International Journal of Environment and Climate Change

Volume 14, Issue 7, Page 814-823, 2024; Article no.IJECC.120762
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Studies on Operational Parameters of Drone Mounted Sprayer to Determine the Application Rate for Herbicide Application in Crops

Satish [a*], Sunil Shirwal [b++], Veerangouda [b#], M, Sushilendra [b†] and Ananda N [c++]

[a] *Department of Farm Machinery and Power Engineering, University of Agricultural Sciences, Raichur, Karnataka, 584101, India.*
[b] *Farm Machinery and Power Engineering, University of Agricultural Sciences, Raichur, Karnataka, 584101, India.*
[c] *Department of Agronomy, College Agriculture, University of Agricultural Sciences, Raichur, Karnataka, 584101, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijecc/2024/v14i74321

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120762

Original Research Article

Received: 20/05/2024
Accepted: 24/07/2024
Published: 27/07/2024

[++] *Assistant Professor;*
[#] *Registrar and Professor;*
[†] *Professor and Head;*
**Corresponding author: E-mail: Satishvk1998@gmail.com;*

Cite as: *Satish, Sunil Shirwal, Veerangouda, M, Sushilendra, and Ananda N. 2024. "Studies on Operational Parameters of Drone Mounted Sprayer to Determine the Application Rate for Herbicide Application in Crops". International Journal of Environment and Climate Change 14 (7):814-23. https://doi.org/10.9734/ijecc/2024/v14i74321.*

ABSTRACT

The experiment was conducted to study the operational parameters drone mounted sprayer to determine the actual application rate required. The hexa-copter drone mounted sprayer of 10 L was selected to for pre-field test. The treatment plot size of 15mx20m area was marked. The drone mounted sprayer operated at autonomous mode. The experiments were conducted at five different levels of independent parameters, viz, forward speed (1, 2, 3.5 5 and 6 m) and height of spray (1, 1.5, 2, 2.5 and 3 m). Dependent parameters like as swath width, application rate and field capacity were determined. The design expert software RSM central composite design was sused for optimal number of experiments. The total combinations of 13 experiment treatments were conducted. The results obtained at the maximum and minimum application rate of drone mounted sprayer was found to be 133 and 33.1 l ha-1. The swath width of drone mounted sprayer was in the range of 1.8 to 6 m.

Keywords: Drone mounted sprayer; application rate; swath width; field capacity.

1. INTRODUCTION

It is predicted that by 2050, there will be nine billion people on the planet from the current 7.7 billion. According to Bilin et al. (2015), there will need to be a 70% increase in global food production in order to feed growing populations. Climate change, crop damage, water scarcity, soil degradation, and shortage of food are the main issues facing the world's upcoming population. A challenging task in the future will be to increase food production in agriculture due to the availability of farm labor. Management of weeds, pests, and nutrients are the three main crop constraints [1].

In the agricultural sector, weed management can be accomplished in a number of ways that improve crop yield and farmer income. Chemical, biological, and mechanical techniques could be used. Mechanical techniques include moving, burning, flooding, hoeing, tillage, smothering with inanimate objects (mulching), hand pulling, and hand weeding [2]. Utilizing live organisms to suppress or manage weeds is one of the biological methods. Weeds can be eradicated by using plant, animal, or microorganisms [3]. These are referred to as bio-agents because they exclusively consume weeds—not crop plants. When the chemicals are inexpensive, effective, and readily available, the chemical method can be very useful in some situations. The weed-controlling chemicals that either suppress or eliminate.

The chemicals are applied using air-blow, boom, and tractor-operated sprayers, as well as manual and battery-operated sprayers. These sprayers have time-consuming, labor-intensive, water-intensive, less uniform, excessive chemical application, cost-prohibitive, yield-losing, and inefficient field characteristics. Because of the muddy soil, it is very difficult to operate a chemical sprayer on crops during the rainy season. A significant drawback of chemical spraying in the field is that farmers' exposure to chemicals has resulted in serious health issues. When a pesticide comes into contact with skin, it enters the body through pores and causes a number of issues. Due to the pesticides they spray, the majority of operators experience a variety of illnesses, including nausea.

The use of agricultural drone for crop management reduces the physical effort of farmers along with saving in time. It also reduces labor cost and improves work efficiency. It helps in reducing chemical wastage, getting higher yield, enhancing income and giving technology to illiterate farmers is achievable [4]. There will be no problems connected with soil compaction or crumpling of plants. They can be particularly useful in the case of spot spraying over a large area. Owing to replacing manual, backpack and tractor sprayers with them, the risk of poisoning of people who perform spraying with herbicide will be reduced as the spraying drone operator will be considerable distance from the place of the application [5].

The primary goal of the current study is to optimize the drone mounted sprayer's operating parameters for applying herbicides, as labor availability is decreasing to 42%, making it challenging to complete tasks with labor [6]. In addition to more labor being required, high volume sprayers require more water. As a result, the expense is high, whereas 500 l ha-1 is needed for a manual sprayer and 50-100 l ha-1 for low volume sprayers [7]. This research could result in the standardization of operational parameters to save time, increase the effectiveness of chemical use, and enhance operator safety.

2. MATERIALS AND METHODS

2.1 Experimental Area

The field experiment was conducted at University of Agricultural Science Play Ground (77.35 E and 16.20 N), Raichur, Karnataka, India, during June 2023. The location is shown in Fig. 1. The area was marked 20m x 15m in the open ground. The rails were conducted keeping different levels of forward speed and height of spray.

The meteorological site conditions were recorded using the a weather meter and anemometer during application of pre and post emergence herbicide, which shows the air temperature of 20-22^{0}C, Relative humidity of 46% - 54%, and wind velocities of 0.9 -1.7 ms^{-1} at morning 7 o clock to avoid the spray drift.

2.2 Spraying Equipment

The drone mounted sprayer was designed and analyzed in the laboratory. The developed drone mounted sprayer is a Hexacopter. The capacity of drone mounted sprayer was 10 L. The drone mounted sprayer was shown in the Fig. 2. The total weight of drone mounted sprayer is 13 kg. The flying endurance of drone without payload and with payload was 25 min and 15 min. The four flat fan nozzles used for herbicide application with discharge rate of each nozzle 0.80 l min^{-1}[8]. It can be controlled by manual and autonomous mode. For the experiments autonomous was selected due to higher accuracy and better operation. The swath width, height of spray and discharge rate of spray was controlled through automatic mode of operation. The technical details of drone mounted sprayer were shown in the Table 1.

Fig. 1. Experiment location

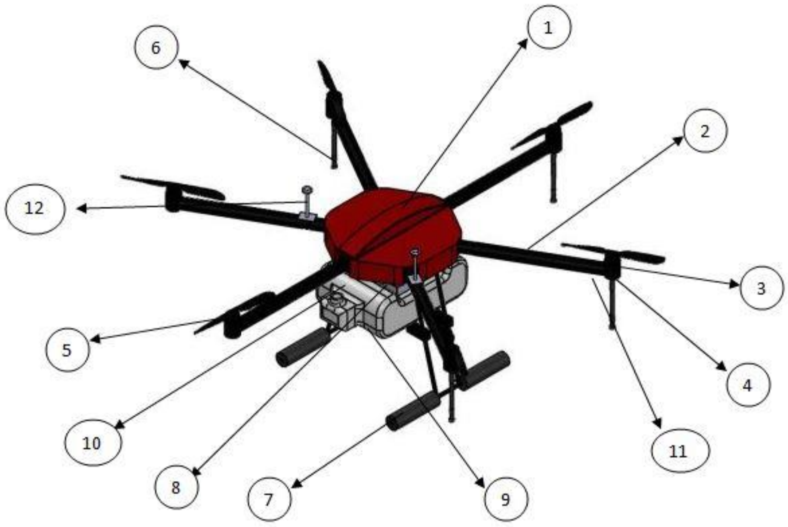

Fig. 2. Isometric view of drone mounted sprayer

Sl. No.	Components	Sl. No.	Components
1	Flight controller unit	7	Landing gear
2	Arms	8	Battery
3	BLDC motor	9	Pump
4	Electronic speed controller	10	Spray tank 10 L
5	Propeller	11	Hose pipe
6	Nozzles	12	GPS

Table 1. Specifications of the drone mounted sprayer

Sl. No	Parameters	Norms and Numerical value
1	Type	Hexacopter
4	Power source	16000 mAhLiPo Battery
5	Payload capacity, L	10
6	Self weight, kg	13 (include one pair batteries)
7	Take -off weight, kg	25
8	Flight height, m	1- 30
9	Forward speed, m s^{-1}	1 – 8
10	Type of spray nozzle	Flat fan shape
11	Number of nozzles	4
12	Discharge rate, l min^{-1}	0- 3.4
15	Pump model	I2 -14S VrHobbywing diaphragm pump
16	Pump operating flow, l min^{-1}	0.1 - 5
17	Pump working pressure, kgf cm^{-2}	3.56
18	Remote controller distance, km	1
19	No load flight time, min	25
20	Load flight time, min	16.90

2.3 Experimental Design

Pre-field evaluation of drone mounted sprayer was done before going to crop field. The application rate was determined how much quantity of chemical spray is required for different levels of operational parameters of drone. The area was marked 20 m x 15 m in the open ground. The trails were conducted keeping different levels of forward speed and height of spray represented. The study swath width, application rate and field capacity were recorded.

The experiments were conducted with CCRD variable parameter combinations were shown in the Table 2. The drone mounted sprayer operated in the autonomous mode marking the area in the A, B, C and D co-ordinate which was shown Fig. 3**.**

2.4 Measurement of Swath Width, Application Rate and Field Capacity

Swath width is effective width covered by the spray nozzles. The swath width of the spray mainly influences the field capacity of the sprayer. The drone mounted sprayer tank was mixed with methylene dye colour before operating UAV at certain height. Swath width of spray was measured by placing 8 m length and 4 cm width of rectangle rod and white colour absorption paper wrapped on it. The drone mounted sprayer operated on the colour absorption paper with spraying liquid. It was measured by measuring the water distribution from edge to edge on the colour absorption paper. The swath width was measured by colour spread on the white water absorption paper sheet with the help of measuring tape which was shown in the Fig. 4 [9].

The actual application rate is the amount of liquid consumed with respect to unit area. Measurements were made by spraying water in the plane field to get exact result. Actual application rate was measured by filling known amount of liquid into the tank and time taken to spray was noted down by using stop watch. The actual application rate is average of three replications. The quantity of the chemical solution sprayed in the field was calculated manually with help of measuring jar shown in the Fig. 5 [6].

Fig. 3. Determination of application rate of drone mounted sprayer various forward speed and height of spray under laboratory conditions

Table 2. Design of experiments using CCRD for laboratory evaluation for drone mounted sprayer

Exp. No	A. Forward speed ($m\ s^{-1}$)	B. Height of spray (m)	Swath width (m)	Application rate ($l\ ha^{-1}$)	Field capacity ($ha\ h^{-1}$)
1	2.00	1.50	2.90	103.33	1.57
2	5.00	1.50	2.90	44.00	3.09
3	2.00	2.50	5.10	79.00	3.18
4	5.00	2.50	5.12	33.33	5.40
5	1.00	2.00	3.80	133.00	1.08
6	6.00	2.00	3.90	42.00	4.41
7	3.50	1.00	1.80	72.00	1.72
8	3.50	3.00	6.20	37.00	5.20
9	3.50	2.00	4.10	54.00	3.60
10	3.50	2.00	4.15	55.00	3.68
11	3.50	2.00	4.10	54.00	3.69
12	3.50	2.00	4.13	55.00	3.72
13	3.50	2.00	4.12	56.00	3.72

The field capacity is the area covered by the drone mounted sprayer with respect to time. Measurements were made by calculating area of drone operated and time of operation (Eq. 1).

$$\text{Field capacity} = \frac{\text{Area covered}}{\text{Timetaken}}\text{, ha h}^{-1} \quad (1)$$

2.5 Statistical Analysis

One of the most commonly used experimental designs for optimization is the response surface methodology (RSM). Because it allows evaluating the effects of multiple factors and their interactions on one or more response variables it is a useful method. In the RSM analysis CCRD design method is applied to uses special orthogonal arrays to study all the design factors with a minimum of experiments. The significant difference was obtained suing analysis of variance (two-way ANOVA) by central composite randomized design method at a test significance of 95% by using statistical software 'Design of experts'.

Fig. 4. Measurement of swath width of UAV at different height

Fig. 5. Determination of application rate of drone mounted sprayer various forward speed and height of spray under laboratory conditions

3. RESULTS AND DISCUSSION

The operational parameters obtained at different combinations of independent parameters are given in the Table 2. The Design Expert software used to analysis of data and ANOVA by response surface mythology in central composite design was shown in the Table 3.

3.1 Swath Width

The swath widthof the drone mounted sprayer was determined at different levels of operational parameters *viz*., forward speed (A) and height of spray (B) presented in Table 2. The maximum swath widthof drone mounted sprayer was 6.2 m obtained at 3.5 m s^{-1} forward speed and 3 m height of spray. The minimum swath widthof drone mounted sprayer was 1.8 m obtained at 3.5 forward speed and 1 m height of spray. The swath widthof drone mounted sprayerwas in the range of 1.8 m to 6.2 m.

The effect of forward speed and height of spray on swath width is presented in Fig. 6. It was observed that as forward speed increased or decreased there is effect on the swath width [9]. It was observed that width of spray increased with increase in the height of spray from 1.0 to 3.0 m. This is due to fact that as the height of spray increases the base of the spray cone also increases which results in wider spray cone base [10,7].

The results of the experiments were statistically analyzed and presented in Table 3. The forward speed and height of spray were significantly influencing the swath width at 1 % level of significance and the interaction effects were non-significant. The mean swath width was observed to be 4.02 m with standard deviation of 0.02 and coefficient of variation was about 0.57 %.The quadratic model was obtained as a best fit with R^2 value of 0.99 and adjusted R^2 value of 0.99 which was in reasonable agreement with predicted R^2 value of 0.99. The signal to noise ratio was about 281.54 and it was greater than 4, which indicate that model can be used to navigate design space. The quadratic equation (Eq. 2) was obtained to determine the relationship between the swath width and selected operational parameters.

$$\text{Swath width(m)} = 4.12 + 0.0230A + 1.56B + 0.0083AB - 0.1333A^2 - 0.0592B^2 \quad ..(2)$$

3.2 Application Rate

The determination of application rate at different operational parameters is important to determine actual amount of herbicide spray liquid required at different dosage level. The application rateof the drone mounted sprayer was determined at different levels of operational parameters *viz*., forward speed (A) and height of spray (B) presented in Table 2. The minimum field capacity of drone mounted sprayer was 33.33 l ha^{-1} obtained at 5 m s^{-1} forward speed and 2 m height of spray. The maximum application rateof drone mounted sprayer was 133 l ha^{-1} obtained at 1 m s^{-1} forward speed and 2 m height of spray. The field capacity of drone mounted sprayerwas in the range of 33.33 to 133 l ha^{-1}.

Table 3. ANOVA for influence of independent parameters interactions on performance parameters

	Swath Width (m)	**Application rate (l ha^{-1})**	**Field capacity (ha h^{-1})**
Source	**F-value**	**F-value**	**F-value**
Model	5530.13	1112.91	540.37
A-Forward speed	6.87	4017.65	1201.41
B-Height of spray	27438.54	535.41	1312.18
AB	0.1884	27.19	16.29
A^2	199.30	902.65	171.61
B^2	38.10	0.2078	9.22
Lack of Fit	1.42	4.39	5.92
Mean	4.02	62.90	3.39
Standard Deviation	0.0230	1.31	0.086
Coefficient of variation (%)	0.5724	2.08	2.56
R^2	0.997	0.998	0.997

*R^2; Regression coefficient ; **Significant at 1% level; *Significant at 5% level;*

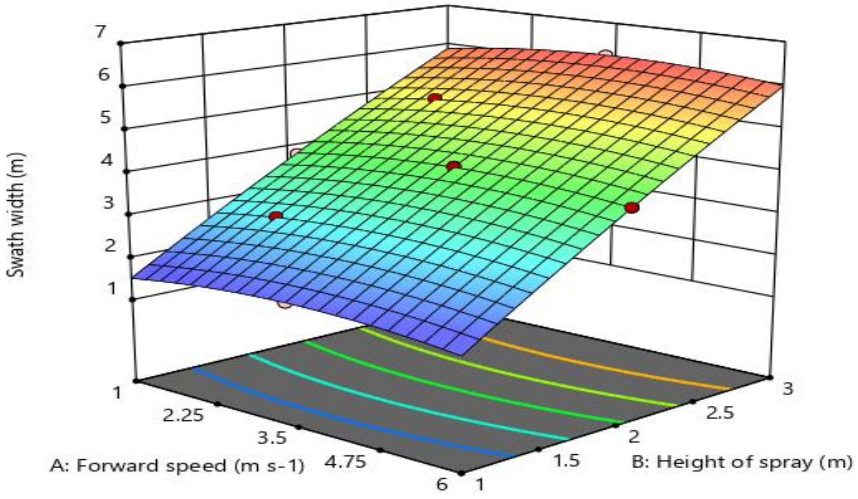

Fig. 6. Swath width as a function of forward speed (A) and height of spray(B)

The influence of forward speed and height of spray on application rate is presented in Fig. 7. It was observed that as the increasing forward speed from 1 m s^{-1} to 6 m s^{-1} decreased in the application rate. This was observed because with increase in the forward speed larger area was covered with lesser spray volume. Similarly as the height of spray increases the application rate was decreased because with increase in the height of spray the swath width also increased which inturn cover maximum area with lesser spray volume [11].

The experiment's outcomes were statistically examined and reported in the Table 3. The forward speed and height of spray were significantly influencing the application rate at 1 % level of significance and the interaction of AxB effects was significant. The mean application rate was observed to be 62.90 l $ha^{-1}$with standard deviation of 1.31 and coefficient of variation was about 2.08 %.The quadratic model was obtained as a best fit with R^2 value of 0.99 and adjusted R^2 value of 0.99 which was in reasonable agreement with predicted R^2 value of 0.99. The signal to noise ratio was about 109.82 and it was greater than 4, which indicate that model can be used to navigate design space. The quadratic equation (Eq. 3) was obtained to determine the relationship between the application rate and selected operational parameters.

$$\text{Application rate(l ha}^{-1}) = 4.12 + 0.0230A + 1.56B + 0.0083AB – 0.1333A^2 – 0.059B^2 \quad (3)$$

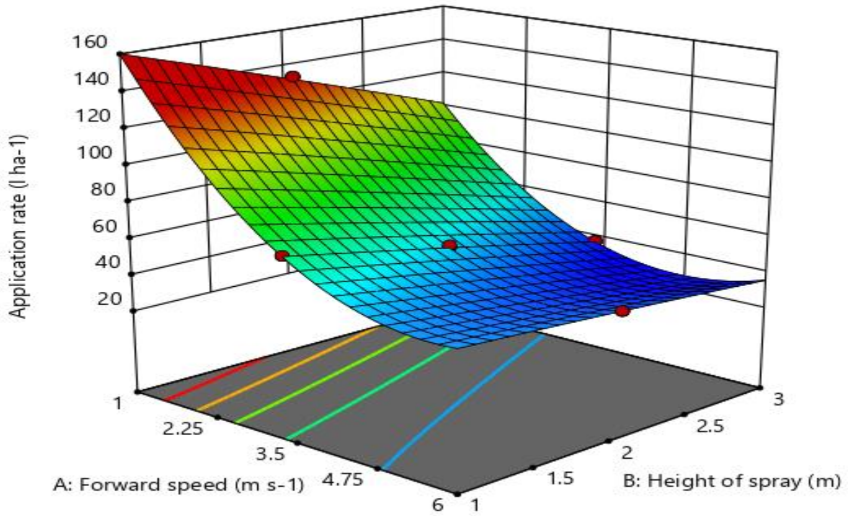

Fig. 7. Application rate as a function of forward speed (A) and height of spray(B)

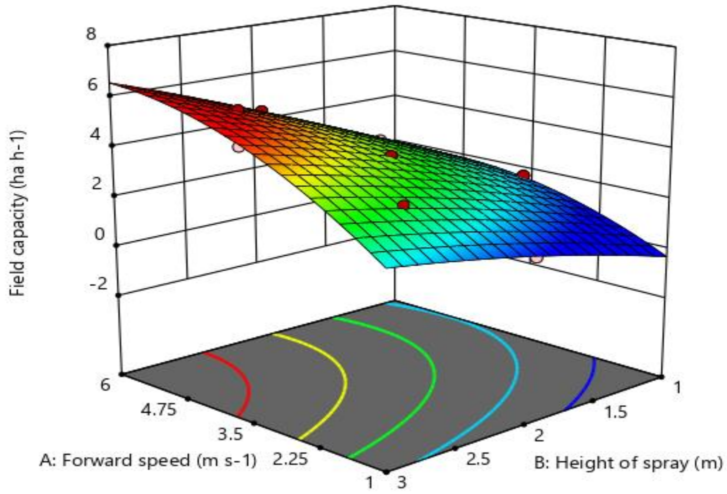

Fig. 8. Field capacity as a function of forward speed (A) and height of spray(B)

3.3 Field Capacity

The field capacityof the drone mounted sprayer was determined at different levels of operational parameters *viz*., forward speed (A) and height of spray (B) presented in Table 3. The maximum field capacityof drone mounted sprayer was 5.40 h ha^{-1} obtained at 5 m s^{-1} forward speed and 2.5 m height of spray. The minimum field capacity of drone mounted sprayer was 1.08 ha h^{-1} obtained at 1 m s^{-1} forward speed and 2 m height of spray. The field capacity of drone mounted sprayerwas in the range of 1.08 to 5.40 ha h^{-1}.

The outcome of forward speed and height of spray on field capacity is presented in Fig. 8. It was observed that field capacity increased by increasing forward from 1 m s^{-1} to 6 m s^{-1}. This is due to fact that as increased forward speed of drone mounted sprayer which covers larger area within less time for same area. It was observed that increased in the height of spray from 1.0 to 3.0 m which increased in the field capacity. It is because increasing the height of spray there is increase in the swath width which result cover larger spray area per unit time [12,7].

The results of the experiments were statistically analyzed and presented in the Table 3. The forward speed and height of spray were significantly influencing the field capacity at 1 % level of significance and the interaction of AxB effects was significant. The mean field capacity was observed to be 3.39 ha $h^{-1}$with standard deviation of 0.08 and coefficient of variation was about 2.56 %. The quadratic model was obtained as a best fit with R^2 value of 0.99 and adjusted R^2 value of 0.99 which was in reasonable agreement with predicted R^2 value of 0.97. The signal to noise ratio was about 71.56 and it was greater than 4, which indicate that model can be used to navigate design space. The quadratic equation (Eq. 4) was obtained to determine the relationship between the field capacity and selected operational parameters [13].

$$\text{Field capacity (ha h}^{-1}) = 3.69 + 1.15A + 1.28B + 0.2917AB - 0.4657A^2 - 0.1097B^2 \ldots \quad (4)$$

4. CONCLUSIONS

The drone mounted sprayer was evaluated in pre-field condition by varying operational parameters *viz*., forward speed and height of spray before going actual field. The reason is determine the application rate before to determine how much quantity of spray liquid required to mix the spray chemical. The dependent parameters considered for study were swath width, application rate and field capacity. To conduct the experiments with drone mounted sprayer 15 x 20 m^2 pre-field plots were selected for crops. The experiments were designed based on RSM and results were statistically analyzed using Design Expert software. The drone mounted sprayer's maximum swath width was 6.2 m, achieved at a forward speed of 3.5 m s^{-1} and a spray height of 3 m. With a forward speed of 3.5 and a spray height of 1 m, the drone-mounted sprayer's minimum swath width was achieved at 1.8 m. The drone-mounted sprayer's swath width ranged from 1.8 to 6.2 m. The drone mounted sprayer's minimum field capacity was 33.33 l ha^{-1}, achieved at a forward speed of 5 m s^{-1} and a spray height of 2 m. With a forward speed of 1 m s-and a spray height of 2 m, the drone-mounted sprayer's field capacity ranged from 33.33 to 133.0 l ha^{-1}.At a forward speed of 5 m s^{-1} and a spray height of 2.5 m, the drone-mounted sprayer's maximum field capacity was 5.40 ha h^{-1}. At a forward speed of 1 m s^{-1} and a spray height of 2 m, the drone-mounted sprayer's minimum field capacity was 1.08 ha h^{-1}. The drone-mounted sprayer's field capacity ranged from 1.08 to 5.40 ha h^{-1}.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chen H, Lan Y, Fritz BK, Hoffmann WC, Liu S. Review of agricultural spraying technologies for plant protection using unmanned aerial vehicle (UAV). International Journal of Agricultural and Biological Engineering. 2021;14(1):38-49.
2. Zhang K, Chen J, Wang C, Han L, Shang Z, Wang G, Wang M, Deng X, Zhang Y, Wang X, Li P. Evaluation of herbicides aerially applied from a small unmanned aerial vehicle over wheat field. International Journal of Precision Agricultural Aviation. 2020;3(1):49-54.
3. Devi G, Sowmiya N, Yasoda K, Muthulakshmi K, Balasubramanian K. Review on application of drones for crop health monitoring and spraying pesticides and fertilizer. Journal of Critical Reviews. 2020;7(6):667-672.
4. Prabhu SS, Kumar AV, Murugesan R, Saha J, Dasgupta I. Adoption of precision agriculture by detecting and spraying herbicide using UAV. Basrah Journal of Agricultural Sciences. 2020; 34(1):21-23.
5. Berner B, Chojnacki J. Use of drones in crop protection. Journal of Agriculture Sciences. 2017;9(1):23-29.
6. Supriya C, Arthanari PM, Kumaraperumal R, Shivaurugan AP. Optimization of spray fluid for herbicide application for drones in irrigated maize. International Journal of Plant and Soil Science. 2021;33(21):137-145.
7. Yallappa D, Veerangouda M, Maski D, Palled V, Bheemanna M. Development and evaluation of drone mounted sprayer for pesticide applications to crops. IEEE Global Humanitarian Technology Conference,19-22, San Jose (USA). 2017; 1-7.
8. Xue X, Lan Y, Sun Z, Chang C, Hoffmann WC. Develop an unmanned aerial vehicle based automatic aerial spraying system. Computers and Electronics in Agriculture. 2016;12(8):58-66.
9. Dhakad S, Salunkhe RC, Dabhi KL, Gupta P. Agricultural drone spraying efficiency enhancement *via*patternater-based effective swath width determination. The Pharma Innovation Journal. 2023;12 (10):952-961.
10. Kumar A, Kumar R, Aman Singh V, Karwasra N. Optimization of nozzle characteristics for different types of sprayers. Indian Journal of Pure and Applied Biosciences. 2020;8(2):273-281
11. Pascuzzi S. The effects of the forward speed and air volume of an air-assisted sprayer on spray deposition in tendone trained vineyards. Journal of Agricultural Engineering. 2013;44(18):125 -135.
12. Sanchavat HB, Chaudhary HS, Bhautik G, Singh SN. Field evaluation of a tractor mounted boom sprayer. *Agricultural Engineering Today*. 2017;41(4):67-71.
13. Ghersa CM. Agroecological basis for managing biotic constraints. Sustainable Food Production. 2013;7(1):18-30.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/120762