AEN-174

Cooperative Extension Service

Drone Sprayer Sizing for Agricultural Applications

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(Photo by Matt Barton)

Sprayers are essential in agriculture, since they apply products that control weeds, pests, and diseases. In recent years, drone sprayers have gained popularity due to advantages associated with their flexibility in application timing, ability to operate without being constrained by ground conditions, and ease of deployment. Given the growing number of manufacturers and the wide range of available sizes, it can be challenging to select an optimally sized drone sprayer for a user's specific needs, as this decision carries significant economic implications.

The optimal drone sprayer size depends on various factors, including drone specifications, operational parameters, spray capacity in acres per hour, desired acreage for treatment, application timeframe, and cost considerations. The aim of this publication is to equip stakeholders in the agriculture sector with data-driven insights and tailored guidance, enabling them to harness the full potential of drone sprayers while making economically sound decisions that align with their specific operational objectives. Subsequent sections within this publication provide a detailed exploration of how each of these factors influences drone sprayer sizing. Additionally, this publication assesses the cost per acre for different drone sizes, offers tailored guidance for both farmers and service providers, and highlights the importance of making an informed choice to avoid potential economic and operational pitfalls.

Drone Specifications and Spray Capacity

Multiple drone specifications and operational parameters can affect spray capacity (Table 1). As a general guideline, larger drones have the capability to carry more substantial payloads. This increased payload capacity enables larger drones to accommodate bigger tanks, more powerful sprayer pumps, and more resilient components such as propellers and propeller motors. As a result, these larger drone sprayers can cover a greater number of acres in a single hour.

For instance, a larger tank size can reduce the number of refills required to cover 1,000 acres. The correlation between tank size and the frequency of refills was found to be nonlinear, with a diminishing rate of reduction in refills as the tank size approached 72 liters. (Figure 1). Nonetheless, having a larger tank on a sprayer drone offers several advantages, including increased spray capacity, enhanced overall efficiency, and reduced downtime due to fewer refills and longer flight times.

Table 1. Impact of drone sprayer specifications and operational parameters on spray capacity.

Specifications and Operational Parameters	Impact on Spray Capacity
↑ Tank size	↑ Acres sprayed per hour
↑ Spray width	↑ Acres sprayed per hour
↑ Drone flight speed	↑ Acres sprayed per hour
↑ Flow rate	↑ Acres sprayed per hour
↑ Spray volume per acre (GPA) [1]	↓ Acres sprayed per hour

[1] Gallons per acre

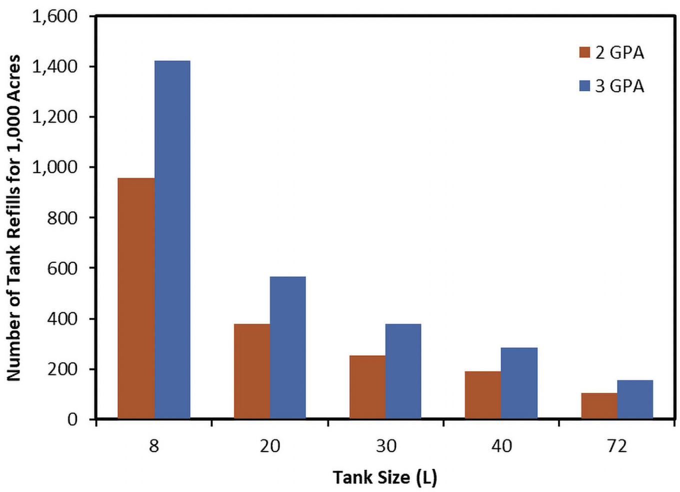

Figure 1. Relationship between tank size and refills required per 1,000 acres for both two- and three-gallon-per-acre (GPA) application rates.

Spray Volume Considerations

To be practical, most drone sprayer applications utilize low spray volumes, or application rates, typically ranging from two to five gallons per acre (GPA). It is important to note that there is an inverse relationship between the spray volume and the number of acres that can be covered in an hour. For instance, certain product labels specify a minimum spray volume of two GPA for aerial applications of corn fungicide. For each additional gallon per acre above this two-GPA minimum, there is a reduction in the number of acres that can be effectively sprayed per hour, typically by 15 to 30 percent (Table 2).

Preliminary research conducted in the context of wheat and fruit trees has indicated that various factors, such as coverage, droplet density, droplet distribution, droplet diameter, and efficacy, are influenced by the spray volume. However, it is important to note that more research is needed to determine whether the recommended minimum spray volume is adequate or if a larger volume is necessary to achieve the desired outcomes. Ultimately, the primary objectives are to ensure the effectiveness and efficiency of the chemical treatment. Therefore, determining the appropriate spray volume may require a personal judgment call, taking into consideration the specific requirements of the application at hand. The key goal is to strike a balance between spray volume and efficacy to achieve optimal results.

Important: Federal regulations require strict adherence to the chemical label specifications.

Table 2. Impact of spray volume on acreage efficiency.

Tank Size (L)	Spray Volume			
	2 GPA	3 GPA	4 GPA	5 GPA
	Acres Sprayed per Hour			
8	7.7	5.6	4.4	3.6
30	21.3	16.8	13.8	11.7
40	32.2	22.6	16.8	13.4
72	49.8	37.1	27.8	22.3

Determining Minimum Spray Capacity

The main factors in determining the minimum capacity needed for a drone sprayer are the target acreage for spraying and the designated time frame for application. For instance, when applying corn fungicides during the tasseling/early silking stage (VT/R1), a typical time window of approximately three weeks to 60 days is considered. Similarly, fungicide applications of wheat during heading may only allow for an application window of approximately one to two weeks. However, the specific optimal time frame can vary, depending on factors such as planting date, crop varieties, and location.

Additionally, it is advisable to allocate extra buffer time to account for unexpected challenges that might arise during the application process. These challenges could include breakdowns, personnel issues, or unforeseen weather-related obstacles. Taking unforeseen contingencies into consideration is essential when planning drone spraying or spreading applications.

Cost Considerations

Achieving a balance between budget constraints and the operational efficiency required for effective agricultural spraying applications is essential. Careful consideration of drone specifications, capacity requirements, desired target acreage, time constraints, and potential contingencies is key for farmers and agricultural sprayer service providers to make informed decisions in selecting the most appropriate drone size for their specific needs.

Assumptions for Calculated Economic Comparison

The economic evaluation of various sizes of drone sprayers was performed using the Drone Sprayer Cost Summary Decision Aid, as described in Decision Aid to Determine the Cost of Using a Drone Sprayer in Production Agriculture (AEN-172). The calculations in this evaluation were based on parameters presented in Table 3 and Table 4. Four different sizes of commercially available drone sprayers were considered in this analysis, as these represent a spectrum of options available at the time of publishing.

Table 3. Sprayer characteristics and operational parameters related to commercially available drone sprayers of varying tank capacities for cost summary analysis.

Operational Parameters	Drone Sprayer Tank Size (L)			
	8	30	40	72
Maximum Flow Rate (L/min)	20	20	12	17
Effective Spray Width (ft)	16	26	32	40
Maximum Operating Speed (mph)	15	15	22	22
Drone Package Cost	$22,000	$30,000	$40,000	$78,500
Additional Costs (e.g., Tank, Pump)	$11,350			
Insurance	$2,500 for farmer, $4,000 for service provider			
Spray Volume per Acre (GPA)	2, 3, 4, or 5			
Application Window	3 weeks (40 hours per week)			

Table 4. Time allocation for personnel responsibilities per drone flight for cost summary analysis.

Personnel Responsibilities	Time Allocated per Flight (Minutes)
Flight Planning and Setup	0.1
Takeoff, Ferrying, and Landing	4
Time Spent Between Flights	2
Actual UAS Spraying Time	Varied with parameters
Visual Observer Time	Same as pilot in command

Economic Analysis

Tailored Guidance for Farmers

This section is specifically tailored for farmers considering the integration of drone sprayers into their farming operations. In this analysis, the cost per hour for farm work was conservatively estimated at $20 per hour. As more acres are covered using drone sprayers, the initial capital investment becomes distributed across a larger area, effectively lowering the overall cost per acre.

The economic assessment reveals a critical threshold for drone viability in terms of acreage. Notably, at the minimum application rate of two GPA, it becomes evident that spraying less than approximately 1,000 acres annually may not yield economic viability across the various drone sizes (Table 5 and Table 6). On farms where the annual acreage is below this threshold, it might be prudent to consider using a sprayer service provider to undertake the spraying work. Contracting the services comes at an estimated cost of approximately $15 per acre at a two-GPA application rate. This rate is similar to the cost of a human-occupied aerial sprayer. However, it is worth noting that the cost could vary depending on the region, availability of services, and demand for sprayer services.

This analysis explores the economic feasibility of using drones of different sizes based on various acreage considerations, given the benchmark service provider price of $15 per acre at two GPA, $22 per acre at 3 GPA, $29 per acre at four GPA, and $36 per acre at five GPA. Table 7 illustrates the minimum acreage needed to justify the purchase of drone sprayers utilizing two GPA. With a 1,000-acre area to cover, using a drone sprayer with an eight-liter tank becomes a financially viable option; however, completing the task would take slightly over three weeks due to the limited tank

Table 5. Cost per acre analysis for various drone sprayer sizes and acreage requirements.

Spray Volume (GPA)	Tank Size (L)	Cost per Acre ($) [1,2]				
		Annual Acres Sprayed				
		500	1,000	2,500	3,000	5,000
2	8	✗ $27	! $16	✗ $10	✗ $9	✗ $8
	30	✗ $28	✓ **$15**	✓ **$7**	! $6	✗ $5
	40	✗ $32	✗ $17	✓ **$8**	✓ **$7**	! $5
	72	✗ $54	✗ $27	✓ **$11**	✓ **$10**	✓ **$6**
3	8	✗ $29	✗ $18	✗ $12	✗ $11	✗ $10
	30	✗ $28	✓ **$15**	! $8	✗ $7	✗ $5
	40	✗ $33	✓ **$17**	✓ **$8**	! $7	✗ $5
	72	✗ $54	✗ $28	✓ **$12**	✓ **$10**	! $7
4	8	! $31	✗ $20	✗ $14	✗ $13	✗ $12
	30	✓ **$29**	✓ **$16**	✗ $8	✗ $7	✗ $6
	40	! $31	✓ **$18**	! $9	✗ $8	✗ $6
	72	✗ $54	✓ **$28**	✓ **$12**	✓ **$10**	✗ $7
5	8	! $33	✗ $22	✗ $16	✗ $15	✗ $14
	30	✓ **$29**	✓ **$16**	✗ $9	✗ $8	✗ $6
	40	✓ **$34**	✓ **$19**	✗ $9	✗ $8	✗ $6
	72	✗ $55	✓ **$28**	✓ **$13**	! $11	✗ $7

[1] Cost-per-acre data is based on estimated farm labor cost of $20 per hour. Color-coded viability assessment compares data to benchmark service provider rates per acre based on spray volume ($15 at 2 GPA, $22 at 3 GPA, $29 at 4 GPA, and $36 at 5 GPA). Green indicates the cost for the farmer is less than or equal to the service provider's rate. Yellow indicates a cost slightly above (~10%) the service provider's rate. Red indicates a non-competitive cost.

Table 6. Spraying time analysis for various drone sprayer sizes and acreage requirements.

Spray Volume (GPA)	Tank Size (L)	Number of 40-Hour Weeks [1]				
		Annual Acres Sprayed				
		500	1,000	2,500	3,000	5,000
2	8	1.6	3.3	8.2	9.8	16.3
	30	0.6	1.2	2.9	3.5	5.9
	40	0.4	0.8	1.9	2.3	3.9
	72	0.3	0.5	1.3	1.5	2.5
3	8	2.2	4.5	11.2	13.4	22.3
	30	0.7	1.5	3.7	4.5	7.5
	40	0.6	1.1	2.8	3.3	5.6
	72	0.3	0.7	1.7	2	3.4
4	8	2.8	5.7	14.2	17	28.4
	30	0.9	1.8	4.5	5.4	9.1
	40	0.7	1.5	3.7	4.5	7.4
	72	0.5	0.9	2.2	2.7	4.5
5	8	3.4	6.9	17.2	20.6	34.4
	30	1.1	2.1	5.3	6.4	10.7
	40	0.9	1.9	4.7	5.6	9.3
	72	0.6	1.1	2.8	3.4	5.6

[1] Color-coded viability assessment is based on designated time-window target of 3 weeks for application. Green indicates that less than 3 weeks is required. Yellow indicates that 3 to 4 weeks is required. Red indicates that more than 4 weeks is required.

[2] Round icons shown in Table 5 indicate overall assessment of economic viability based on both the cost-per-acre estimations in Table 5 and the spraying time estimations in Table 6.

✓ = a cost less than or equal to the service provider's rate and duration of spraying less than 3 weeks.

! = a cost slightly above (~10%) the service provider's rate or a duration of spraying between 3 and 4 weeks.

✗ = a non-competitive cost or a duration of spraying exceeding 4 weeks.

Table 7. Range of acreage requirements for different drone sizes using a two-GPA spray volume.

Tank Size (L)	Minimum Acres to Achieve $15/Acre Spray Cost	Maximum Acres Covered in 3-Week Period [1]
8	1,116	919
30	980	2,561
40	1,137	3,872
72	1,871	5,974

[1] Assumes 40 hours of spraying conducted per week.

size. Beyond the 1,000-acre mark, the time required to complete the spraying becomes impractical for the smallest drone model. For farms with acreages exceeding 1,000 acres, moderately sized drones with 30- and 40-liter tank capacities become more desirable options. The choice of drone size further correlates with farm scale; as farm acreage increases, opting for a larger drone with greater capacity becomes more advantageous.

In scenarios where the yearly acreage to be sprayed approaches 5,000 acres, the optimal choice is the largest drone, which is equipped with a 72-liter tank. This aligns with the economic analysis, which indicates that the largest drone becomes more economically feasible as the acreage increases. To achieve a cost per acre below the $15 benchmark at two GPA, the 72-liter tank drone would need to cover more than 1,870 acres; however, it is important to recognize that below this acreage threshold, the economic viability of the largest drone diminishes rapidly.

Spray Volume

The spray volume used by farmers in drone applications is a crucial factor in the economic equation and should be carefully considered. Notably, when the spray volume increases, it is expected that the service provider's rate will also rise. This change in dynamics affects the minimum annual acreage necessary for justifying the investment in a drone sprayer.

From a cost-per-acre perspective, the shift to higher application rates requires a reevaluation of the minimum annual acreage needed to make acquiring a drone economically viable. Specifically, for farmers opting to use four- or five-GPA spray volumes, the minimum acreage required to justify the purchase of small or moderately sized drone sprayers decreases to approximately 500 acres.

However, the transition to higher spray volumes, particularly at five GPA, involves tradeoffs that go beyond just economic factors. When farmers opt for a five-GPA spray volume, the time required for the task roughly doubles compared to two-GPA applications. Consequently, the amount of acreage that can be effectively covered within the desired time frame is also reduced.

As the acreage to be sprayed at five GPA approaches 2,500 acres, the most favorable choice is the largest drone equipped with a 72-liter tank, especially when operating within a roughly three-week time frame. The alignment of drone size, spray volume, number of acres, and desired time window becomes essential for optimizing efficiency and operational feasibility. It is advisable to carefully assess the desired spray volume before investing in a drone sprayer.

Multiple Drone Operations

The concept of using multiple drones simultaneously has gained traction among agricultural producers seeking to enhance the efficiency of aerial spraying. However, it is essential to carefully consider the efficacy of this approach compared to using a single, appropriately sized drone. Although using several smaller drones may initially appear advantageous, a more in-depth analysis reveals potential drawbacks that could undermine overall cost-effectiveness and operational efficiency.

For instance, consider a scenario where a farmer wants to cover 3,000 acres with drone sprayers within a three-week time frame. One option is to use four of the smallest drone sprayers, each with an eight-liter tank. While this approach would achieve the desired acreage coverage, it is important to consider the cost per acre. Surprisingly, when using these smaller drones, the cost per acre would be around $14.18, which is quite high. In contrast, using a moderately sized drone with a 40-liter tank would be more cost effective, costing only $6.50 per acre. The cost difference between the two options is significant, with the moderately sized drone proving to be the more economical choice.

The advantages of using an appropriately sized drone are evident. A larger drone, with its greater payload capacity and wider spray width, can efficiently cover larger areas. This leads to a substantial reduction in operational costs per acre. Additionally, overseeing and coordinating a single larger drone is more straightforward when compared to managing multiple smaller ones. This results in enhanced operational efficiency and reduces the likelihood of logistical complications.

While the concept of using multiple drones in agriculture holds promise, the most effective and economically viable approach at present is to select a single, appropriately sized drone. By carefully assessing cost-per-acre considerations and recognizing the operational benefits of larger drones, farmers can make informed decisions that enhance operational efficiency and reduce costs for aerial spraying operations.

Tailored Guidance for Service Providers

This section is specifically tailored for sprayer service providers considering the integration of drone sprayers into their operations. Sprayer service providers are addressing the gap created by various cooperatives and dealers no longer offering spraying services. For this analysis, a rate of $15 per acre for the sprayer service fee was assumed, based on a spray volume of two GPA. It is important to note that the cost per acre can vary significantly due to factors such as regional availability, demand for services, and the selected spray volume. Moreover, the analysis considered a conservative application time window of three weeks (minimum window for corn fungicide applications). However, service providers have the flexibility to extend this period to a maximum duration of approximately 60 days by expanding their service area.

From a financial standpoint, sprayer service providers should generally adopt a "bigger is better" approach when sizing a drone sprayer. Moderately sized and larger drone sprayers offer service providers the potential for optimal income generation (Table 8 and Table 9). Larger drones, in particular, offer significant advantages during the narrow application time window, as they can efficiently cover more acres, leading to increased revenue. The largest drones, with their greater payload capacities and wider

Table 8. Calculated per-acre income and expenses of various drone sprayer sizes.

Tank Size (L)	Acres Sprayed [1,2]	Per Acre		
		Revenue	Expenses	Net [3]
8	919	$15.00	$13.44	$1.56
30	2,561	$15.00	$5.66	$9.34
40	3,872	$15.00	$4.48	$10.52
72	5,974	$15.00	$4.78	$10.22

[1] Maximum acres sprayed over a 3-week period.
[2] Assumes 40 hours of spraying conducted per week.
[3] Does not account for taxes or travel.

Table 9. Calculated overall revenue and expenses of various drone sprayer sizes over a three-week period.

Tank Size (L)	Acres Sprayed [1,2]	Revenue	Expenses	Net [3]
8	919	$13,785	$12,351	$1,434
30	2,561	$38,415	$14,495	$23,920
40	3,872	$58,080	$17,347	$40,733
72	5,974	$89,610	$28,556	$61,054

[1] Maximum acres sprayed over a 3-week period.
[2] Assumes 40 hours of spraying conducted per week.
[3] Does not account for taxes or travel.

Table 10. Relationship between spray volume and sprayer service rate required for equal net income.

Spray Volume (GPA)[1]	Maximum Acres Covered over a 3-Week Period[2]	Sprayer Service Rate Charged per Acre
2	3,872	$15
3	2,686	$22
4	2,014	$29
5	1,611	$36

[1] Drone sprayer with 40-liter tank used as baseline.
[2] Assumes 40 hours of spraying conducted per week.

Table 11. Relationship between drone size, spray volume, and acres sprayed.

Tank Size (L)	Maximum Acres Sprayed over a 3-Week Period[1]			
	2 GPA	3 GPA	4 GPA	5 GPA
8	919	671	528	436
30	2,561	2,009	1,655	1,405
40	3,872	2,686	2,014	1,611
72	5,974	4,456	3,340	2,672

[1] Assumes 40 hours of spraying conducted per week.

spray widths, prove to be especially valuable during this crucial period. By effectively covering more acres within the constrained timeframe, service providers can maximize their income potential and serve a larger clientele.

Spray Volume

A significant consideration for sprayer service providers involves adjusting service rates in response to varying spray volumes. The relationship between these variables is crucial for sustaining a viable income stream. The baseline sprayer service rate charged per acre should increase as the requested sprayer volume increases. For instance, when transitioning from a two-GPA application to a three-GPA application, it is imperative that the sprayer service rate correspondingly increases. In this scenario, the rate charged to farmers should rise from $15 per acre to approximately $22 per acre. This incremental adjustment ensures that the net income stream remains consistent despite changes in operational parameters (Table 10).

The relationship between spray volume, drone size, and the acreage treated within a specified time window is highlighted in Table 11. An increase in spray volume leads to a reduction in the area that can be effectively covered within a specified time frame. As a result, this decrease in operational coverage necessitates a proportional increase in the service rate. This adjustment in rates and volume aims to strike a balance, ensuring both operational efficiency and revenue generation. However, it is important to consider that higher spray volume applications during periods of lower demand for sprayer services may require a modified or reduced service rate to remain competitive in terms of price per acre.

Conclusion

In agriculture, where efficiency, productivity, and profitability are of utmost importance, the incorporation of drone sprayers into farming operations can bring significant benefits when it comes to implementing various management strategies for controlling pests, weeds, diseases, and nutrients. When considering the purchase of a drone sprayer, both farmers and sprayer service providers should follow a comprehensive approach. This includes conducting thorough analyses of the available options, seeking advice from Extension specialists and current users, and assessing the specific requirements of their agricultural applications.

Selecting the optimal drone size involves evaluating various factors, such as drone specifications (e.g., spray capacity in acres per hour), operational parameters, targeted acreage for spraying, application time frame, and cost-related considerations. Ultimately, the decision on the spray volume comes down to balancing operational efficiency, time investment, and economic viability. It is important to note that there is no one-size-fits-all solution when it comes to determining the optimal drone size. For farmers, the choice depends on factors such as the crop, the desired acreage, the required spray volume, and the desired time frame in which to complete the work. On the other hand, service providers can generally optimize their earnings by utilizing moderately sized or larger drones. This economic analysis suggests that, for sprayer drone service providers, maximizing the size of the drone is the most favorable option.

As the agricultural technology landscape continues to advance, it is important to stay informed about the evolving developments within the industry. New and more efficient drone sprayer options may become available, offering enhanced capabilities for farming needs. However, the focus should always remain on practicality and cost-effectiveness to ensure the successful integration of drone sprayers into farming operations.

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Lexington, KY 40506 Issued 03-2024