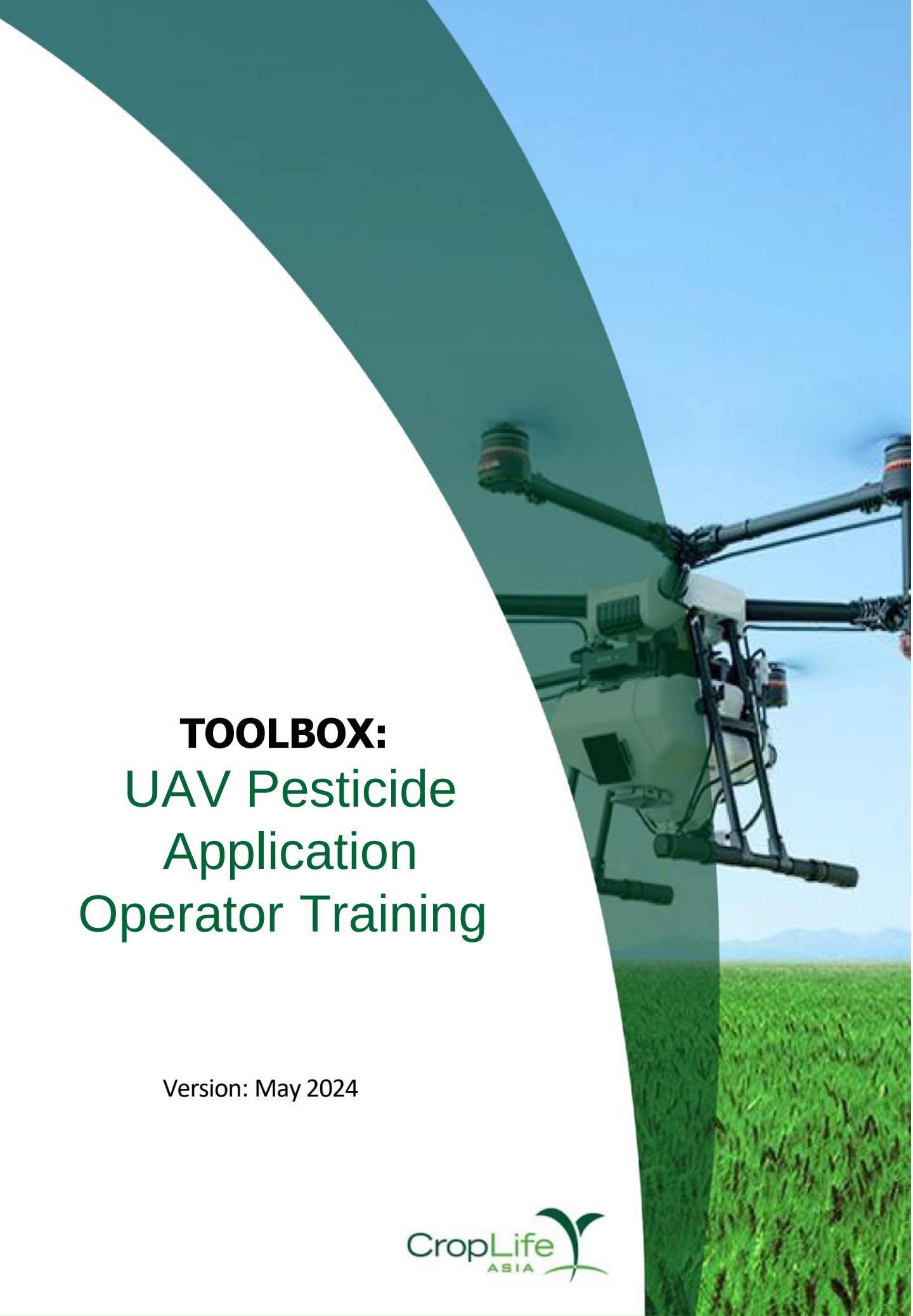


TOOLBOX:
UAV Pesticide Application Operator Training

Version: May 2024

CropLife ASIA

CONTENT

CONTENT

INTRODUCTION

This toolbox has been prepared by the CropLife Asia Drone Task Force. The objective of this toolbox is to provide recommendations on the knowledge and skills required of Unmanned Aerial Vehicles (UAV) or UAS operators to be licensed to operate pesticide applications safely and effectively.

The main target group for this toolbox are UAV operators for pesticide application, government stakeholders involved in accrediting UAV operators, and training agencies for UAV operations that are used for pesticide application. With the understanding of pesticide knowledge provided by this toolbox, readers should be able to understand the practical implementation of pesticide application by UAVs.

It should be noted that the scope of UAVs specified in this toolbox includes multi-rotor UAVs and Radio-Controlled Helicopters (RCH). Specifically, the best application practices in this toolbox (Toolkit 4) are based mainly on the knowledge, study and commercial adoption experiences on UAS 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 the 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.

Toolkit 1:

UAV: TRENDS, LAWS, AND REGULATIONS

- Societal trends & technology development
- Building a sound regulatory framework
- Recent regulatory progress across Asia
- Global adoption of drones for pesticide application
- Japan: A well-established regulation on UAV application & pilot licencing
- Benefits for Asia's small-holder farming

| Bjoern Roepke | Linda Wang | Christina Liu | YingNan Jiang | Li Zhaoqiang |

CropLife ASIA

Helping Asia's Farmers Grow

DRONE: TRENDS, LAWS, AND REGULATIONS

1.1 Societal trends & technology development

Aging Farmers & Labor Shortage

Societal Trends in Asia

Labour shortages due to an ageing population and increasing urbanization, leading to rising labour costs.

- *75% farming population are above the age of 65*
- *Observed 30% farmer decrease in the last decade*

Safer Operations

Efficiency & Safety

- *High application efficiency, comparable efficacy*
- *Introduction of Civil Aviation Laws, SOPs, and operator training to ensure flight safety*
- *Reduced operator exposure risk*
- *Reduction of off-target movement governed by wind & flight speed/height, moisture, temperature, droplet size*

Regulatory Management

Regulatory management for Crop Protection Application by UAS

- *UAVs are just another form of spray application*
- *Japan Ministry of Agriculture and Forestry, stipulates that registered crop protection products can be applied safely within the GAP at comparable efficacy & residue levels without repetition of studies*

1.2. Building a sound regulatory framework

Local civil aviation laws and regulations are the primary guide for the management of UAS pesticide application. This toolbox serve to provide supplementary guidelines for the safety and efficacy of UAS pesticide application, but readers should always defer to local laws and regulations when available.

Local civil aviation laws: Operating under the umbrella civil aviation law, vehicle specification are regulated by the competent authority	Drone company
Standard Operating Procedure (SOP) for the Safe Use of Drones for pesticide application: Safety during spray operations is enforced within pesticide regulations setting piloting requirements and safe use practices	Drone Operator
Permissions for spray application: Product approval for spray operations may refer to existing spray-registration and established or amended regulatory procedures	Pesticide Manufacturer

1.3. Recent regulatory progress across Asia

Country	Civil Aviation Law Enacted [Civil Aviation Authority]	Procedures on Drone Operation Activity - SOP [Department of Agriculture]	Clear Guidelines on Registration Data Requirements for Drone Spraying [Regulatory Authority]	Commercial Application of PPP [Drone Service provider / Drone Operator]	Guidance document for use of Drone in Agriculture
Japan	✓	✓	✓	✓	If product already registered, only phytotox trial is required. If product not yet registered for any use, standard registration requirements apply.
South Korea	✓	✓	✓	✓	Requirement: 2 trials biological efficacy data & phytotoxicity and residue data.
Australia	✓	🔒	✓	✓	SOPs not established. Possible drone spray with existing labels where aerial application allowed.
China	✓	✓	🔒	✓	Commercial spray of registered products permitted, while guidelines evolves.
Taiwan	✓	✓	✓	✓	Commercial spray of registered products permitted.
India	✓	✓	✓	✓	Regulatory requirements & SOP crop-specific established.
Philippines	✓	✓	✓	✓	Regulatory requirements & Checklist of requirements for licensing of Commercial Applicator – drone spraying operator established.
Malaysia	✓	✓	✓	✓	SOP from DoA established. Commercial drone spray is allowed.
Indonesia	✓	🔒	✓	✓	All registered products/crops can be applied with same dose rate and less water. Commercial drone spray is allowed.
Thailand	✓	🔒	✓	✓	All registered products/crops can be applied with same dose rate and less water. Commercial drone spray is allowed.
Vietnam	✓	🔒	✓	✓	SOP for bioefficacy trial protocol published in Jan 2023.
Myanmar	✓	🔒	🔒	🔒	No drone application allowed – unstable political situation.
Pakistan	✓	🔒	🔒	🔒	SOPs included in draft policy presently under review.

1.4. Global adoption of drones for pesticide application

North America:

- The Federal Aviation Administration (FAA) is part of the U.S. Department of Transportation. It is responsible for both UAS regulation and its enforcement (Public Law 112-95).
- Neither Canada nor the U.S. have UAS regulations for pesticide application

LATAM:

General legislation on recreational use and agricultural surveillance, application regulations are all in initial stages.

- **Brazil.** Draft application regulation has reached Congress for first discussions.
- **Argentina:** Advances initiatives and demonstrations. CASAFE states labels must be adjusted first as the recommended volumes generate conflict with the capacity of the UAS. Technical discussion on definitions of drones and aerial application.
- **Mexico:** SAGARPA's public consultation for the inclusion of appendix on UASs in current legislation

DRONE: TRENDS, LAWS, AND REGULATIONS

Africa: SHF size of field well adapted for UAS application. Drone seen as a mitigation tool, improving the safety, replacing Backpack. Civil aviation for UAS application in place, application guidance (to be shaped)

Europe:
Switzerland has indeed a legislation that authorizes aerial applications of pesticides. Applications by drones are authorized in this frame
UK leading **OECD** working group Drone applications are also under authorization process in **Hungary** & Portugal which benefits from derogation for aerial application)
France, Italy and Spain drive national pilots (vineyard, orchard, slope, wet conditions).

Australia: Pilots applying pesticides onto any land in NSW, and people or companies employing such pilots, must have specific qualifications, hold EPA licences and meet certain legislative requirements under the Pesticides Act 1999 and Pesticides Regulation 2017.

New Zealand: Regulations in 2019 legalized commercial UAS-based spraying for (1) Part 102 Certificate holder specifying agricultural operations and operating an aircraft over 25kg and (2) certificate holder in aerial application

1.5. Japan: A well-established regulation on UAS application & pilot licencing

Licensing of UAS operators

- Regulatory conditions for safe UAS operations in Japan:
  1. Vehicle needs are approved
  2. Pilots are licensed and trained for pesticide application by UAS
  3. Pesticide product is registered
  4. Label instructions of the product are adhered to
- Country authorities to supervise and accredit training facilities to ensure a standardized training program
- Certification and licenses to be regularly renewed and refresher courses conducted routinely

Registration requirements of pesticides by UAS application

Japan has 30 years of experience in drone trials & regulations
J-MAF concluded on *equivalence* of efficacy & residues after drone & conventional at the same use rate

Type of data requirement	**Label extension** of registered formulation from conventional application to drone application	**New formulation** for drone application
Bio-efficacy data	**Exempted** if pest/disease claim and critical GAP (Crop, Dose, PHI) is within the range of existing registration. If not, full data requirement	**Full data requirement** by drone application
Crop residue data	**Exempted** if critical GAP is within the range of existing registration. If not, full data requirement	**Exempted** if critical GAP is within the range of existing registration
Crop safety data	**Full data requirement** by drone application	**Full data requirement** by drone application

1.6. The use of UAVs has been tremendously beneficial for Asia's small-holder farming in overcoming labour shortage and aging farmers

Less water Volume
3% water volume of manual application

Comparable efficacy
Comparable or even better control efficacy VS manual

Cheaper Cost
50% treatment cost vs manual application

More efficient
30 times faster VS manual application

Safer to operator
Lower PPE requirements vs manual application

Labor Saving
Overcoming labor shortage

Toolkit 2:

PESTICIDE KNOWLEDGE

- What are pesticides?
- Classification by formulation
- Pest: Insect, disease, and weed
- Pesticide label
- Measures to prevent violations of the usage standards

| Varun Goel | Vicki Rizki Arneldi |

2.1. What are pesticides?

A pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth

Type of Pesticides	Pest Controlled
Insecticides	Insects
Fungicides	Fungi
Herbicides	Weeds
Acaricides	Mites
Rodenticides	Rodents
Nematicides	Nematodes
Molluscicides	Snails

2.2. 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 that have no activity against pests

2.2.1. 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)

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 contain 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 the 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.
- May be 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

2.2.2 Formulation types - only those 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 most 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

2.3. Pest: Insect, Disease, and Weed

2.3.1. 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.

2.3.2. Insects and their damage

The animal groups of the greatest importance as agricultural pests are (in order of economic importance) insects, mites, nematodes and astropod molluscs. 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 mouthparts 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 mould 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.

2.3.3. 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.

2.3.4. 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

2.3.5. 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 by 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

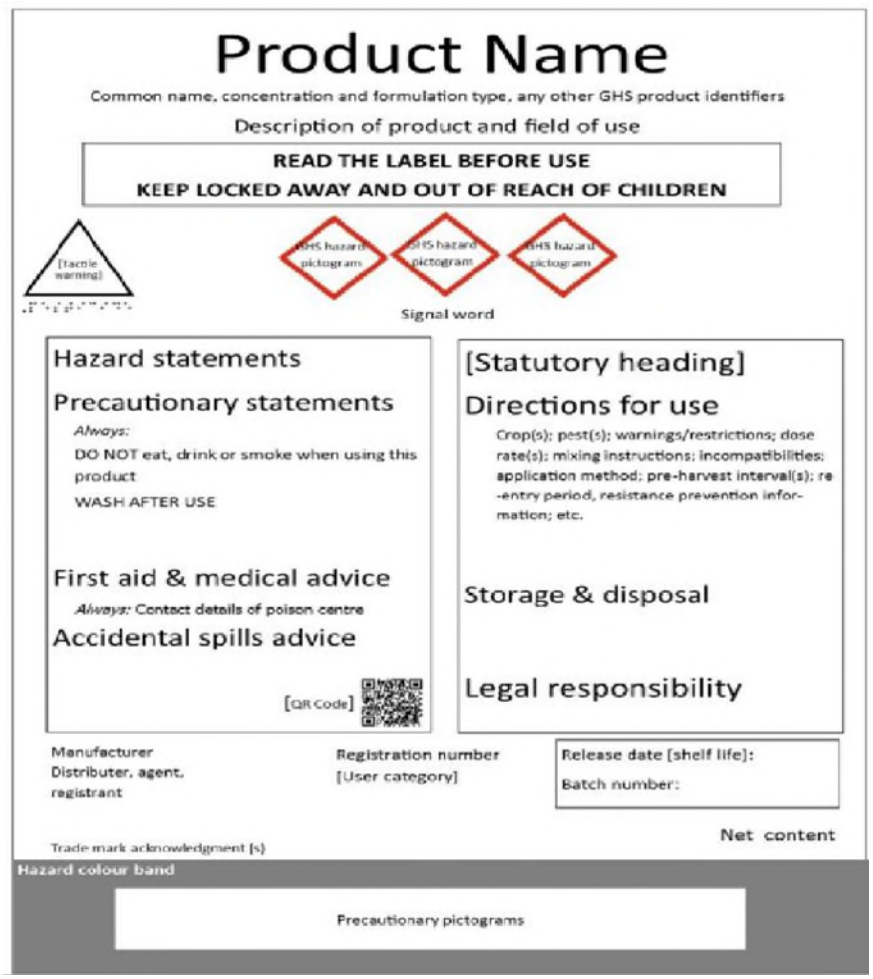
- Grasess (*Echinocloa sp*, etc.), broadleaf (*Boreria sp*, etc.), fern (*Axonopus sp*, etc.), Sedges (*Cyperus sp*, etc.)

2.4. Pesticide Label

- 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 that 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 a pesticide. 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

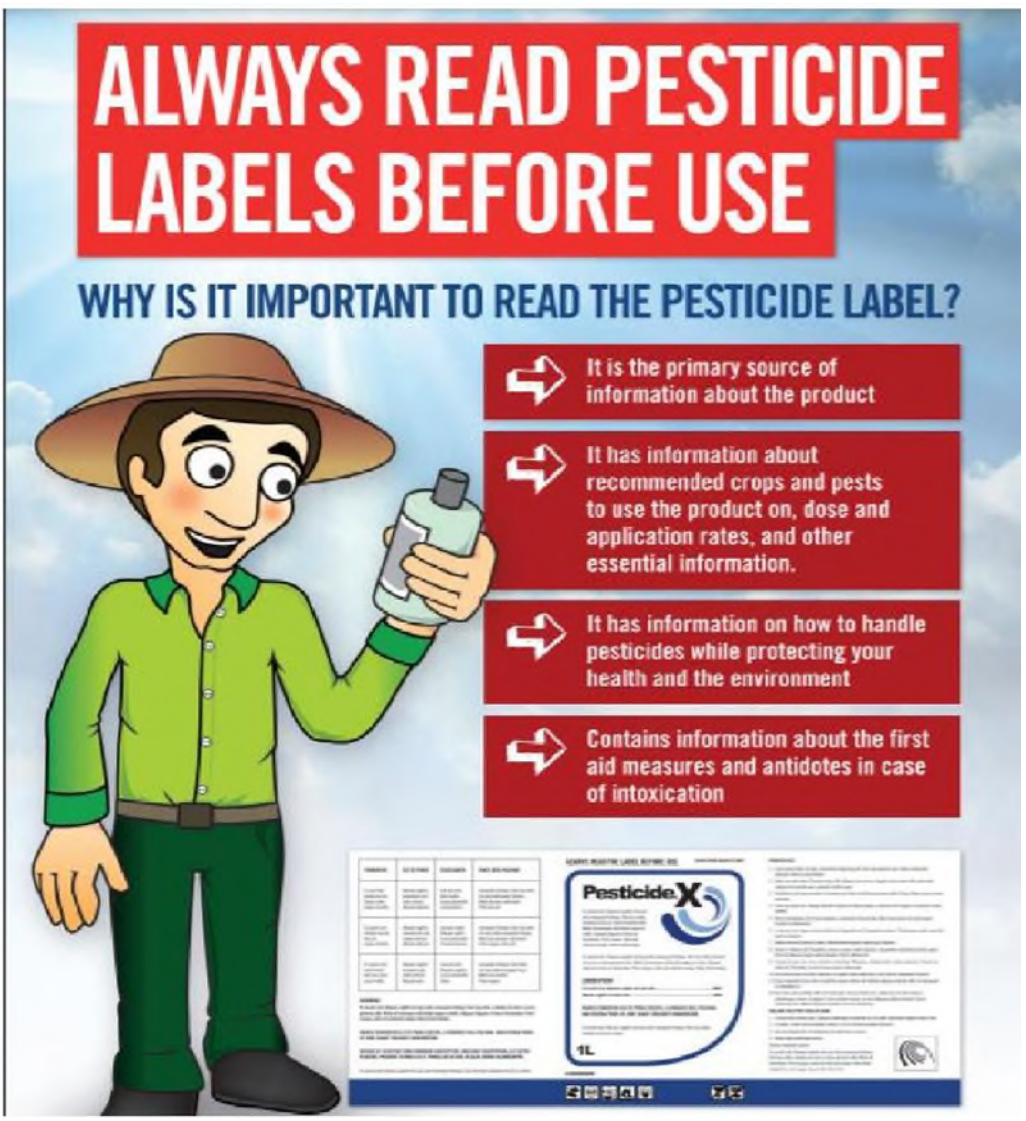
PESTICIDE KNOWLEDGE

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

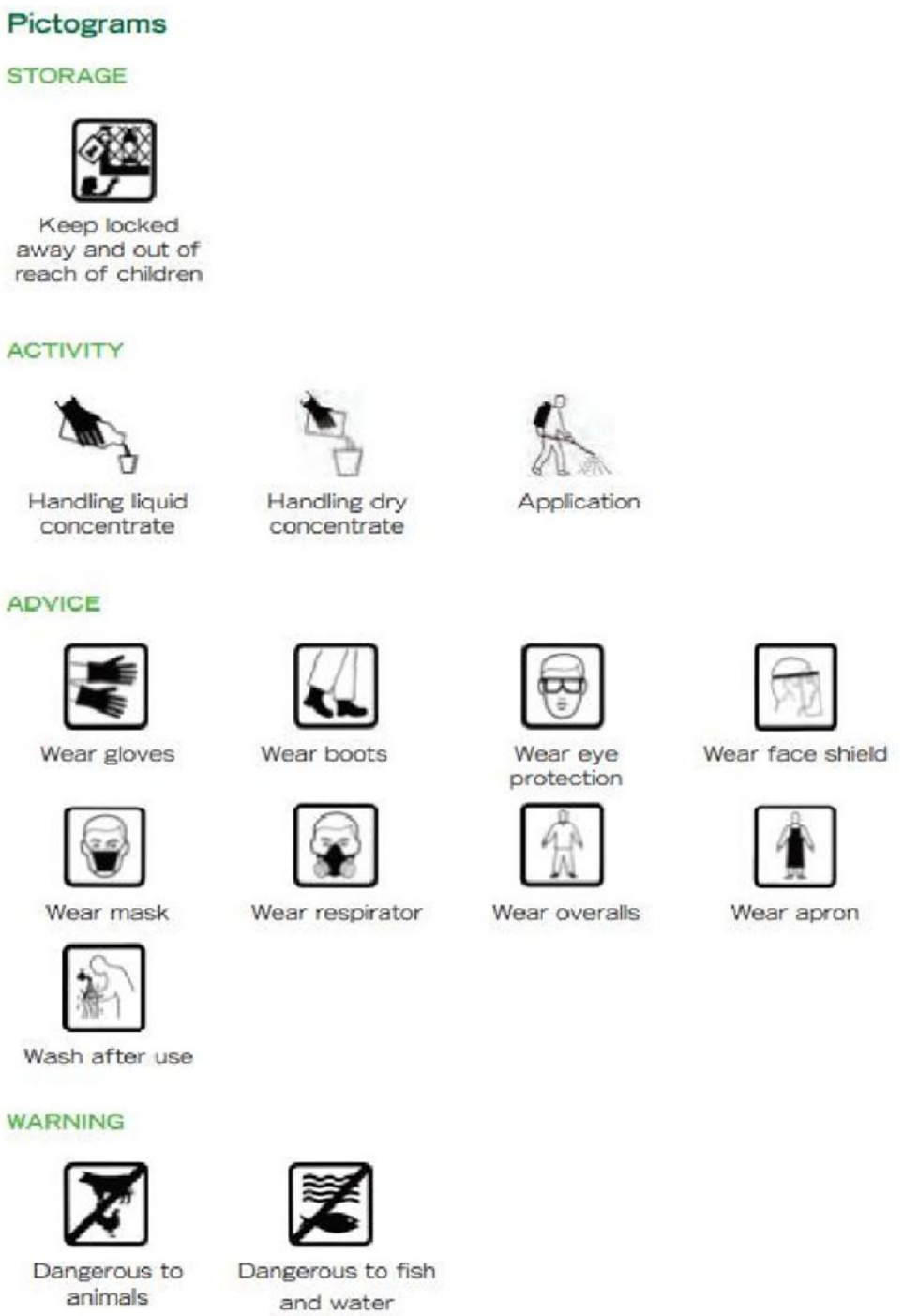


PESTICIDE KNOWLEDGE

- Always READ the pesticide label before use



2.4.1. Pictograms



2.4.2. 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.

2.4.3. 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 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, also 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.

2.5. 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 done 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, and 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.

Toolkit 3:

SAFE USE OF PESTICIDES

- Safe and proper use of agricultural chemicals
- Pesticide residue and safety assessment
- Pesticide residue standards and limit
- Emergency and accident response

| Esley Ng | Rishelle Wang |

3.1. Safe and proper use of agricultural chemicals

3.1.1. Responsibilities of pesticides users

- Pesticide users have a responsibility to ensure that your actions do not cause harm to:
  - other people or their property
  - yourself or
  - the environment
- Responsibility extends to effects caused by drift, runoff or residues.
- User should also:
  - comply with relevant legislation
  - familiarise themselves with the relevant safety information of the products they plan to use.

3.1.2. 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

3.1.3. 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

- **PPE**
  - 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 the contamination with pesticide residues.
  - No mobile phones during application and wearing PPE.

- **Application**
  - Do not eat, drink, and smoke
  - Choose appropriate application techniques and equipment that will minimize exposure of personal 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 the label and leaflet for first aid information to assist the doctor in the event 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 the field.
  - Rinse spraying equipment thoroughly (at least 3 times) after the application of each mixture.
  - Dispose of rinsing liquid by spraying on discarded areas. Refer to the UAS manufacturer guidelines for rinsing if any.

3.2. Pesticides residues and safety assessment

3.2.1. 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

3.2.2. Toxicity assessment of pesticide 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 pesticide residue cause interruptions in export and import.
- Agricultural produce such have faced rejections and even bans in markets due to presence of higher levels of chemical residues than approved levels.

- The Organisation 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

3.2.3. ADI and ARfG

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 the known facts at the time of the evaluation. It is expressed in milligrams of the pesticide per kilogram of body weight.
- ARfD – an 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)

3.3. Pesticide residue standards and limit

3.3.1. 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 are pesticide registration withholding limits?

- 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) maintains 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.

3.4. Emergency and accident response

3.4.1. 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

3.4.2. 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.

3.4.3. In case of poisoning

If in eyes

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

If on skin or clothing

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

If inhaled

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

Toolkit 4:

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

- Basic requirement
- Before application
- Application
- After application

| Pamela Wang |

CropLife ASIA

Helping Asia's Farmers Grow

4.1. Basic Requirement

4.1.1. Agricultural UAVs

- The UAS shall comply with the local technical specification of quality evaluation for agricultural UAVs. UAVs equipped with precise navigation, obstacle avoidance, and flight control systems such as RTK centimeter-level positioning for route planning, and terrain tracing flight are recommended to be used.
- Registration of UAS 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 if required.
- All local laws and regulations precede the above requirements.

4.1.2. Operator

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

4.1.3. Insurance

- Obligatory insurance for UAS and operators is needed unless otherwise stated by local laws and regulations.

4.1.4. Proper application timing for pest

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

4.1.5. Pesticides and Formulations

- Refer to local laws and regulations and use pesticides safely and effectively. Pesticides should be registered and must follow local registration regulation laws.
- Choose feasible formulations for 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 show 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.

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

- **Choose feasible formulations on UAS application**

  - B. Corteva tested EC, EW, ME, OD, SC, CS, CE, WDG, Bait formulations in the 306 trials. Liquid formulations are the most tested formulations in 214 trials while the remaining 92 trials were tested with solid formulations. All these formulations showed very good technical feasibility on UAS application.

Corteva tested formulations

Formulations	
Formulations	Total
EC	25
Bait	6
CE	4
CS	1
EC+OD	9
EW	24
ME	13
OD	16
SC	122
WDG	86
Grand Total	**306**

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**
Grand 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.

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

- **Choose feasible formulations on UAS application**
  - D. Jun Zhang study the formulation feasibility on UAS application and gives us a general summary.

Table. Formulation feasibility on UAS application

Formulation	Feasibility on UAS Application	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)>=98%, Suspensibility >=80%
OD	++	Wet Sieving test (75um)>=98%
EC	++	Stability: Qualified after 200 times dilution, water content <=0.5%, the solvent must not be highly corrosive
WDG	++	Suspensibility >=60%, wet timing <=2m
WDT	++	Suspensibility >=60%, water content <=3%
SP	+	Degree of fineness >=80 mesh sieve, wet timing <=2m, water content <=3%, wet sieving >=98%.
WP	+	Degree of fineness >=325 mesh sieve, diameter <=5um, wet timing <=2m, suspensibility >=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 suitable for applications with UAS than solid formulations.
  - Pay attention to WP, SLX formulations since they have a higher risk to block hydraulic nozzles.
  - Formulations containing emulsifiers are likely to drift. Prudence is needed when such formulations used for UAS application. Water based formulations (like SC) can provide better anti evaporation attribute. For example, EC formulation is easier to evaporate, and drift compared with other formulations like SC, SL.
  - Physical compatibility for used products with other representative tank mixing partners under low water volume should be tested at the very beginning.
  - Formulation selection should also consider different nozzles used on UAS. Centrifugal nozzle and hydraulic energy nozzle are two commonly used nozzles equipped on current drones. Centrifugal nozzle dominant China 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 good on UAS.
    - However, hydraulic energy nozzles are easier blocked when spray WP formulation compared with centrifugal nozzle. So, when spray WP formulations, centrifugal nozzle drone is more 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.

4.1.6 Adjuvant

Adjuvant is useful but needs to be tested before using and it needs to be used correctly. The function of adjuvant used on UAS focus on anti-drift and anti-evaporation. The most used adjuvant in China is oil. See below adjuvant properties and performance to know more.

Adjuvant properties and performance range from Momentive

Performance Scale: 1=Poor, 10=Exceptional

Type	Spreading	Penetration	Deposition	Moisture	Retention	Adhesion
Water	1	1	1	1	1	1
Vegetable Oils	5	5	7	4	8	7
Silicones	10	3	4	10	2	2
Silicones + MSO Oil	5	10	8	7	6	3
Stickers	4	3	5	5	5	10

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. Below give you an example how adjuvant improve performance of product.

4.2. Before Application

4.2.1. Check on factors that affect UAS application efficacy

- **Environmental conditions:** Relative Humidity (RH), temperature, wind speed, wind direction, air inversion, time of application, solar angle, etc.
- **Pesticide and adjuvant selection:** Active ingredient, formulation, adjuvant, physical compatibility, use rate, application timing, application times and interval etc.
- **UAV specifications:** UAV type, flight mode, nozzle type (closely related to droplet size), water volume, flight parameters (application speed, application altitude, spray swath or flight line spacing, flow rate, etc.)
- **Operator skill:** professional knowledge, skill, license, insurance (maybe needed for some countries), etc.

4.2.2. Conduct an environment survey

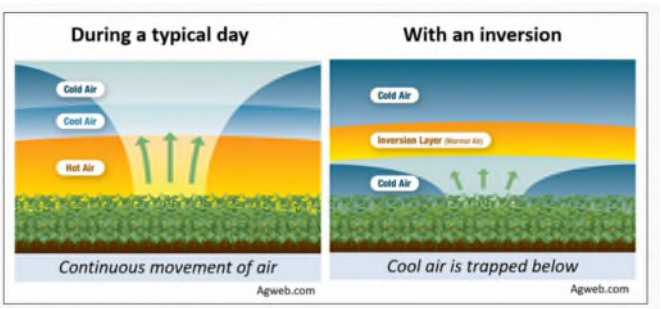
- **Clear of No-Fly Zones, restricted Fly Zone and airspaces.** UAVs should not be operated in no-fly areas. UAS Operations are permitted only over agricultural land. Clearance is needed before fly in No-Fly Zones. Appropriate buffer zone needs to be set up (see 4.3.4).
- **Notification of and permission for pesticide application by the owner of the field should be given in advance.** The application team should inquire the owner of the field to determine whether there is any nearby areas that may be affected by the application of pesticides, including aquaculture area (shrimp, crab, fish, etc.), bird, beekeeping area, sericulture area and such sensitive areas/bodies.
- **Obstacles affecting safe flight such as trees, high-voltage towers, electric wires, poles and wind turbines in and around the application plot should be determined in advance**. The application team should determine whether the area can be treated using a UAS. Avoid spraying close to high voltage lines and cables, farmland plastic films, branches, dust areas, etc.

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

Operators should observe the weather conditions to determine whether it is suitable for UAS application. The suitable weather conditions are as follows:

- **Wind speed** ≤3 m/s (10.8 km/h); Application must be avoided below 0.8m/s due to variable wind direction and high inversion potential. Once it comes to herbicide application especially for non-selective herbicide application, it is strongly recommended to do the application when the wind speed is less than 2m/s (7.2 km/h). When there are variable wind direction and high inversion potential and the wind speed is below 0.83m/s (3 km/h) at the same time, application must be avoided. Avoid of application when there are high possibility of gust.
- **Temperature:** The (common) optimum temperature for spraying is 10℃-30 ℃, and the application should be suspended when the atmospheric temperature exceeds 35 ℃, Small spray droplets can be carried upwards by convective thermal currents. The temperature feasibility is also dependent on the active ingredient of the pesticides. For example, some herbicides can be applied at lower temperatures.
- **Relative Humidity: T**he relative humidity should be within the range of 40-90% when spraying; Do not apply when temperature is high, and RH is low.
- **Rain:** if there is rain forecast within 4 - 6 hours of application, no pesticide shall be applied.
- **Application time of a day:** Application should be done early in the morning or late afternoon. Applications may also be done at night with suitably equipped spray drones. Application in general should be done when atmosphere is neutrally stable. Spraying is recommended between sunrise and morning when the airflow is relatively stable (attention to the temperature reversal layer). DO NOT apply under conditions of strong thermal inversion. For radiation air inversion, it is often indicated by little (<3 km/h) or no wind from shortly before sunset to soon after sunrise in the absence of heavy cloud cover, especially early morning.

Normal situation vs Air Inversion



Source: https://www.nickelblock.com/wx-info-what-is-atmospheric-ducting/

4.2.3. Preparation work for UAS

- **Inspection and Calibration**

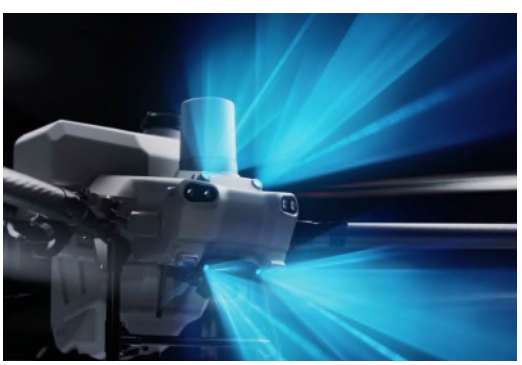
- Before the application, the UAS should be inspected and calibrated according to the requirements of the UAS manufacturer and local aviation requirements. Check preflight settings e.g., GPS, compass, LED status; satellite locks, gimbal level, flight controls.
- Necessary calibration items of spray system should include flow rate, compass, flight controller, flight control system, altimeter, avoidance systems, radar, inertial measurement unit (IMU), effective spray swath. Firmware needs to be updated to the newest version. For detail, please follow UAS manufacturers 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 non target or sensitive areas.
- Obstacle avoidance system usually contains Radar system, Vision system and Positioning system. See below the obstacle avoidance system of DJI Agras T50
- Most flight control software will allow the operator to align the flight lines to optimise 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.

UAV crash

DJI Agras T50 obstacle avoidance system: Radar + Binocular system



- 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 and 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 relative 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 the 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 the technology, it is worth to try lower water volume such as 8 L/Ha which used a lot in Japan.

- **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.

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

- It is advisable that the deposition density of droplets on the edge of the spray belt be no less than 15 /cm^2 to 30 /cm^2 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. Fly too close to the crop would cause damage to the crops and create more drift as there is a 'bounce' from the ground. Fly too high, drift risk will increase.
- **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 or fly on tall crops, application speed should be appropriately reduced, application pressure can be increased, and fine droplet size can be chosen, all these adjustment can increase the 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 UAVs can be calculated and verified using the following formula *(based on UAS application standards of CCPIA China)*:

    - $V=\frac{Q\times 10000}{q\times D\times 60}$
    - 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) classified 8 categories of droplets size (see left bottom table). Among it, Fine and Very Fine (<150 microns in diameter) are listed as having a potential drift risk.
- Droplet size and and number follow *The one to eight rule. That is meant: e*very time the median diameter of spray is doubled, there are eight times fewer droplets.

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

Source: American Society of Agriculture and Biological Engineers (ASABE)

- Depending on Guobin Wang's study, the optimum biological droplet size for flying insects, larva or nymph of insects, disease and weeds are 10-50 μm, 30-150 μm, 30-150μm and 100-300 μm respectively. For example, a very fine spray with droplets smaller than 50um is suitable for airborne targets, e.g. mosquitoes and other flies.

The biological optimum droplet size of different target

Control Target	Flying insect	Larva or nymph of insects	Plant disease	Weed
The biological optimum droplet size	10-50 μm	30-150 μm	30-150 μm	100 -300 μm

Source: Droplet size and coverage density of insecticide and their relationship with control efficacy against wheat aphids, Guobin, Wang;

Pump, nozzle type and droplet size

- **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:** Pressure of hydraulic nozzle is to spray under 2-4 bar pressure. T30, T10 such drones from DJI equipped with hydraulic nozzle.
  - **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. Easy broken and needs frequent replacing.
- For **rotating centrifugal nozzle, working** principle of rotary atomiser is by centrifugal force that creates different droplet size according to rotational speed. Drones from XAG, EAVISION and some drones from DJI are all equipped with rotary atomiser.
  - **Pros:** Even atomization, less 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 centrifugal nozzle are not stable. For motor driven board with carbon brush, the service life is short and changing frequency is high. Easier to drift when using small droplet on long-stalked crops or crops with thick canopy like fruit trees.

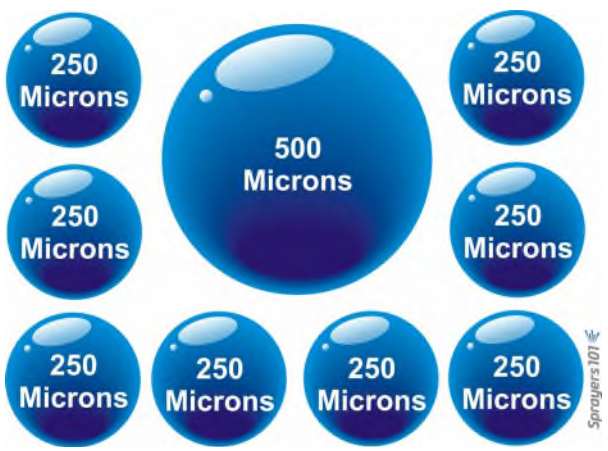
DJI: Hydraulic Nozzle

Eavision: CCMS mist nozzle on EA-J100

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 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 of drift, you can use medium or coarse droplet size to do herbicide application, like coarser than VMD 150 or 200 μm. For centrifugal nozzle, you can adjust the automizer speed to realize different droplet size. For hydraulic nozzle, you can choose anti-drift nozzle such as AIXR, AI, TF, TT rather than XR nozzles. But fine or very fine droplet can better reach to lower part of crop and back side of leaves. Fine or very fine droplet size are needed for thick canopy application like fruit tree application. And the droplet size of centrifugal nozzle can be adjusted, it can realize very fine or fine droplet size like T40 with droplet size ranged from 50μm to 500 μm. So, you can choose 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 spray is halved, there are eight times more. (Source: sprayer 101.)

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

How to choose proper parameters

- Flight parameters are highly depending on UAV 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 requirement 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 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 "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 to you 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. Higher payload can produce strong downwash wind field. 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 same area. Do Not use this application method on herbicide. 6. Night application is suggested for orchard such tall and thick canopy crops.	
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)	Based on DJI recommendation, Spray width or flight line spacing is around 3 - 10 meters for row crops and vegetables.	Flight line spacing recommended to be 2.5 - 5.5 meters for orchard. Flight line spacing for orchard should be narrower compared with row crops to ensure better droplet distribution 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 for orchard. The heavier the payload, the higher flight altitude.
Flight speed (m/s)	Application speed recommended to be 3.5 - 7 m/s for row crops and vegetables.	Generally, it is 1.5-3 .5 m/s for orchard application. Application speed is much slow for orchard application compared with it is on row 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 to do the application during night to well manage drift and evaporation. Pay attention to drift and evaporation.

Suggestions to choose proper flight parameters

Major impact factors	Application Scenario	General suggestions	Suggestions for major parameters					Remark
			Water volume	Droplet size	Flight speed	Flight line spacing	Flight altitude above crop canopy	
Different crops	Crop canopy is big, tall and dense, like tree	More conservative parameter setting	Increase	Decrease	Decrease	Decrease	Increase	Usually, more water volume and fine droplet size suggested to be used for thick and tall canopy crops such as trees compared with row crops such as rice. 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 "bounce back" effect between the downwash 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 same area. Do not use this method on herbicide application.
	Crop canopy is small and sparse, like wheat	Less conservative parameter setting	Decrease	Increase	Increase	Increase	Decrease	
Growth stage of crop	Later growth stage, crop canopy is big, tall and dense	More conservative parameter setting	Increase	NA	Decrease	Decrease	Increase	
	Earlier growth stage, crop canopy is small and sparse canopy	Less conservative parameter setting	Decrease	NA	Increase	Increase	Decrease	
Infested position of pests	Mainly distributed at lower part or inner side of crop canopy	More conservative parameter setting	Increase	NA	Decrease	Decrease	Decrease	Theoretically, disease and insect management needs very fine or extremely fine droplet size; weeds management needs relative medium and coarse droplet size.
	Mainly distributed at upper part or surface of crop canopy	Less conservative parameter setting	Decrease	NA	Increase	Increase	Increase	
Infestation level of pests	High severity	More conservative parameter setting	Increase	NA	Decrease	Decrease	NA	Preventive and integrated application, but not late application under high pest pressure.
	Low severity	Less conservative parameter setting	Decrease	NA	Increase	Increase	NA	
Different pesticides	Herbicide	NA	Increase	Increase	NA	NA	Decrease	Be careful of drift. Uniform application and avoid of missing and duplicate application. Wind speed <2m/s.
	Fungicide and insecticide	NA	Decrease	Decrease	NA	NA	NA	Preventive and broadcast application are strongly recommended. Wind speed: <3m/s.
	Contact pesticides	More conservative parameter setting	Increase	NA	NA	NA	NA	Good coverage is needed
	Systemic pesticides	Less conservative parameter setting	Decrease	NA	NA	NA	NA	Coverage can be improved by the systemic movement of pesticides in the crops to some extent.
Weather	Higher wind speed and temperature, low relative humidity	More conservative parameter setting	Increase	Increase	Decrease	Decrease	Decrease	Pay attention to drift and evaporation.
	Lower wind speed, feasible temperatue, high relative humidity	Less conservative parameter setting	Decrease	Decrease	Increase	Increase	Increase	

How to choose the proper parameters

- Appendix A summarizes flight parameters recommended by DJI, Eavision, XAG, YAMAH 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

Drone manufacturers	Models	Crops	Appendix A
DJI	MG-1S, MG-1P, T16, T10, T20, T30	Rice, wheat, corn, cotton	1. DJI Row crops T30, T20, T10, T16, MG series.png
DJI	T40, T20P, T30, T20	Citrus, mango, wax berry, litchi, apple, pear, peach, plum	2. DJI Fruit trees T40, T20P, T30, T20.png
DJI	T40, T20P	All crops	3. DJI All crops T40, T20P.png
DJI	T50, T25	All crops	4. DII All crops T50, T25.png
XAG	P100 Pro, V50 Pro	rice, vegetables, fruit trees	5. XAG All crops P100 PRO, V50 PRO.png
EAvision	Tho:EA-20X, EA-20XE HERCULES:EA-30XP, EA-30X	Corn, soybean, cotton, sunflower, rice, alfalfa, potato, tomato, mango, banana, coffee, apple, citrus, sugarcane, olive, pistachio, large almond, lemon, hazelnuts	6. EAvision Parameter Reference Guide.pdf
MARUT, India	AG365	Rice, cotton, red gram, soybean, groundnut, sesame, safflower	7. Drone recommendation (Page7, 9, 10, 11, 12, 13, 14)

- Please be noted that these operating parameters of UAV are based on DJI drones like T10, T20, T30, T40, T20P, T50, T25, 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; YAMAHA and other major drone models in India. This is just general recommendation; parameters needs to be adjusted depending on detail 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 main representative UAS in the market by drone manufacturers.

4.3. Application

4.3.1. Basic criteria of operation team

- Follow the operating recommendations of the UAS manufacturers. The flight route should follow the designated fly route. Do not arbitrarily change flight routes and flight parameters during flight. Ensure uniform application – To avoid streaked, missing, uneven, overlapped or wrong application.
- The flight distance shall be controlled within the visual line of sight (VLOS), and air space control requirements shall be understood.
- Flight shall conform to aviation regulations and not in proximity to people, animals, urban areas or airports.
- The width of buffer zones should be defined according to the product label and will depend on droplet size, crop height and the possible impact of drift downwind of treated area. Follow the operating recommendations of the UAV manufacturers. Take-off and landing flights should be at least 6-10 m away from obstacles, parallel flight should be more than 10 m away from obstacles. Be sure to keep a distance of 20 m or more between the UAV and the application team.
- The application team should avoid being in the downwind position of spray, avoid entering the application area, wear appropriate personal protective equipment (PPE) when handling pesticides, and avoid contamination of operators, bystanders, and the environment according to the product label. Smoking, eating, and drinking are prohibited during work.

4.3.2. Operation of the UAS

- 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 if possible.
- 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 UAS enter these areas. And farmers should be notified.

BEST APPLICATION PRACTICES FOR UAS PESTICIDE APPLICATION

- The application status of the UAS 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 UAV 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 UAV missed due to irregular blocks of field or other reasons, application should be conducted separately. Cautiously apply the pesticide during hovering and turning of UAS.
- If the nozzle becomes blocked during application, stop spraying and return aircraft to take off area to clean nozzle. Aircraft flight control should allow UAS to return to same location where spraying was interrupted.
- Obstacle avoidance system should be turned on throughout the application.
- In case of aircraft crash, signal interference, technical problems during flight etc. Report and record any incident accordingly.

- **4.3.3. 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 UAV application practice. Such as, tank mixing requirement and taboo 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 temperature is higher than 35℃, whether the products you used are qualified or not, etc.

Tank mixing with pesticide with potassium dihydrogen phosphate

Good mixing Bad Mixing

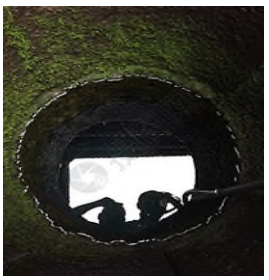
Source, Corteva

4.3.3 Basic criteria for pesticides loading and mixing

To ensure safely and effectively tank mixing using of pesticide by UAV 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 product used in the mixtures.
2) It is always recommended to do physical compatibility study before using chemicals on UAV application if possible. Consistent and stable mixture is the precondition. 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 turbidity. 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 performance.
    - 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.

Source of water



Maybe No

Yes

4.3.3 Basic criteria for pesticides loading and mixing

4) Proper tank mixing order and procedure (next page's table) are very important to ensure good tank mixing compatibility of pesticides, plant growth regulator, foliar fertilizer, and adjuvants. Secondary dilution method is always recommended.

- 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 – bad examples

Several pesticides tank mixing using on rice caused tip burning of rice leaves.

Untreated check

Source: Seven Wu of Corteva

4.3.3 Basic criteria for pesticides loading and mixing

- 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).

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.

4.3.4. Recommended risk management method

Based on field trials, field drift studies, commercial adoption experiences and key learnings, scientific articles, DJI, we generated this recommended risk mitigation methods.

- **Flight parameter**

- Appropriate flight parameter like decrease flight altitude or reduce flight speed or increase water volume under high risky application scenario.
- Use Automatic control mode all the time to avoid of duplicate, wrong and missing application
- Using coarse or coarser droplet size (> 300 μm VMD). Using centrifugal nozzle to adjust the droplet size to medium or coarse; Or using anti-drift hydraulic nozzle such as AIXR, AI, TF, TT rather than XR nozzles.
- Hydraulic energy nozzles are easier blocked when spray WP formulation compared with centrifugal nozzle; Nozzle blocking, and physical compatibility test are strongly suggested for products in WP and EC formulation especially for drone with hydraulic nozzle.
- Rinse the spray system and whole machine correctly and timely.
- Use two tanks for UAS, one use for herbicide application, another one use for others.

4.3.4. Recommended risk management method

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℃ and relative humidity lower than 55%.
- Choose the most appropriate time of day to fly. In general, early morning or late afternoon or night is the ideal choice. Application should also be avoided when there is strong temperature inversion.
- Application during night can help to alleviate drift and evaporation.
- Application when there are dew on the leaf would be good for herbicide application.
- Good water management is needed for rice paddy application according to the detail pesticide requirement. Keep high soil moisture while application will be helpful to improve herbicide performance on up-land crops.
- Conduct a good environment survey.
- Pay special attention to sensitive nearby crops. In sensitive application scenarios, it is recommended to set a buffer at least 300 meters wide. Or avoid to do application when there are sensitive aquatic lives, plants and such lives nearby. In other less sensitive cases, a minimum of 15 buffers is still recommended.
- Pay special attention on the application of nonselective herbicide.

4.3.4. Recommended risk management method

Feasible Formulation for UAS application

- Tank mixing the pesticide correctly.
- Adjuvant can reduce drift potential but must be tested and used correctly. Adjuvant can be used scientifically on herbicide application, fine or very fine droplet size application, 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 granule formulations of rice herbicides in Japan which can spread into water almost without drift.
- Among liquid formulations, SC and SL is 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 oil-based formulations.

Outlook

- By establishing drift prediction model and embedding the model into the control system, the drift area can be predicted automatically during the operation, and the route planning and operation parameter adjustment can be guided.

4.4. After application

- **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.
- **Waste disposal:** Refer to toolkit 3: 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.
- **Equipment maintenance, repair and storage:**
    - Follow manufacturers' recommendation on the other maintenance, repair, and storage.
    - Drone cleaning: The UAS surfaces, spray lines, tank, and associated mixing equipment should be cleaned timely after application. Tanks and spray lines should be triple rinsed to remove pesticide residues and washings disposed of according to local regulations and product label requirements. It is strongly recommended to use detergents to wash the tank and pump and use the brush to clean the pump after every task.
    - Use two tanks for UAV, one use for herbicide application, another one use for other pesticides, PGR, and fertilizer application.
- **Operator:** Refer to toolkit 3: 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. (Please take reference from Appendix B for more details).

- **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, and 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 conduct the investigation according to the visual assessment method: five-point assessment method, checkerboard method or zigzag method.

- **Flight hazards and Incident reporting**
  - Refer to toolkit 3: 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 UAS and any damage to property outside of the UAS should be reported according to appropriate authorities and company's policies.
  - Dry powder extinguisher should be prepared during operation.

BEST APPLICATION PRACTICES FOR CROP PROTECTION UAS APPLICATION

- **Spray quality requirement**
  - Where possible, spray quality should be evaluated for any new products used by UAS application or any products which never used by UAS before.
  - In general, the distribution uniformity of droplets (coefficient of variation) should be within the range of ≤ 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. UAS 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%

APPENDICES

APPENDIX A: UAS application flying parameters

1. DJI Row crops T30, T20, T10, T16, MG series.png

1. DJI Row crops T30, T20, T10, T16, MG series.png

2. DJI Fruit trees T40, T20P, T30, T20.png

2. DJI Fruit trees T40, T20P, T30, T20.png

3. DJI All crops T40, T20P.png

3. DJI All crops T40, T20P.png

4. DII All crops T50, T25.png

4. DJI All crops T50, T25.png

5. XAG All crops P100 PRO, V50 PRO.png

5. XAG All crops P100 PRO, V50 PRO.png

6. EAvision Parameter Reference Guide.pdf

Foxit PDF Reader Document

7. Drone Recommendation – Telangana State Agricultural University, India

Foxit PDF Reader Document

APPENDIX B: Application Recording Template

Application Parameters Recording Template

Operator Name				
Contact Information				
Application Date				
Detail location				
Item	Appl 1	Appl2	Appl 3	…
Farmer				
Telephone				
Crop				
Target				
UAS Type				
Application Order				
Detail application timing for each treatment				
flight Mode				
flight speed (m/s)				
Spray swath (m)				
flight height (m)				
Water volume (L/HA)				
Number of used nozzles				
Nozzle type				
Flow rate (L/min)				
Droplet size (um)				
Residue mixture in the tank (ml)				
Wind speed (m/s)				
Wind Direction				
RH				
Temp				

APPENDIX C: Definitions and Terminology

Agriculture UAS (Unmanned Aerial Vehicle) or Agriculture Drone: Unmanned aircraft equipped with a pesticide spraying system or granular spreading system for agriculture operations. In some documents, it is also called Unmanned Aerial Spray Systems (UASS). It should be noted that the scope of UAVs specified in this toolbox includes multi-rotor UAVs and Radio-Controlled Helicopters (RCH).

Buffer zone: The buffer zone between pesticide spraying operations should not be applied. To avoid pollution caused by pesticide spraying, it is usually set in the direction of the downwind field to isolate the application area from the sensitive area around the pesticide spraying. Refer to the product label for setting the buffer zone.

Droplet deposition density: Droplet number of targeted unit area.

Deposition distribution uniformity: Deposition distribution uniformity of droplets on the targeted collection sampler, it is generally expressed by coefficient of variance (CV).

Droplet Volume Median Diameter (VMD) : Median droplet volume size, where half of the spray volume is smaller than the droplet and half of the droplet volume is larger than the median. When the droplet size is read by water-sensitive paper or sampling card, the result should be corrected depending on the appropriate droplet spreading coefficient.

Operator: A person engaged in, or offering to engage in, an operation involving a UAS.

Spray altitude (Flight height): The distance from the spraying device to the top of the canopy of the crop during UAVs operations.

APPENDIX C: Definitions and Terminology

Spray coverage: Percentage of the area covered by droplet deposition to the total target sampling area.

Spray drift: The droplets of pesticide solution were not effectively deposited into the target region during or after application. (US Environment Protection Agency (EPA) definition)

Spray swath, Swath width or flight line spacing: UAS operation will form a spray belt, the distance between the center lines of two adjacent spray belts.

REFERENCES

REFERENCES

1. *The International Code of Conduct on Pesticide Management of FAO*
2. *CropLife International Facilitators Manual – Integrated IPM - Section 8.7*
3. *CropLife International Facilitators Manual – Integrated IPM - Section 8.7-8.8*
4. *CropLife International Stewardship guidance for us of unmanned aerial vehicles (UAVs) for application of crop protection products – Section 5.10*
5. *CropLife International Integrated IPM Manual Handout 1.2*
6. *FAO- Recommendations for improved weed management- Section1.1*
7. *CropLife International Integrated IPM Manual Section 8.14*
8. *Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.3*
9. *Guidelines on Good Labelling Practice for Pesticides – FAO - Section 4.1*
10. *CropLife International Resources – Label*
11. *CropLife International Integrated IPM Manual Handout 8.4*
12. *CropLife International Integrated IPM Manual Handout 8.5*
13. *Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.4*
14. *Guidelines on Good Labelling Practice for Pesticides – FAO - Section 1.4*
15. *CropLife Asia "Recommendations for UAS operator training and certification requirements" (2020)*
16. *CropLife Asia: "Recommendations for building a Standard Operating Procedure (SOP) for pesticide application by UAS"*
17. *Safety guideline for aerial application of agricultural chemical from unmanned multicopper, 2019, Japan*

REFERENCES

18. *Manual of Unmanned Aerial Vehicle (UAS) for Spraying Pesticide of Korea*
19. *Chen, H., Lan, Y., Fritz, B. K., & Hoffmann, C. (2021). Review of agricultural spraying technologies for plant protection using unmanned aerial vehicle (UAV). International Journal of Agricultural and Biological Engineering, 14(1), 38-49. https://doi.org/10.25165/j.ijabe.20211401.5714*
20. *Guidance for Aerial Application of Pesticides of FAP and WHO.*
21. *FAA-2003-1832-0001 attachment 5: Commercial Applicator Training Manual for Arkansas Drone Solutions.*
22. *The UAS Rules, 2021, India*
23. *Drone Recommendation- Telangana State Agricultural University of India*

24：China:

1) *UAS of Plant Protection and Chemical Application, Xiongkui, He*
2) *Agricultural UAS Operation, Zhongyi, Cheng, Xiongkui, He*
3) *GB/T 8321.1~8321.10 Guideline for safety application of pesticides（1）~（10）*
4) *GB/T 18678 Equipment for crop protection – Agriculture spray – Nominal capacity of spray tank and diameter of filling*
5) *GB/T 25415 Guidelines on practice for aerial application of pesticides*
6) *NY/T 1276 General guidelines for pesticide safe use*
7) *NY/T 1533 Guidelines on good practice for aerial spray application of agrochemicals*
8) *NY/T 3213 Technical specification of quality evaluation for crop protection UAS*
9) *MH/T 0017 Technical terminology for agricultural aviation*

REFERENCES

10) T/CCPIA 019 Specification for safe application of pesticide by crop protection UAS

11) T/CAMA 06 Crop protection UAS — Spraying quality

12) 2021.6 version Operation recommendations of DJI Agriculture's full series of plant protection UAS, Huifei UAS Application Technology Training Center

13) Corteva: Corteva Best Application Practices of Acanto Way against rice, wheat and peanut disease control by UAS application

14) Agricultural Unmanned Aircraft Operation Management System (Model), DJI Huifei UAS Training, Tang Xiuwei Huifei, 2023

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

Best Application Practices (BAP)

- Special thanks to below experts and peers to provide valuable comments, insights and suggestions.
- Thanks to Matthews, Graham A from Imperial College London and Edward Bals from ISO to provide the valuable comments, inputs and suggestions to the BAP.
- Thanks to Joanna Wang and Zhong Yi Cheng for their support on the parameter setting and sharing the recommended parameters on their major drone models;
- Thanks to Spring Song from Eavision give us great support to understand the commercial adoption status of their drone and generous sharing of their parameters and other reports.
- Thanks to Shenghua Li, Mei Lan Wu, Weibo Huang from XAG to provide the recommended parameters and comments.
- Thanks to Ricky Ho, Ying Nan Jiang, Delisa Jiang from CLA to guide the generation of the BAP and make sure our objective can meet the pain points of key stakeholder in APAC.
- Thanks to Bharani A Deepan for their support on the India's parameter's part.
- Thanks to Application Technology team members Chris Qi from Bayer, Charlie Ni from FMC, Haytham Shbaita SGSG from Syngenta, Xu Wang from Bayer, Asad Ali IDCK and Putra Candra IDCK from Syngenta, Chandrashekhar Kulkarni from BASF, Bharani Deepan and Ray Xie from Corteva to provide great support on the review of the BAP and provide valuable comments on the work.
- Thanks to those who provided comments and insights, although they may not be on the list above.