License Required: <i>Generally Yes, but strict.</i> The EU banned aerial spraying of pesticides in 2009 (Sustainable Use of Pesticides Directive 2009/128/EC), allowing exceptions only with regulatory approval[57][58]. Some member states have begun to legalize limited drone spraying: e.g., France (2025) now allows drones to apply “low-risk” <i>biocontrol pesticides</i> on steep vineyards and banana plantations, under strict conditions[59][60]; Germany permits drone use in vineyards with altitude and speed restrictions[61]; Bulgaria and others are developing standards. In all cases, pesticide applicators must be certified per national law – typically meaning the operator needs a pesticide applicator license just as a ground applicator would. Training: This involves a course on safe use of plant protection products and passing an exam (per EU Directive 2009/128/EC each member state must have training/certification for professional pesticide users). Drone-specific modules are

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	entities). Issuing Authority: EASA framework licenses are issued by national aviation authorities (e.g., DGAC in France, ENAC in Italy, etc.). Renewal: The EU drone pilot certificate typically does not expire (the Open category cert is valid for 5 years in some states); however, Specific category authorizations are time-limited and require renewal/validation of continued competency.	being added in countries like Spain and Italy for aerial applicators. Testing: National exams (usually a written test on pesticide knowledge and regulations). Issuing Authority: National pesticide regulatory agencies or ministries (e.g., French Ministry of Agriculture for applicator certificates, German state agricultural chambers, etc.) issue these licenses. Renewal: Yes, typically every 3–5 years with required continuing education. Additional one-time approvals are often needed for each drone spraying operation – for instance, French operators must obtain case-by-case authorization despite being licensed, due to the exceptional nature of aerial spraying.
United States	License Required: Yes. The U.S. Federal Aviation Administration (FAA) requires any drone pilot conducting commercial operations (including pesticide application) to hold a Part 107 Remote Pilot Certificate [62][63]. To get this, candidates must pass a 60-question aeronautical knowledge exam covering regulations, airspace, weather, and drone operations. Training: While formal training is not mandatory, most pilots prepare through courses or materials (around 15–20 hours of self-study or classes) for the Part 107 test. Testing: The Part 107 exam	License Required: Yes. All U.S. states require a state pesticide applicator certification for anyone applying pesticides commercially (including by drone) [67][68]. Typically, a drone applicator must become a Commercial Applicator in category appropriate for the target crop (e.g., Category 1A: Agricultural Plant Pest Control) and often must specifically pass the Aerial Application (Category 11 or equivalent) exam in that state [69][70]. Training: Most states provide training

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	is administered at FAA testing centers; a recurring recurrent test or training is required every 24 months to keep the certificate valid[4]. Beyond Part 107: Agricultural spraying additionally triggers FAA Part 137 (Agricultural Aircraft Operations) requirements. Operators must obtain an FAA Agricultural Aircraft Operator Certificate (AAOC)[64], which entails developing operating manuals, obtaining operating exemptions (since small drones cannot meet all manned-aircraft requirements in Part 137), and possibly a practical skills check[65]. The FAA often grants exemptions to certain Part 137 rules for drones, but operators must apply for these and demonstrate procedures for safe dispensing of chemicals[66]. Issuing Authority: The FAA issues the Part 107 Remote Pilot Certificate and the Part 137 Operating Certificate (after compliance). Renewal: Part 107 certificate holders must complete renewal training or pass a recurrent exam every 2 years[4]. The Part 137 operator certificate must be maintained via ongoing compliance (no specific expiration, but any changes in operation require FAA approval).	manuals and optional classes; topics include pest management, pesticide safety, drift reduction, and equipment calibration. Testing: Operators must pass a general core exam and a category-specific exam (and in many states an Aerial applicator exam focusing on aviation application safety)[68]. Some states (like Kansas in the example) also require registering the drone and insurance proof with the agriculture department[71][72]. Issuing Authority: State Departments of Agriculture (or equivalent) issue the pesticide applicator license. For example, Illinois' Department of Agriculture and Kansas' KDA oversee their state's exams and licensing[73][71]. Renewal: Yes – state licenses must be renewed typically every 1–3 years. Renewal often requires continuing education credits or re-testing. For instance, many states mandate refresher courses or a renewal exam every 3 years to ensure applicators stay up to date on regulations and new technology.
Latin America (selected)	Brazil: Yes. Brazil's National Civil Aviation Agency (ANAC) requires licensing for heavy drones; initially, some operations even required a	Brazil: Yes. In 2021, Brazil's Ministry of Agriculture (MAPA) issued Ordinance No. 298 regulating drones in agriculture[78][79]. It requires

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
	licensed manned pilot as safety pilot[74], though dedicated drone pilot rules are emerging. Training: ANAC has indicated plans for mandatory training and certification even for basic operations[75]. Testing: In practice, companies like <i>Sprayhawk</i> have been permitted with pilots who have commercial licenses plus factory training[76]. As regulations modernize, Brazil is moving toward a drone-specific pilot license. Issuing Authority: ANAC issues any pilot licenses; the process is being updated to accommodate drone-specific ratings[77]. Renewal: Per ANAC’s draft regulations, a remote pilot license would need periodic renewal (likely aligning with manned pilot standards).
 Other LATAM: Several countries require aviation authorizations. E.g., Mexico requires a DGAC permit and training for UAVs over 25 kg; Uruguay and Costa Rica treat drone sprayers as agricultural aircraft, needing a licensed agricultural pilot to operate[47]. Many nations are in early regulatory stages, so training is often informal or manufacturer-led, and pilots rely on general drone permits.	that drone spraying professionals complete a preparatory course and register with MAPA[79]. Training: Courses cover operational safety, environmental precautions, and Brazilian crop-spraying norms. MAPA is accrediting educational institutions for this purpose[80][81]. Testing: After training, operators likely take an exam or evaluation as set by MAPA’s Agricultural Aviation Division. Issuing Authority: MAPA registers qualified drone applicators and the drones themselves in a national database (only ~2,618 drones were registered for spraying by 2025, indicating enforcement is ongoing)[79]. Renewal: Brazil plans to require periodic renewal of certifications; new ordinances under development aim to implement updated rules for training, accreditation, and recertification of drone applicators[82].
 Other LATAM: Argentina and Chile are drafting rules – likely requiring existing ground applicator licenses plus additional drone operation clearance. Colombia and Mexico allow some drone spraying experimentally[83], with authorities monitoring results to craft training requirements. In these countries, general pesticide

Country/Region	Drone Pilot Licensing (Civil Aviation Authority)	Pesticide Applicator Certification (Agriculture/Pesticide Authority)
		applicator certification (which involves courses and exams on pesticide use) is mandatory for any commercial spraying, and drone operators must comply with those laws (e.g., Colombian law requires an agronomist or licensed applicator supervise the use of agricultural pesticides). Renewals in LATAM generally follow the pattern of requiring refresher training every few years as in their standard applicator licensing.

Table 2. Comparison of Pilot vs Drone Spray Operator Certification Frameworks by Country/Region (Training testing time, issuing authority, and renewal)

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
China	Yes – UAV operator license required. Training largely via private academies (DJI, XAG) with CAAC/AOPA oversight[5][7].	Not a separate PCO license; pesticide training integrated into drone course (focused on safe mixing, drift control).	5–10 day courses: theory (aviation regs, UAV systems) + extensive hands-on flying and spraying practice. Must pass written and practical exams[9][30].	CAAC-recognized bodies (AOPA or manufacturer academies) issue drone pilot certificates.	No formal expiry yet on certificates; industry and govt recommend refresher training as tech evolves[44][45]. Moves toward official renewal intervals in progress.
India	Yes – DGCA Remote Pilot Certificate (RPC) required for >2 kg drones (crop-spraying drones)[17]. Obtain via DGCA-approved RPTO training + exam.	No dedicated pesticide license for drone operators; general pesticide use must follow Agriculture Ministry SOPs. (If offering services, adherence to Insecticides Act guidelines expected.)	~5 days (~40 hours) at RPTO: drone theory, simulator and field practice. DGCA online written exam + practical flight test for RPC[18]. Some RPTOs include basic crop protection modules.	DGCA (civil aviation) issues RPC via DigitalSky[19]. (Ministry of Agriculture issues SOP guidelines but no certificate.)	RPC valid 10 years[18]. Renewal requires refresher (online test or training). Agriculture SOP updated periodically; operators expected to stay updated (through KVK trainings, etc.).

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
Japan	Yes – All drone spray operators need a license. Since 2019, private training schools (authorized by government) provide training[28]. Historically JAAA handled licensing.	Yes – Must hold a Pest Control Operator license or equivalent for pesticide use[33]. (Drone license and PCO license are separate.)	Intensive training (1–2 weeks): includes drone flight skills, maintenance, and pesticide application techniques. Exam includes written test and flight demo (precise maneuvers, spraying simulation).	MAFF-accredited training bodies issue drone licenses; PCO license issued by prefectural authorities. JAAA manual often used as a standard[29].	Drone pilot license requires periodic refresher (every 3 years typically)[37]. PCO license renewal as per national pesticide law (often 5-year refresher). Regular re-training mandated by MAFF[37].
South Korea	Yes – Remote pilot license required. Training by certified private academies, per KCAA/RDA guidelines[40].	Yes – Pesticide applicator certification required (separate from drone cert)[41]. Drone pilots typically also get pest control operator permit.	1–2 week courses: classroom (drone systems, regulations) + field practice on spraying. Testing involves written exam and supervised flight test (including emergency procedures).	Korea MOLIT/Civil Aviation issues drone pilot licenses (via test centers); Agriculture authority (RDA or local gov) issues pesticide applicator license.	Drone license renewal interval (every 3 years; refresher course or test). Pesticide license renewal per law (usually 2–3 years with continuing ed). Ongoing training encouraged by RDA as drones advance[44].

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
Thailand	Yes – Effective 2024–25, all drone operators must obtain CAAT drone pilot certificate[56]. Training courses emerging via CAAT and private sector.	Not yet a formal separate license. General pesticide use laws apply; training programs include safe use principles. Future regulations may integrate an agriculture ministry certificate.	~3–5 day training programs (many by manufacturers): basic flight control, maintenance, and spraying techniques. CAAT’s exam (theory) plus practical flight check for license.	CAAT (Civil Aviation Authority of Thailand) will issue pilot certificates. (Agriculture Ministry currently just endorses training; no certificate).	CAAT certificate renewal requirements pending (likely periodic proficiency check). Ad-hoc training needs as new rules roll out. Expect eventual re-tests or refreshers for pilots.
Vietnam	Yes (general) – CAAV requires drone registration; pilot permit process nascent. No specific small-drone license yet, but commercial operators need permission.	No dedicated drone applicator license yet. MARD through Plant Protection Dept. provides certificates for those who complete approved training[60]. Pesticide applicator training being drone-	Short courses (2–3 days for initial pilot program) focused on trial officers: included theory on UAV and pesticide safety, plus hands-on in field[58]. Evaluation by practical demo. Future farmer trainings likely	Plant Protection Dept. issued course certificates for drone operation[60]. (Civil aviation authority to formalize pilot licensing soon.)	Certificates from training courses – currently one-time acknowledgment. As framework develops, likely will require re-training every few years. Anticipate formal pilot license with renewal and mandatory CE (continuing education) on

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
		adapted.	~1 week.		pesticide updates.
Malaysia	Yes – CAAM Remote Pilot Certificate required via approved training (RPTO)[66]. Also requires an Authorization to Fly for operations.	Effectively yes – Must obtain Unmanned Aerial Work Certificate (UAWC) for agricultural spraying operations[74][68]. Ensures compliance with ag payload dispensing rules.	Standard RPTO course (5 days typical) for drone basics + specialized module for ag (mixing, spraying, mapping fields). Testing: CAAM theory exam, practical flight test; additional assessment of spraying procedure for UAWC.	CAAM issues Remote Pilot Cert. and the UAWC (operational certificate for ag work)[68]. Endorsement from Dept. of Agriculture may be part of UAWC process.	RPC renewal per CAAM rules (every 3 years with competency check). UAWC typically annual renewal (submit records, any incidents). Pesticide regulations require ongoing compliance; any new standards (e.g. drone nozzle drift data) must be adopted – possibly via refresher training mandates.
Indonesia	Yes – DGCA remote pilot permit required for commercial use. Pilot must pass theory & practical	Not yet separate. No formal pesticide applicator license for drones; general pesticide use must follow agriculture	Increasingly via industry-academic programs : e.g. Terra Drone Academy 40–50 hour courses with hands-on	DGCA issues pilot permit. No official ag certificate; however, companies (Terra, DJI, etc.) issue their own certificates to trainees (industry-	DGCA permit renewal likely every 2 years (with refresher). Industry certificates – no formal expiry, but operators update skills

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/ Recertification
	test[62]. (Heavier or BVLOS ops need special approval under DGCA.)	ministry guidelines. Emerging practice: companies require internal certification of pilots for spraying tasks.	plantation spraying practice[119][120]. DGCA exam covers aviation; practical skills assessed within training program.	recognized).	as new models come. As government formalizes ag drone use, expect introduction of refresher training requirements.
Pakistan	Yes (in principle) – PCAA’s UAS Rules require operator license, but implementation is slow[82]. Currently ad-hoc permissions (NOCs from defense, etc.) are used.	No official category yet. Discussion of requiring licensed pest control technician or approved training for drone operators. Currently, no structured pesticide license for drone spraying.	Few formal options yet: some pilots trained abroad or via NGO workshops. Emphasis in policy on need for “dedicated training center” and certification program[84]. Likely future course ~1–2 weeks covering aviation and agri topics.	PCAA would issue drone pilot license (when framework operational). Agriculture Dept. may issue certificates for any interim training programs, but none standard yet.	N/A – since not fully launched. Future: pilot licenses with periodic renewal; any agri-drone certificate likely needs renewal as well. (Pakistan’s policy documents call for continuous capacity building and periodic skills evaluation.)
Philippines	Yes – CAAP UAV Controller Certificate	Yes – FPA license as Commercial Pesticide Applicator	Pilot training ~5 days (basic drone	CAAP issues remote pilot license. FPA (Dept. of Agriculture)	CAAP license: 2 years validity (with refresher or

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
	(remote pilot license) required for commercial drone use. Training via CAAP-accredited schools, plus theory/practical exam.	(Aerial category) required if spraying for others[92]. Essentially, need to be a certified pest control operator in addition to drone pilot.	operations, local airspace rules, emergencies). Pesticide applicator training separate ~3 days (law, pest management, safety). Testing: CAAP written & flight test; FPA written exam (and possibly demonstration).	issues pesticide applicator license/certification.	check). FPA license: 1–3 years (requires continuing education credits or re-exam to renew). Both authorities maintain separate renewal processes.
United States	Yes – FAA Part 107 Remote Pilot Certificate required for any commercial drone (spraying included)[93]. For heavier drones or spraying ops, Part 137 certificate (or	Yes – State-specific Pesticide Applicator License (often in Aerial category). Must pass state exam on pesticide use; mandatory for offering spray services.[99]	Part 107 training is typically self-study or via school (~20 hours study) + FAA 60-question exam. Part 137 process: demonstration operational knowledge, may require	FAA issues Part 107 certificate; FAA issues Part 137 operating certificate (to company or individual). State agriculture agency issues pesticide applicator license.	Part 107 renewal every 2 years (recurrent online training)[26]. Part 137 certificate renewal per FAA (usually ongoing if in compliance, with periodic checks). Pesticide licenses renewed 1–3 years depending on

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
	exemption) also required[94].		practical test/ inspections. State pesticide training varies (usually 1–2 day prep course) + state exam.		state, with continuing education or re-testing.
European Union	Yes – EASA-compliant Remote Pilot competency required (A1/A3 basic + A2 or Specific Category cert for larger operations) [121]. Training often online + exam via National Aviation Authority.	Yes – National Pesticide Applicator Certification per EU Dir. 128/2009. All professional users need certificate from training on safe use. Drone operators must have this general certification.	Drone pilot training: online modules (for basic) + additional practical training for Specific category (could be ~2–3 days with exam). Pesticide training: typically 3 days course covering all application methods (drone topics now being included) + exam. Special drone-spraying permit: case-by-case risk	Nat. Aviation Authority issues remote pilot cert. Ministry of Agriculture (or environment) in each country issues pesticide applicator cert. Special aerial spray permits granted by either ag or aviation authority depending on country (often both).	Pilot cert: no fixed expiry for basic, but higher category licenses may require re-evaluation especially if tech or rules change. Pesticide cert: usually 5-year validity; renewal via refresher course. Any drone spray permit given is time-limited or project-limited, requiring new approval for new operations [102][103].

Country/Region	Drone Pilot License Requirement	Pesticide Applicator License Requirement	Training & Testing	Issuing Authority	Renewal/Recertification
			assessment submission.		
Latin America	Yes – Most countries require a basic drone pilot license (e.g. Brazil’s ANAC license, which includes theory & practical) [14] . Regulations are evolving; some are in early draft stages.	Generally yes – Modeled after existing aerial applicator or ground applicator permits. E.g. in Brazil, crop-sprayer pilots needed authorization under RBAC 137; draft regs aim to specifically cover drones. Many countries in initial phase of adding drone-specific clauses [113] .	Pilot training: varies by country (Brazil has formal course & exam akin to private pilot theory; others rely on shorter courses). Pesticide training: many are developing modules – often pilots attend a standard applicator course. Testing: Civil aviation exams; agriculture ministry exams for applicators.	Civil aviation authorities in each country issue drone pilot licenses. Ag ministries or plant protection agencies issue applicator licenses. (In some places, no formal applicator license system exists yet for drones, so interim certificates from training workshops serve as credential.)	Pilot licenses: 2–3 year renewal (some require annual pilot medical exam, e.g. if treated like manned in Brazil). Applicator: yearly in many LATAM countries or tied to specific season/region permits. As frameworks mature, expect structured recertification courses. Brazil’s new approach may simplify to one-time certification plus operator responsibility with periodic audits [14] .

Example of other countries

China and Japan are two examples of countries that have developed a framework for training and licensing UAV operators. Both countries employ different approaches and

governments can similarly tailor its approach based on the landscape of agricultural drone use in their respective countries.

In China, training and licensing of drone operators is largely privatized due to the influence of leading Chinese drone manufacturers such as DJI and XAG that are dominant players in the global drone market. DJI for example has set up training schools for drone operators and works with CropLife and the crop protection industry to tailor their training for pesticide application by drones.

Japan on the other hand, with a history of using Radio Controlled Helicopters (RCHs) had more centralized control of licensing operators through the Japan Association for Agricultural Aerial Control (Nosui-Kyo). In 2019, however, the government of Japan authorized privatized drone training and licensing. The training manual developed by the Association however continues to be used as a base reference with new editions released to reflect new drone-related regulations in 2019 and 2020

References

1. Best Management Practices for Safe and Effective Application of Pesticides Using Unmanned Aerial Spray Systems (UASS)- Hector E. Portillo, Sarah Hovinga, Neill Newton, Tyler Gullen.
2. The International Code of Conduct on Pesticide Management - FAO
3. CropLife International Facilitators Manual – Integrated IPM - Section 8.7
4. CropLife International Facilitators Manual – Integrated IPM - Section 8.7-8.8
5. CropLife International Stewardship guidance for use of unmanned aerial vehicles (UAVs) for application of crop protection products – Section 5.10
6. CropLife International Integrated IPM Manual Handout 1.2
7. FAO- Recommendations for improved weed management- Section 1.1
8. CropLife International Integrated IPM Manual Section 8.14
9. Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.3
10. Guidelines on Good Labelling Practice for Pesticides – FAO - Section 4.1
11. CL International Resources – Label
12. CropLife International Integrated IPM Manual Handout 8.4
13. CropLife International Integrated IPM Manual Handout 8.5
14. Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.4
15. Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.4
16. CropLife Asia “Recommendations for UAS operator training and certification requirements” (2020)
17. CropLife Asia: “Recommendations for building a Standard Operating Procedure (SOP) for pesticide application by UAS”
18. Japan: Safety guideline for aerial application of agricultural chemical from unmanned multicopter, 2019
19. Korea: Manual of Unmanned Aerial Vehicle (UAS) for Spraying Pesticide

20. Safety guideline for aerial application of agricultural chemical from unmanned multicopper
21. FAO/WHO: Guidance for Aerial Application of Pesticides
22. FAA-2003-1832-0001 attachment 5
23. Korea: Manual of UAS for crop protection(Revised edition)_Korea Final (ENG)
24. India: The UAS Rules, 2021
25. India: Drone Recommendation- Telangana State Agricultural University
26. UAS of Plant Protection and Chemical Application, Xiongkui, He
27. Agricultural UAS Operation, Zhongyi, Cheng, Xiongkui, He
28. GB/T 8321.1~8321.10 Guideline for safety application of pesticides (1) ~ (10)
29. GB/T 18678 Equipment for crop protection – Agriculture spray – Nominal capacity of spray tank and diameter of filling
30. GB/T 25415 Guidelines on practice for aerial application of pesticides
31. NY/T 1276 General guidelines for pesticide safe use
32. NY/T 1533 Guidelines on good practice for aerial spray application of agrochemicals
33. NY/T 3213 Technical specification of quality evaluation for crop protection UAS
34. MH/T 0017 Technical terminology for agricultural aviation
35. T/CCPIA 019 Specification for safe application of pesticide by crop protection UAS
36. T/CAMA 06 Crop protection UAS – Spraying quality
37. 2021.6 version Operation recommendations of DJI Agriculture's full series of plant protection UAS, Huifei UAS Application Technology Training Center
38. Corteva : Corteva Best Application Practices of Acanto Way against rice, wheat and peanut disease control by UAS application.
39. Agricultural Unmanned Aircraft Operation Management System (Model) ,DJI Huifei UAS Training, Tang Xiuwei Huifei, 2023