AEN-171

University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

General Considerations and Requirements for Drone Spraying

Josh Jackson, Karla Ladino, and Gabriel Abdulai, Biosystems and Agricultural Engineering

The purchase of an unmanned aircraft system (UAS) sprayer, also known as a drone sprayer, must be evaluated carefully. For farmers and sprayer service providers who are thinking about purchasing drone sprayers for their operations, this publication summarizes the potential uses, background information, certificates and licenses required, equipment needed, utilities used, software implemented, insurance needed, maintenance and repairs executed, cost metric utilized, time allocated, and application effectiveness considerations. With regard to cost, a separate Decision Aid to Determine the Cost of Using a Drone Sprayer in Production Agriculture (AEN-172) has been developed to estimate the cost per acre, cost per flight, and cost per hour for a drone sprayer. The decision aid is for use by farmers and service providers to compare different drone sprayers and evaluate the cost against traditional sprayers.

Potential Uses

Drone sprayers can be used for spraying the whole field, for spot spraying, or for fence-line management. For whole-field spraying, the capacity (acres per hour) of the drone sprayer needs to be matched to the number of required acres and desired time window. The capacity of the drone is affected by spraying speed, width, pump flow rate, refill frequency (tank size), ferrying time, time between flights, other time investments, and spray volume per acre. If a drone's capacity cannot cover the required number of acres within the desired timeframe, multiple or larger drones should be considered.

Spot spraying can be conducted based on prior ground scouting, previous maps (weed, pest, disease, soil type, or topography), or prior remote sensing flights. The goal of spot spraying is to minimize the overall use and cost of chemical applications. A drone can be effective in quickly reaching remote spots in fields.

An additional use for drone sprayers is fence line spraying. If fence lines are clear of trees, flight paths can be developed and used to spray and control weeds along various fence lines.

Background

Spraying crops is essential for the control of pests, weeds, and diseases. Spraying can be conducted using a variety of systems, including ground-based sprayers; human-occupied aerial sprayers (HOAS), or helicopters and planes; and more recently, drone sprayers. Selecting which spraying system to utilize can be complex (Table 1). Field characteristics, crop type, crop maturity, and weather dictate what type of sprayer could be deployed. For instance, large rectangular fields in Western Kentucky are more conducive to HOAS or ground-based spraying than smaller, irregularly shaped fields interspersed with trees in Central Kentucky. Farmers ideally want to use the system that is timely (covers the desired acreage at the right stage and in an expedited manner) and cost effective (allows for the cost per acre to be optimized). Sprayer service providers have similar goals, but they would also seek to optimize their profit. Regarding crop and maturity, the desired spray system may change throughout the grow-

Table 1. Comparison of spraying systems.

Sprayer System	Advantages	Disadvantages
Ground-based sprayer	• Lowest cost per acre • Moderate capacity (acres/hour)	• Soil conditions • Compaction of soil • Crop damage • Limitations based on trees, powerlines, waterways, or irregularly shaped fields
Human-occupied aerial sprayer (HOAS)	• High capacity (acres/hour) • No limitations based on soil conditions	• Limitations based on trees, powerlines, waterways, or irregularly shaped fields • Limited or zero availability of HOAS in some parts of the state
Drone sprayer	• Timing • No limitations based on soil conditions • No limitations based on trees, powerlines, waterways, or irregularly shaped fields • Spot spraying • Fence-line applications	• Frequent refills and battery changes • Low capacity (acres/hour)

ing season. Initially a ground sprayer may be utilized until the crop reaches a certain stage of maturity, and afterward, HOAS may be preferred. Weather conditions, specifically wetness, can limit the use of ground-based sprayers.

Ground-based sprayers (Figure 1) typically offer the lowest cost per acre ($5–$8 per acre). Ground-based sprayers can apply higher spray volumes than aerial sprayers; however, ground-based sprayer applications can cause crop damage and soil compaction to occur. The severity of crop damage from ground-based sprayers, which can be as high as 5 percent of the plants, is dependent upon the crop and stage of maturity. Trees, powerlines, ditches, waterways, and irregularly shaped fields can limit the ease with which ground-based spraying can occur. Ground conditions such as wetness can also restrict the use of ground-based sprayers.

Human-occupied aerial sprayers (Figure 2) can avoid the ground-sprayer wheel track's crop-related damages and associated yield losses. They can cover a large number of acres, and they are not limited when soil conditions are unfavorable. The cost of application per acre for aerial spraying ($10–$40 per acre) is typically more expensive than ground-based spraying. While higher spray volumes could be used by HOAS, the frequency of refills quickly becomes a practical concern. Also, the weight at takeoff will limit the overall tank capacity for HOAS. Thus, HOAS applicators use higher concentrations of chemical compounds and thereby lower carrier application volumes. But not every chemical can be aerially applied. The chemical must be specifically labeled for aerial application and for the lower carrier volumes used by aerial applicators.

Important: The chemical label specifications must be followed, as this is a federal regulation.

There are some major drawbacks to HOAS. Commercial HOAS contractors can be very busy and may only visit an area when a threshold number of farms (minimum number of acres) have signed up for their services. With a high demand for their services, aerial applicators can be more selective and provide preference to larger fields that are square or rectangular, as these will be fields where income is most easily generated from spraying. Power lines, trees, and other terrain features can restrict the potential coverage area for these aerial sprayers. Another concern is that low-flying helicopters and planes create noticeable noise and require associated space for turning. Thus, concerned neighbors are likely to call and inquire about what is being

Figure 1. Sprayer in alfalfa.

Figure 2. Human-occupied aerial sprayer (HOAS) in action. (Photo by 6381380 via Getty Images)

sprayed and how the chemical sprayed may influence them.

With recent technological advances, drone sprayers are being considered as a viable option for conducting spraying applications on farms (Figure 3). For corn producers and service providers, timing is the primary reason for purchasing drone sprayers. A three- to four-week window is available for applying corn fungicide. For these producers and service providers, traditional HOAS often do not make it to their region or farm within the desired time frame, and rainfall limits the use of ground-based sprayers. Drone sprayers allow them to not only conduct the initial spraying, but if follow-up spraying is needed, this can be more easily achieved. As such, drone sprayers offer flexibility regarding timing and preference of chemical for application. (HOAS contractors typically dictate what products will be used with their HOAS.) Drone sprayers are utilized for their dynamic deployment capabilities and flexibility for maneuvering in irregularly shaped or smaller fields. Power lines, trees, waterways, wet ground, and other features would not limit what could be sprayed and would only need to be accounted for in the flight planning. Drone sprayers also possess the capability to spray fence lines and perform spot spraying on impacted areas.

Drone sprayers are limited by the number of acres that can be sprayed per hour and the frequency of refills. These limits can be overcome by utilizing larger drones with greater tank capacities or multiple drones. Ideally, the drone spraying capabilities would match the desired acreage and application time window. Another challenge is that drone sprayers are still relatively new. Thus, if the takeoff and landing location is adjacent to a high-traffic area, passersby are likely to stop and potentially distract those working with the sprayer.

Drone Sprayer Certificates and Licenses

The operation of drone sprayers must follow the rules and regulations laid out by the Federal Aviation Administration (FAA), as well as state and local regulations. License requirements vary with the weight of the drone sprayer. The FAA Part 107 Remote Pilot Certificate is required for the operation of drone sprayers weighing less than 55 pounds. Drones over 55 pounds are operated under FAA Part 91 (General Operation and Flight Rules), but the Remote Pilot Certificate is still required. FAA Part 137 (Agricultural Aircraft Operator) regulates the dispensing of chemicals and agricultural products.

Figure 3. Drone sprayer operating in the field. (Photo by Matt Barton)

Petitions for exemptions from certain FAA rules are needed, as specific sections of the FAA rules fundamentally prohibit spraying or would not be applicable to drone sprayers. For instance, Part 137 was originally passed in the mid-1960s and was specific to HOAS. While there have been updates and amendments to Part 137, sections related to seat belts and carrying of certificates on the aircraft, for example, are not applicable to drone sprayers. Drone pilots must file petitions for exemptions to these non-applicable sections. These petitions must be completed 120 days prior to the exemption commencing. Once completed, FAA Part 137 requires that the Agricultural Aircraft Operator Certificate Application be turned in to the nearest Flight Standards District Office (FSDO).

Drone Sprayers Less than 55 Pounds at Takeoff

For drone sprayers weighing less than 55 pounds at takeoff, FAA Part 107 requires that individuals pass the FAA Remote Pilot Certification Knowledge Test. The knowledge test is composed of 60 questions and requires a score of 70 percent or greater to pass. The cost for taking the knowledge test is $175. Furthermore, Part 107 dictates that all drones must be registered with FAA; the current cost of a three-year registration is $5.

Petitions for exemptions to non-applicable sections of Part 107 and 137 must be submitted to the Federal Docket Management System (FDMS) online or by mail. For instance, Section 107.36 (carriage of hazardous material) must be exempted, as there are several agricultural chemicals that are dispensed that could be classified as hazardous materials. Additionally, several sections of Part 137 that are not applicable to drones would need to be exempted as

Table 2. FAA exemptions needed for agricultural spraying.

Federal Aviation Regulation	Description	Under 55 lb.	Over 55 lb.
§ 107.36	Carriage of hazardous material	X	
§ 137.19(c), (d), (e)(2)(ii), (e)(2)(iii), (e)(2)(v)	Certification requirements	X	X
§ 137.31	Aircraft requirements	X	X
§ 137.33	Carrying of certificate	X	X
§ 137.41(c)	Personnel, pilot in command	X	X
§ 137.42	Fastening of safety belt and shoulder harness	X	X
§ 61.3(a)(1)(i)	Requirements for certificates, ratings, and authorizations		X
§ 91.119(c)	Minimum safe altitudes: general		X
§ 91.121	Altimeter settings		X
§ 91.151(b)	Fuel requirements for flight in VFR (visual flight rules) conditions		X
§ 19.403(b)	Maintenance, preventative maintenance, or alterations		X
§ 91.405(a)	Maintenance required		X
§ 91.407(a)(1)	Operation after maintenance, preventative maintenance, rebuilding, or alterations		X
§ 91.409(a)(1), (a)(2)	Inspections		X
§ 91.417(a), (b)	Maintenance records		X
§ 91.7(a)	Civil aircraft airworthiness		X
It is important to check the most current FAA regulations, which are available here: https//faa.gov https://www.faa.gov/uas/advanced_operations/dispensing_chemicals			

well (Table 2). Once the petitions have been submitted, FAA Part 137 requires that the Agricultural Aircraft Operator Certificate Application be submitted to the nearest FSDO. Be sure to allow for ample time for various applications and exemption processing to be completed.

Operation of Multiple Small (Less than 55 pounds) Unmanned Aircraft (14 CFR § 107.35)

Part 107 allows for only one drone to be flown by a remote pilot in command (PIC) at a time; however, with the 107.35 waiver, multiple drones can be flown simultaneously by the PIC, as shown in Figure 4. Waivers can be submitted through the FAA DroneZone. Flying multiple drone sprayers will improve the operational

Figure 4. Multiple drones prepared for takeoff.

capacity, as more acres can be covered per hour. With multiple drone sprayers in operation, at least one visual observer (VO) is required for flights. The VO helps ensure that operations are conducted in a safe and effective manner. Furthermore, additional help with refilling spray tanks and switching batteries would be desirable.

Drone Sprayers Greater than 55 Pounds at Takeoff

For drone sprayers weighing more than 55 pounds at takeoff, the petition for exemptions must be expanded to include sections of FAA Part 61, 91, and 137 (Table 2). Additionally, an exemption under the Special Authority for Certain Unmanned Systems (§44807) is needed. The Part 107 Remote pilot license is still required. Again, submit the Agricultural Aircraft Operator Certificate Application to the nearest FSDO after the petition for exemptions has been submitted. Part 47 (Aircraft Registration) requires that drone sprayers over 55 pounds be registered using the Aircraft Registration Application (AC Form 8050-1). The registration is valid for three years and costs $5.

Restrictions for Drone Sprayers Greater than 55 Pounds

Currently, at least one visual observer is required for operation of a single large drone sprayer. Furthermore, the use of drone sprayers weighing more than 55 pounds requires adherence to a 500-foot buffer zone restriction from all persons, structures, vehicles, and vessels not participating in drone operation. This would mean that spraying with drones weighing more than 55 pounds must take place no less than 500 feet away from houses, roads, cars, trucks, certain waterways, etc. If the PIC meets certain conditions (minimum number of hours of experience, flying less than 20 feet above ground level, and other provisions/permissions), the drone sprayer could be operated within 100 feet of vessels, vehicles, and structures.

Kentucky Pesticide Applicator's License

The Kentucky Department of Agriculture (KDA) manages private, non-commercial, and commercial pesticide certifications and controls the enforcement of federal and state pesticide (chemical application) laws and regulations in Kentucky.

Both non-commercial (local, state, or federal government workers that use the pesticide as part of their jobs) and commercial licenses require passing applicator certification exams with a $25 testing fee. Study and reference materials can be found through the UK Pesticide Safety Education Program (PSEP), provided by the Department of Entomology in the College of Agriculture, Food and Environment at the University of Kentucky.

Licenses must be renewed on a yearly basis, while pesticide certification must be renewed every three years. If the license expires before renewal, a new certification exam must be taken. Kentucky law also requires 12 continuing education units (CEU) every three years to maintain pesticide certification. For the CEU, there are 13 categories of pesticide applicators. At least 1 hour of CEU must be performed in the category relevant to their applications. Drone sprayers must obtain Commercial Category 11: Aerial Certification and the categories relevant to the type of application (i.e., fungicide). Maintaining certification via CEUs is essential for certification renewal.

Farm owners get an exemption from needing private applicator certification if they apply general use pesticides with ground equipment. To be classified as a private applicator, producers must apply pesticide to their own land, rented land, or other ground without a fee. The University of Kentucky has a memorandum of agreement with the KDA to manage and run the Private Applicator Program. Private applicators would undergo a three-hour training at their local extension offices. With the Private Applicator Program, there are no fees or tests for producers, and the three-hour training is conducted through the county extension offices. Only producers using restricted use pesticides as well as those making aerial applications (both manned and unmanned) need to be certified. EPA now requires specialized training for aerial applications, which moves those applicators into the commercial/non-commercial Category 11 certification.

Equipment

For a full day of spraying applications, the minimum equipment requirements include a drone sprayer and controller station package, charging unit, spare batteries, generator, real-time kinematic (RTK) global positioning system (GPS) to ensure accurate spraying, chemical tanks, replacement parts (propellers, landing gear, etc.), and fill stations.

Other equipment related to personal comfort has been deemed essential by those conducting spraying. As most flights are conducted in the summer, a tent or other shade-providing device would be desirable to reduce fatigue. Fans also reduce the heat stress experienced by the remote pilot in command. Since spraying can take a while to perform, chairs are a nice way to reduce exhaustion. Personal insect repellent reduces the annoyances encountered. Tables also provide a good work surface for repairs and inspections. Additionally, an elevated area or platform is essential for maintaining visual line of sight over corn and other taller crops. Some drone sprayer operators use the top of a box trailer as an elevated platform. Safety railings and extra precautions must be taken when using elevated platforms. Pesticide labels may require a certain level of personal protective equipment (PPE) when mixing and applying. A PPE kit consisting of eye, hand, foot, and respiratory protection would be essential. In case of pesticide exposure, other safety equipment (eyewash bottle, chemical burn kit, first aid, etc.) would be essential to purchase as well.

Drone Specifications

The drone sprayer specifications (spray tank volume, maximum operating speed for spraying, effective spray width, maximum flow rate, maximum flight time, and maximum sprayer application time) are important considerations when selecting among the various drone sprayer options available. Regarding flow rate, for example, two drone sprayers, similar in all specifications except maximum flow rate, will have different calculated field capacities (Figure 5). Except for very low application rates, the sprayer with the higher maximum flow rate will typically cover more acres in a similar timespan. If costs or billing for spraying are developed on a per-acre basis, the drone with the higher flow rate would result in additional income; if they are made on a per-hour basis, this additional capacity for covering more acres could be used to justify the cost of application over another potential competitor. Furthermore, for farmers spraying their own property, the sprayer with the higher flow rate would allow for a more efficient utilization of time.

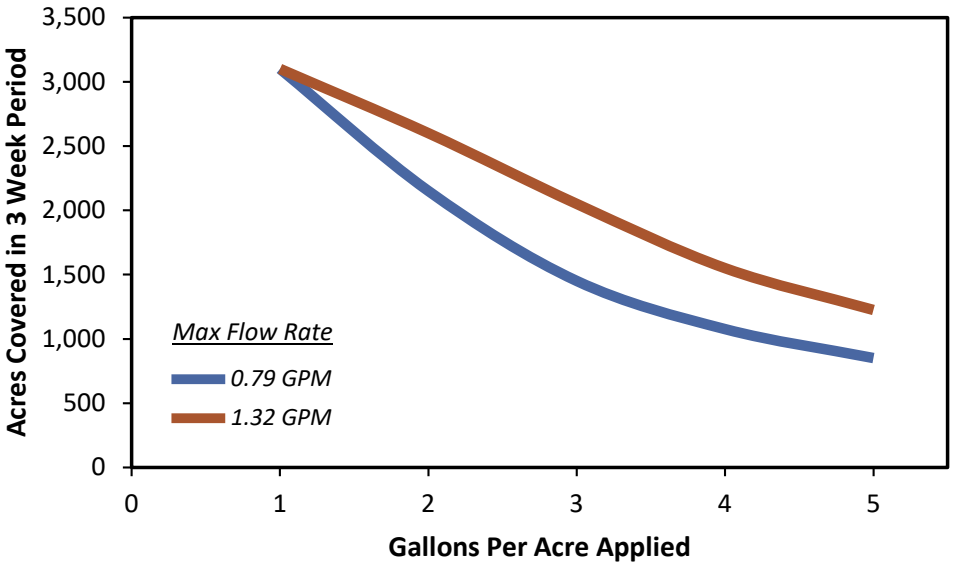

Figure 5. Example data set that shows the impact of flow rate and spray volume applied (gallons per acre) on the calculated total area covered over a three-week period (assuming 40 hours per week of spraying). For similar-sized drones with equivalent spray widths (16 feet), the increased flow rate typically results in more acres being covered, with the exception being for flow rates of one gallon per acre. (Maximum speed of each sprayer was 15 mph, but actual operating speed during spraying varied with flow rate and spray volume.)

Spray tank volume is also an important factor in drone selection. Due to the tank volume limitations of most drone sprayers, the tank will need to be refilled frequently during application. The frequency of refills will depend on factors such as the spray tank volume, application rate, drone speed, and spray width. It is important to note that the time required to carry out the tank refill or change out can add up to a substantial duration if a large area of land is to be covered. As such, investments in time-saving equipment need to be carefully considered. Quick-change options for tanks and batteries could minimize downtime between flights. Alternatively, easy-to-use and portable fill stations would improve efficiency in supplying the desired chemical mix to the tank.

In this calculated example, increasing only tank volume allows for the calculated number of acres covered to be expanded, as there is less downtime associated with filling the tanks (Figure 6). Using AEN-172 for this calculation, increasing tank size from 2.6 to 5.3 gallons (from 10 to 20 liters) allows for 19 percent more acres to be sprayed over an equivalent three-week period, and increasing tank size from 5.3 to 7.9 gallons (from 20 to 30 liters) results in 6 percent more acres being sprayed over the same duration. Increasing tank volume usually results in other specifications of the drone sprayer changing simultaneously. Increased tank volume typically equates with a larger drone being used. The increased flight capacity of the larger drone allows for larger sprayer pumps and sprayer rigs to be used. More acres could be covered per hour with this increased flow rate and improved spray width. In actuality, the commercially available drone sprayer with the 7.9-gallon tank (30 liters) would cover twice as many acres as the sprayer with the 2.6-gallon tank (10 liters) over the same time period (Figure 7). Keep in mind that for commercially available drones, increasing tank volume may result in the purchased drone falling into the category for equipment over 55 pounds. Thus, consider the drone sprayers' specifications and intended uses carefully before purchasing.

Utilities

Most drone sprayers will use batteries, liquid fuel, or a hybrid system (i.e., fuel and batteries). Batteries could be charged using either conventional electric sources (Figure 8) or by using a generator. Most of the spraying is likely to be conducted in remote locations, so the majority of the charging for battery-powered drone sprayers will likely be done using a generator. The generator will need to have ample capacity to charge as many batteries simultaneously as the operation needs, in addition to powering other equipment such as pumps, fans, lights, and computers.

The number of batteries to be purchased is also an important consideration. In the past, due to longer charge times, some manufacturers would suggest eight or

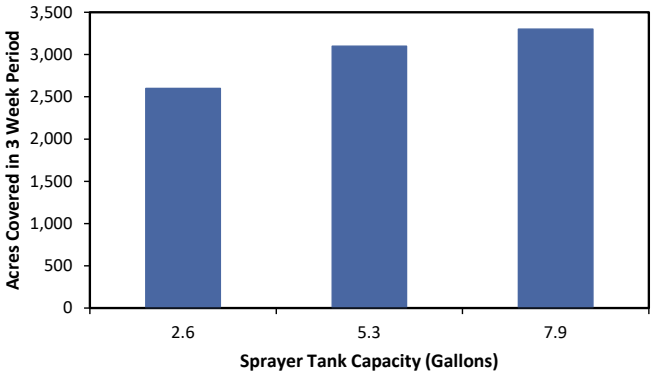

Figure 6. Calculated acres covered over equivalent three-week period, assuming only tank size is modified. All other aspects are equivalent to drone sprayer specifications of a commercially available 2.6-gallon (10-liter) drone sprayer. (Spray volume is two gallons per acre, effective spray width is 16 feet, and maximum flow rate is 1.32 gallons per minute.)

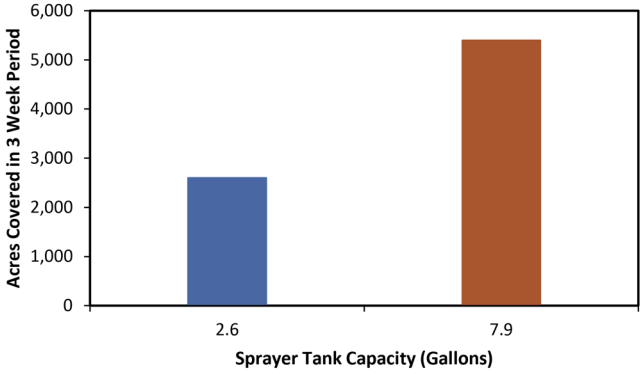

Figure 7. At an equivalent spray volume of two gallons per acres, the larger drone sprayer (tank size of 7.9 gallons or 30 liters, effective spray width of 30 feet, and maximum flow rate of 5.29 gallons per minute) will cover twice the area of the smaller drone sprayer (tank size of 2.6 gallon or 10 liters, effective spray width of 16 feet, and maximum flow rate of 1.32 gallons per minute).

Figure 8. Charging of drone sprayer batteries.

more batteries per drone sprayer per day. The introduction of quick-recharge batteries and improved charging stations has reduced the number of batteries needed. Battery capacities and charging times need to be carefully considered when determining the number of batteries required for continuous operation.

Software

Most drone sprayers come equipped with the software needed to conduct typical field-spraying operations; however, some manufacturers or distributors may require specialized software upgrades or licenses for support. If there is a desire to potentially expand the number of drone sprayers used, consider drones with software that allows for multiple drone sprayers to be operated by one controller station. **Reminder: Follow the rules and regulations from the FAA**.

Insurance

Insurance is necessary to ensure that operators of agricultural drone sprayers protect themselves from financial difficulties that may arise due to claims caused by a drone sprayer accident. Since traditional resources for insurance may not offer the desired coverage or plans for drone sprayers, insurance plans from dedicated aviation insurance companies should be investigated. General drone sprayer insurance would typically involve hull and liability insurance. Hull insurance would cover damage to the drone sprayer equipment; liability insurance would cover bodily injury, property damage, and personal injury that might result from an incident. Depending on the insurance coverage, additional coverage related to the risk associated with chemical transport, application, drift, and potential damages to the user's or neighboring crops must be considered. As such, it is important to obtain several quotes on different types of coverage plans, keeping in mind that contacting dedicated aviation insurance companies may be required.

Maintenance and Repairs

Similar to other farm equipment, maintenance and repairs are essential for the continuous function and timely deployment of a drone sprayer. Due to the narrow time windows associated with crop maturity and weather, a drone sprayer must be operable when it is time to fly. The cost of maintenance and repairs required will vary based on the quality standards of the drone sprayer manufacturer and personal attentiveness to standard operating procedures (SOP) for maintenance. Until the costs for maintenance and repairs for drone sprayers are more clearly defined, assume the annual cost to be at least 5 to 10 percent of the initial cost of the drone.

Another important factor to consider when purchasing a drone sprayer is the ingress protection (IP-SL) rating, which refers to how resilient the aircraft is to the incursion of solids and liquids into essential electrical components (Figure 9). Since agricultural drones are regularly spraying chemicals and flying over areas with higher dust particle concentrations that could degrade sensitive aircraft components over time, IP ratings will influence the level of maintenance and repairs required throughout the drone sprayer's service life. For instance, an IP-67 rating would mean that electrical components would be dust tight and protected against temporary immersion in water.

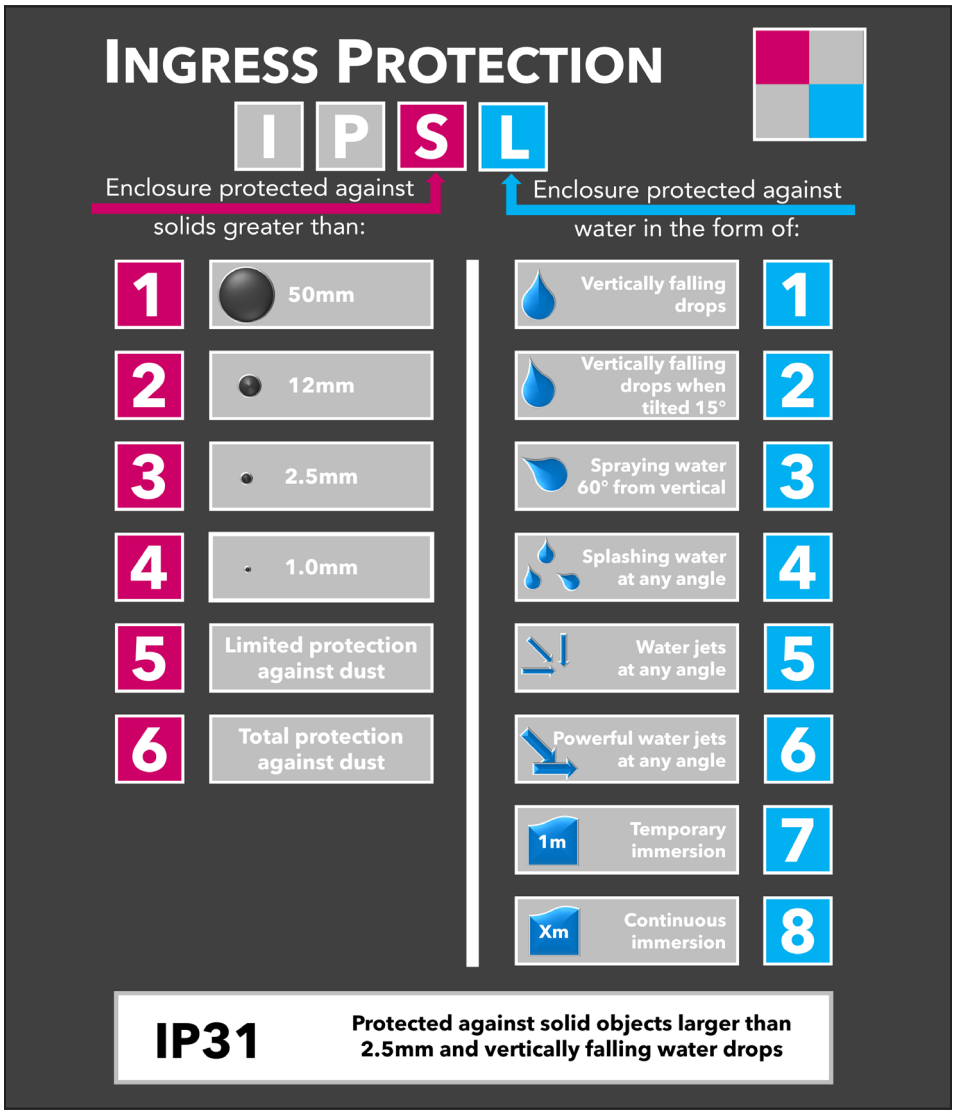

Figure 9. Ingress protection chart. (Graphic by Donnie Stamper)

Time Investment

The time required for a farmer or service provider to conduct drone spraying may be different than for ground- or HOAS-based spraying. The capacity (acres per hour) at which a drone sprayer can operate is typically quoted on the manufacturer's website. This capacity considers several unique factors, including drone specifications (discussed earlier), flight planning and setup, time associated with ferrying from launch site to spraying location and back, actual UAS spraying time, time spent between flights, and data-processing time. The time commitment of any additional workers, such as a visual observer, must be included. Visual observers are required when the drone sprayer is greater than 55 pounds or if multiple drones are flown simultaneously. The time required for the visual observer would be the same as that of the PIC. Depending upon the worker's skill set, the visual observer may have an hourly rate equal to or less than that of the PIC.

Flight planning would include the time required to develop the application map and create flight boundaries for the desired fields. Plans should be made to avoid waterways, environmentally sensitive areas, and any potential flight hazards. Flight planning may take more time for spot-spraying operations than for whole-field spraying.

Setup would involve preparing the launching and landing site for flights. If the launching and landing location is in a grassy area, mowing may be needed to ensure that tall grass does not become entangled in the drone sprayer propellers. It would also include the setup of tents, chair, tables, and other items for personal comfort. The inspection of the drone, flight conditions, and other equipment would be conducted at this time.

Ferrying involves the time it takes to fly the distance between the launch and landing site and the desired spraying location. Ferrying should be minimized to keep the operation as efficient as possible. Some farms may possess a centralized point between fields that could be utilized for an entire day of spraying, while other farms may require frequent relocation of the launching and landing point. Actual spraying time duration is automatically calculated from the input drone specifications.

Time spent between flights includes the time required to change batteries and refill (or change) the spray tank. Quick-change options can result in significant time savings. For example, if the time between flights for the 1.32-GPM (gallons per minute) sprayer in Figure 5, applying a rate of three gallons per acre, is 30 seconds instead of one minute, a 20-hour time savings would be realized over a three-week period.

In most cases, post-processing of data should not be required; nonetheless, an exception might occur if spot spraying was conducted. Additional time might be required to prepare an as-applied map.

Other time-consuming activities could include travel to the field, logistical planning, mixing of chemical components, and cleaning tanks and spray equipment.

Drone Sprayer Cost Metrics

There are three main ways in which a cost can be assigned for spraying: cost per acre, cost per flight, or cost per hour. The cost of application per acre for drone sprayers will vary with the labor cost, but it can be comparable to traditional ground or aerial sprayers. The cost per flight for the drone sprayer is pertinent to ascertain, but with the large number of flights required (about 1,893 flights are needed to spray 2,500 acres at two gallons per acre with a drone sprayer possessing a 16-foot spray width, a maximum speed of 15 miles per hour, a maximum flow rate of 1.32 gallons per minute, and a 2.6-gallon spray tank), it may not be as useful for economic decision-making. Knowing the cost per flight may be useful when spraying fence lines. Alternatively, the cost per hour will vary, but $150–$200 per hour for each drone sprayer flown is not unreasonable for service providers. This cost is charged by service providers to cover their costs and earn a profit. If flown by farmers on their own property, the cost per hour could be based upon the opportunity cost of other work that could be performed. This could be $8–$20 per hour. There is a potential for cost savings if the farmer, or the farmer's employees, have the time to invest in spraying.

The overall cost will be dependent on the sum of the purchased equipment, utilities, software, insurance, repair and maintenance, and time invested. The size and number of drone sprayers must match the desired time window for the planned acreage.

Drone Sprayer Application Effectiveness

Similar to the other spray systems, the effectiveness of the drone sprayer at controlling weeds, pests, and diseases is dependent upon several factors (Table 3). Simply spraying a crop will not ensure success, and the factors must be considered. Drone Fungicide Applications in Corn demonstrated that response to spraying fungicide in corn was influenced by location and the disease severity.

Table 3. Factors that will influence drone spraying efficiency and efficacy.

Factor	Related Characteristics
Meteorological conditions	• Temperature • Wind direction and speed • Humidity • Barometric pressure
Drone sprayer design characteristics (multirotor, single rotor, fixed wing)	• Maximum duration of flight • Varied propeller wash
Drone sprayer configuration	• Nozzle type • Pressure • Location of nozzles on drone sprayer • Tank capacity • Spray width
Operational parameters	• Spray height • Spray volume • Speed • Flow rate
Plant canopy cover	• Enclosed canopy • Open canopy
Functionality (mode of action) and concentration of chemicals being applied	• Appropriateness of product for the target
Timing of application	• Planting date • Maturity • Sensitivity
Location	• Site-specific conditions

Conclusion

Utilizing agricultural drone sprayers can be an effective way to apply desired chemicals to a crop. For farmers and sprayer service providers, the flexibility of timing and deployment provides the greatest benefit over traditional sprayer options. The overall cost and cost metrics would need to be determined when selecting among the various options offered. See Decision Aid to Determine the Cost of Using a Drone Sprayer in Production Agriculture (AEN-172) for more information about how to develop the cost structures for comparing different drone sprayers. The feasibility and practicality of a drone sprayer will be dependent upon potential cost saving, time saving, or increased revenue generated on a case-by-case basis.

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