Plant Archives **Vol. 25, Special Issue (ICTPAIRS-JAU, Junagadh) Jan. 2025 pp. 771-778**
e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.SP.ICTPAIRS-111

A COMPARATIVE STUDY OF DRONE SPRAYING AND CONVENTIONAL SPRAYING FOR PRECISION AGRICULTURE

S.K. Gaadhe*, D.B. Chavda, T.D. Mehta, S.K. Chavda, K.M. Gojiya and R.D. Bandhiya

Department of Farm Machinery and Power Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India.
*Corresponding author E-mail : skgaadhe@jau.in

ABSTRACT

In recent times, the integration of mechatronics, sensors, IoT and other technological advancements in agriculture has become indispensable. Among these, drone have emerged as a pivotal tool for effectively managing agricultural operations and optimizing resource utilization across vast fields. Drones offer a myriad of applications within agriculture, livestock management, horticulture, fisheries, and forestry. They can be employed at every stage of plant growth, from seed germination to the final harvest. Drones provide farmers with a comprehensive overview of their fields, empowering them to make informed decisions regarding various agricultural tasks. Furthermore, the deployment of autonomous drones enables precise input application rates, a critical factor for efficient and sustainable farming practices. The application of drones in agriculture is their role in pesticide and fertilizer spraying. Traditional spraying methods, which often involve human labor and expose individuals to harmful chemicals, present health and safety concerns. The WHO estimates a substantial number of pesticide-related illnesses and deaths annually, especially in developing countries.

In this study, the performance of a drone spraying system was rigorously evaluated for precision agriculture. The evaluation parameters such as discharge rate, application rate, water utilization, field capacity and field efficiency. The test results indicated that the drone spraying system demonstrated an average application rate of 26.96 l/ha, along with a field efficiency of 76.5% and an effective field capacity of 4 ha/h. Conversely, the Knapsack spraying system showed an average application rate of 490.28 l/ha, a field efficiency of 87.23%, but had a significantly lower coverage rate, managing only 0.082 ha/h. The drone spraying system exhibited highly effective pesticide utilization, reaching up to 85%, whereas the Knapsack spraying system had a maximum utilization of only 30%. Also, the drone system showed potential water savings of up to 94.51% compared to the Knapsack system. These results were obtained under average wind conditions of 10–14 km/h in the field.

Key words : Agriculture, Application rate, Chemicals, Field efficiency, Drone, Health, Sprayer.

Introduction

In the agricultural sector, chemical spraying is a useful way to control insects, diseases and weeds. It is also important for growing high-yielding, quality crops and pasture. Applying the right amount of chemical at the right time and perfect place is a major factor in ensuring successful control. In past time, farmers had to bring or throw fertilizers and pesticides by hand, which was hazardous to their health.

Now a days agriculture has advanced significantly in terms of technology, and the old method of farming has been outgrown. Crops are protected and grown using various technologies. One of the top priorities is spraying technology. Farmers can now conveniently spray fertilizers or some other appropriate liquid for their crops using handheld devices.

Traditional sprayers were heavy machinery, so farmers may have to face problems ahead as handheld sprayers might not get produced compared to tractor and trailer mounted sprayer. In general farmers use mostly traditional (manual) method for the spraying of chemical in agriculture crop. While mechanical method was used for horticulture crops. But manual spraying practices required a greater number of labour and higher liquid as well as in this practice operator direct contact with chemicals and sprayer equipment. Therefore, it may be hazardous and unergonomic practices. Now a days many farmers are involved in mechanical energy utilization, but it creates more pollution (Vala *et al.*, 2023). Another disadvantage of tractor operated sprayer can't be directly utilized after the rain in field. Thus, a need to be required to overcome this problem in a greater mechanization way.

The use of drones in agricultural spraying has increased in recent years as the technology has become more affordable and accessible. Drone spraying offers several advantages over traditional methods of crop spraying, including greater accuracy, improved efficiency and reduced environmental impact. A major reason for adopting drones in agriculture is that they can cover a larger area in less time. Additionally, drones can be equipped with GPS technology to precisely target areas that need to be treated. It helps to reduce the numbers of labour and amount of chemicals used, as well as the possibility of overspray. Another benefit of using drones for spraying is that it reduces the risk to humans. Traditional spraying methods require workers to be close to the chemicals being used, which puts them at risk of exposure. It eliminates this exposure by keeping workers at a safe distance from the substances. Workers also have lower risks of health issues caused by prolonged and repetitive movements when using traditional knapsack sprayers and similar equipment (Chen *et al*., 2021). Additionally, drones can be equipped with cameras that allow operators to see exactly where they spray. This helps ensure that chemicals are only being applied to needed areas. In traditional methods more power is required to do the job and this power is being generated from fossil fuels. Fossil fuels are very costly and harmful for the environment; therefore, it needs to be proposed to use an alternate of this fossil fuel it can be only possible through the electric power would be utilize for this operation (Anonymous, 2022a).

Materials and Methods

Location of experiment

Junagadh (21.5° N,70.5° E and 60 m AMSL) is in the foothills of Mount Girnar in the south Saurashtra agro climatic zone of Gujarat, represents an irrigated, mechanized and input intensive cropping area of the Indo Gangetic Plain region.

Agricultural Spraying Drone

A hexa copter drone sprayer (Agribot, IoTech World Avigation Pvt., Ltd, Haryana, India) was used in field tests (Fig. 1) with a folded size of 762 mm length, 762 mm width, and 483 mm height. The drone sprayer was equipped with a 10-L polypropylene container, with maximum takeoff weight (Including battery) 23.2 kg. Four extended-range flat-fan nozzles with a maximum flow rate of 0.85 L/min and a working swath width of 4-6 m. During the operations, the sprayer can fly at a maximum speed of 8.0 m/s with a maximum hovering time of 25 min (Figs. 2 to 7).

Operation Mode for Drone Spraying

Operation mode is a comprehensive solution developed by several agricultural drone manufacturers in recent years for aerial pesticide spraying. The main

Fig. 1 : Agricultural Spraying drone (With 10 L tank capacity).

Fig. 2 : Six rotor agricultural spraying drone.

Fig. 3 : Twin blade rotor.

Fig. 4 : Drone control unit (Remote controller).

Fig. 5 : Agricultural Spraying nozzle.

Fig. 6 : Battery set (Power source).

Fig. 7 : Agricultural spraying pump.

steps include aerial surveying and mapping, flight route planning and spraying operation. Before the operation, the mapping route was first planned through the controller of the PHANTOM 4 RTK, and the flight speed, height and other parameters were set according to the crop conditions, then the drone was operated to conduct the mapping mission after the RTK data were ready. Fruit trees, buildings, utility poles, water and other targets or obstacles were identified intelligently, and the identification results could be corrected manually in the map. The 3D flight route was planned on the reconstructed map. Two spraying methods, continuous spraying and spot spraying, were selectable, and the route planning methods included automatic, semiautomatic and manual planning (Wang *et al*., 2022).

Experimental design

To study the effect of application parameters of agricultural spraying drone. The experiment involved three different flight scenarios, denoted as R_1, R_2 and R_3. The spray solution was pure water (Fig. 8). Three types of continuous spraying pattern were applied in field experiments for continuous spraying intra-row: the UAV sprayer flew right above and along the row. The first aspect considered was the distance covered by the drone during each flight scenario. The time taken for the drone to complete the flight was also recorded, allowing the calculation of the flying speed for each scenario (Shaw and Vimalkumar, 2020). For better test performance, a weather station IAAS (Integrated Agro meteorological Advisory Services) at Junagadh Agricultural University was employed 100.0 m away from the field to monitor wind speed, wind direction, temperature, and relative humidity at a height of 2.0 m. The experimental parameters and meteorological conditions are shown in Table 1. The effects of two flying speeds, on flying time, application rate (L/ha) and filed efficiency, were compared through three treatments at a height of 2.0 m. This information was crucial for determining the efficiency of the spraying process. The area covered by the drone in terms of hectares per hour was also calculated, providing insights into the drone's productivity. Field efficiency, a key metric in the experiment, was determined based on the area covered and the application rate. This metric indicates how effectively the drone was able to spray the target area, considering factors such as flight time and spray intensity. These findings will be instrumental in optimizing the design and operation of the spraying drone, contributing to the development of more efficient and effective agricultural practices.

Performance evaluation of sprayer parameters

Flying Time : The flight time of a drone refers to the duration for which a drone can remain airborne on a single battery charge or power source before it needs to

Fig. 8 : Spraying in groundnut crop.

land and recharge or replace its batteries. This is a critical factor in drone operation, as it directly impacts the drone's ability to perform tasks, cover distances and collect data. It includes both productive time (time spent in spraying) and non-productive time (time spent in manoeuvres, reloading, etc.).

Rate of Application : Rate of Application is typically expressed as the amount of the liquid (usually water and chemical) applied per unit area (usually per hectare) during a single application. It is an essential parameter because it directly affects the effectiveness of the treatment and the uniformity of coverage. The application rate was calculated as per the ASABE standard. The mean value of discharge rate, travel speed, and effective spray width were measured, and application rate was calculated with the formula below (Dengeru *et al*., 2022).

$$\text{Application rate}\,(R) = \frac{Q \times K}{S \times W} \qquad (1)$$

Where,

R = Application rate (l/ha);

Q = Output rate (l/min);

K = Constant, 600;

S = Travel speed (km/h);

W = Effective spray width (m).

Area Cover (ha/h) : This parameter represents the rate at which the drone covers the agricultural field in terms of hectares per hour. It is calculated by dividing the area covered by the drone during the flight by the total flight time.

$$\text{Area Cover} = \frac{\text{Area Covered}}{\text{Total Flight time}} \qquad (2)$$

Theoretical field capacity : It is the rate of field coverage of the implement, based on 100 per cent of time at the rated speed and covering 100 per cent of its rated width.

Theoretical field capacity (ha/h) =

$$\frac{\text{Width}\,(m) \times \text{Speed}\,(m/h)}{10000} \qquad (3)$$

Effective field capacity : It is the actual area covered by the implement, based on its total time consumed and its width.

$$\text{Effective field capacity}\left(\frac{ha}{h}\right) = \frac{\text{Area covered}}{\text{Total flight time}} \qquad (4)$$

Field Efficiency : It is ratio of effective field capacity and theoretical field capacity expressed in per cent (Nandaniya *et al*., 2022).

$$\text{Field efficiency}\,(\%) = \left(\frac{\text{Effective field capacity}}{\text{Theoretical field capacity}}\right) \times 100 \qquad (5)$$

Weather Parameter : Weather conditions play a crucial role in the functionality and operational efficiency of agricultural drones. Wind represents a critical factor affecting drone operations, particularly high winds, which can challenge the drone's ability to maintain stable flight and cause it to veer off its intended course. Smaller drones are particularly vulnerable to strong gusts, and wind direction is also vital in-flight planning, as crosswinds can impact stability. Temperature variations can significantly affect drone battery performance. Cold temperatures may reduce battery efficiency and capacity, potentially leading to shorter flight durations, while extreme heat can impact both battery function and the drone's internal components. Elevated humidity levels pose risks to the drone's electronics and sensors, potentially causing malfunctions due to condensation. Additionally, high humidity can diminish visibility, a crucial aspect for both navigation and accurate data collection by onboard sensors. Various forms of precipitation, including rain and snow, can be detrimental to drones, potentially causing damage to sensitive electronics and sensors. Operating a drone in precipitation can also diminish visibility and compromise the drone's overall stability and performance. Reduced visibility due to factors like fog, rain, snow, or low clouds can create unsafe conditions for drone operation. This diminished visibility can also impair the effectiveness of cameras and sensors, thereby compromising the reliability of data collection.

These weather parameters, along with their associated formulas, were employed to assess the performance of the spraying drone in terms of speed, productivity, accuracy and efficiency during the experimental trials.

Results and Discussion

This research offers a comparative analysis of precision agriculture techniques, drone spraying versus conventional spraying. The study was conducted at the Instructional Farm within the Department of Farm Machinery and Power Engineering at the College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. The field experiments encompassed both barren land and groundnut crop scenarios, involving variations in operational speed. The drone's performance was evaluated based on multiple parameters, including flight duration, field efficiency, area coverage, and application rate. The ensuing results and discussions provide valuable insights into the strengths and constraints of utilizing drone technology for spraying in agricultural contexts.

Crop Parameters

In the context of the spraying operations conducted on groundnut crops, various agronomic factors were considered and subsequently measured (Gaadhe *et al.*, 2023). The recorded results were subjected to analysis to assess the performance of the spraying drone.

Crop variety

The spraying and weeding activities were carried out on groundnut crops of the G-20 variety. This crop variant, renowned for its high yield, enjoys widespread popularity among farmers in the Junagadh district.

Crop height

In the groundnut field where the spraying operations were executed using a Spraying Drone, the height of the groundnut crop assumed significant importance in relation to the drone's functionality. To ensure the consistent and even distribution of the pesticide solution across the entire crop, measurements of the average crop height were taken at various locations within the field. This average height, calculated to be 37.5 cm, served as a reference point for adjusting the spraying height. This adjustment aimed to strike a balance between achieving comprehensive coverage and effectiveness in pest control while safeguarding the health and integrity of the groundnut crop.

Row-to-Row Spacing

The experimental groundnut crop featured a row-to-row spacing of 50 cm.

Soil characteristics

The composition of soil, specifically the relative proportions of sand, silt and clay, determines its texture. In the Saurashtra region, where this study was conducted, most soils are clayey and characterized by fine texture. Most of these soils have well-drained properties, although some isolated areas exhibit excessive drainage. The soil type prevalent in the Junagadh district of the Saurashtra region is known as black cotton soil. Water levels in Junagadh are relatively shallow, ranging from 5 m to 20 m below ground level across most of the district. Soil samples, collected from the uppermost 0-30 cm soil layer, were used to determine soil moisture content and bulk density (Gaadhe and Tiwari, 2022).

Observed Weather Parameter (Table 1)

Test parameters

The assessment of a drone-based spraying system's performance in an experimental field required the measurement of several important factors. These factors included Flying Speed, Flight Duration, Application Rate (l/ha), Discharge Rate (l/min), Area Cover (ha), Field Efficiency (%), Effective Field Capacity (ha/h), Theoretical Field Capacity (ha/h) and Weather parameter. Table 2 displays the recorded values for each of these factors for both the drone sprayer and the knapsack sprayer. These factors serve as the basis for evaluating and comparing the performance of the drone sprayer with that of the knapsack sprayer.

Operational Speed (km/h) : The drone sprayer's operational speed was assessed in three separate trials, and the results for these trials are provided in columns R_1, R_2 and R_3. The average operational speed for the drone sprayer is computed to be 13.201 km/h. Likewise, the operational speed of the knapsack sprayer was determined through three replicates, resulting in an average operational speed of 1.833 km/h.

Application Rate (l/ha) : The application rate of

Table 1 : Observed Weather parameters.

S. no.	Temperature (°C)		RH (%)	W.S.
	Max.	Min.		(kmph)
1	40.3	21.5	76	4.4
2	41.5	22.3	67	5
3	41.4	23.1	78	5.7
4	39.9	23.7	84	6.3
5	42.8	23.9	65	5.5
6	40.4	25.7	79	8.1
7	41.4	24.7	80	6.7
8	39.5	26	80	8.4
9	37.2	26.3	76	11.8
10	37.6	25.9	78	11.4

Table 2 : Observed values of filed parameters.

Parameters	Drone Sprayer				Knapsack sprayer			
	R_1	R_2	R_3	Ave	R_1	R_2	R_3	Ave
Operational Speed (km/h)	12.704	13.355	13.543	13.201	1.720	1.880	1.900	1.833
Application rate (l/ha)	28.810	26.380	25.716	26.969	504.350	491.70	474.800	490.283
Effective field capacity (ha/h)	4.047	4.038	4.052	4.046	0.078	0.083	0.087	0.083
Theoretical field capacity (ha/h)	5.106	5.342	5.450	5.299	0.094	0.094	0.094	0.094
Field Efficiency (%)	78.260	76.170	75.190	76.540	82.979	88.298	92.553	87.943

the drone sprayer was assessed across three separate trials (R_1, R_2, R_3), resulting in an average application rate of 26.969 liters per hectare (l/ha). Similarly, the application rate of the knapsack sprayer was determined through three replicates, yielding an average application rate of 490.283 l/ha. The reasons for the higher application rate in the knapsack sprayer compared to the drone sprayer are, the automated system of the spraying drone utilizes advanced technology and control mechanisms that allow for precise and consistent delivery of the desired amount of product. This accuracy leads to a lower application rate in the drone sprayer. The drone spraying system reduces the potential for human error, such as uneven application or overlap the application. The spraying drone system incorporates advanced features like sensors, GPS guidance, and real-time monitoring, which contribute to maintaining a consistent application rate.

Effective Field Capacity (ha/h) : The drone sprayer's effective field capacity was noted as 4.047, 4.038 and 4.052 in three separate observations, with the average effective field capacity calculated at 4.046 hectares per hour (ha/h). Similarly, the effective field capacity of the knapsack sprayer was assessed as 0.078, 0.083 and 0.087 in three measurements, resulting in an average effective field capacity of 0.083 ha/h.

Fig. 9 illustrates that the drone spraying system demonstrates superior performance in this aspect compared to the traditional (knapsack sprayer), indicating its ability to cover a larger area in a shorter period. The reason for the higher effective field capacity is drone spraying system has higher operational speed with precise operation.

Theoretical Field Capacity (ha/h) : The theoretical field capacity of the drone sprayer, with a consistent value of 5.299 ha/h. Similarly, the theoretical field capacity of the knapsack sprayer remains consistent across all replicates and is noted as 0.094 ha/h.

Field Efficiency (%) : The field efficiency of the drone sprayer was assessed through three separate trials, resulting in measurements of 78.26%, 76.17% and 75.19%. The average field efficiency was calculated to be 76.540%. Similarly, the field efficiency of the knapsack sprayer was determined in three replicates, yielding measurements of 82.29%, 88.29% and 92.55%, with the average field efficiency calculated at 87.943%.

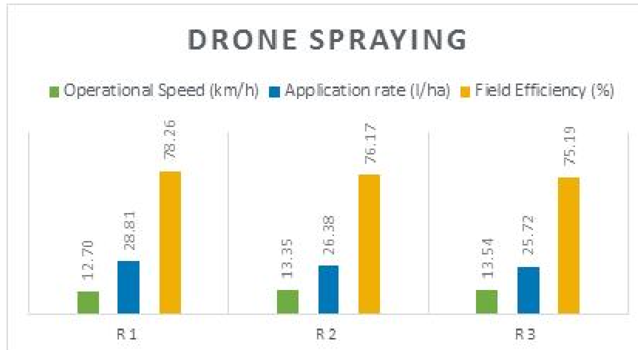

Fig. 9 : Measured parameters of Drone spraying system in field.

Fig. 9 depicts that the drone spraying system exhibits superior performance in terms of field efficiency, primarily attributable to its greater effective field capacity. The factors contributing to the higher field efficiency of the drone spraying system compared to the traditional knapsack sprayer are as follows:

i. Automated and precise operations result in increased field efficiency.

ii. By minimizing waste and optimizing resource usage, the drone spraying system achieves higher field efficiency.

iii. The drone spraying system reduces reliance on human involvement, thereby minimizing inconsistencies, variability, and limitations that can affect field efficiency in the traditional knapsack sprayer.

iv. The traditional knapsack sprayer tends to experience higher non-productive time due to challenges associated with human operation, which can have an adverse impact on field efficiency.

These parameters are essential for assessing the performance and efficiency of the two types of sprayers in agricultural or similar applications (Figs. 9 and 10).

Table 3 : Comparison of different spraying method.

Particular	Traditional spraying way	UAV drone crop sprayer
Adaptability	Crops, flowers and fruit are easily damaged, trampled or dropped by humans. Some high stem crops are difficult in spraying.	Strong adaptability. Not affected by mountains, hilly terrain, and paddy field. Not be influenced by crop growth stage, can solve the problem of ground machinery is hard to enter inside to work, during the middle and later stage of the crop growth as well as in rainy season.
Pesticide utilization	Applying large amount of pesticide liquid, but with bad atomization performance, the pesticide utilization efficiency is very low. It causes serious pollution in the environment.	Its pest control efficiency more than traditional plant conservation ways, effective utilization of pesticides more than traditional method.
Water consumption per hectare	Traditional immersion jet spraying, resulting in waste of water, and most of the pesticides lost into the soil along with water.	Spraying uniformly with low dilution rate and high concentrated liquid pesticide, the water can be saved more than 90% compared with the traditional plant protection working mode.
Safety	Pesticides enter human body by mouth, respiratory passage, or skin contact, easily lead to pesticide poisoning.	Away from field during spraying to avoid the pesticide poisoning

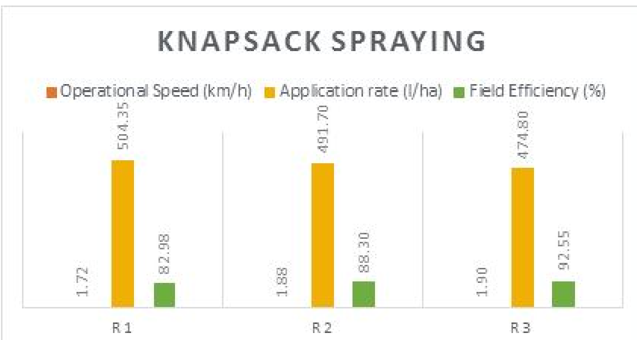

Fig. 10 : Measured parameters of Traditional (Knapsack) spraying system in field.

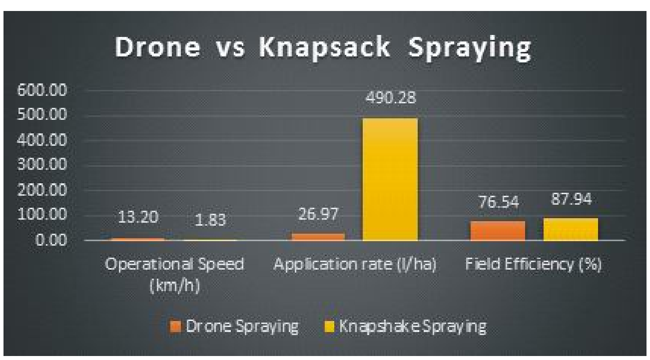

Fig. 11 : Comparison of Drone Spraying with Existing Spraying Methods.

Researchers can use this data to determine which sprayer is more effective based on criteria like speed, application rate, field capacity, and efficiency.

Fig. 11 presents a comparison between Drone Spraying and Knapsack Spraying, across three key parameters. In terms of Operational Speed (km/h), the Drone Spraying method significantly outpaces the Knapsack Spraying method, with a speed of 13.20 km/h compared to 1.83 km/h. An application Rate, the Knapsack Spraying method surpasses the Drone Spraying method, with an application rate of 490.28 l/ha compared to 26.97 l/ha, indicating a much higher volume of liquid sprayed per unit of land. Field Efficiency of the Knapsack Spraying method also demonstrates superior performance, achieving an efficiency rate of 87.94%, while the Drone Spraying method records an efficiency rate of 76.54%. The examination of the terrain (route planning) constituted approximately 10% and this duration could be reduced through the implementation of autonomous route planning and sorties. The aim of route planning algorithm with the minimum return number, to decrease ineffective energy consumption during non-operational situations and concurrently enhance operational efficiency (Shilin *et al.*, 2017).

Conclusion

The use of conventional agricultural spraying techniques presents a range of difficulties for farmers. These issues arise when employing these methods: Exposure of humans to potentially harmful chemicals, Labor-intensive procedures, Reduced effectiveness at elevated altitudes, Health risks linked to manual spraying, Equipment damage resulting from tractor-operated spraying approaches, Ineffectiveness in precisely targeting areas needing treatment, Reliance on fossil fuels for energy supply, Environmental contamination stemming from traditional spraying procedures and Inability to conduct efficient spraying during rainy seasons. The test results indicated that the drone spraying system demonstrated an average application rate of 26.96 l/ha, along with a field efficiency of 76.5% and an effective field capacity of 4 ha/h. Conversely, the Knapsack spraying system showed an average application rate of 490.28 l/ha, a field efficiency of 87.23%, but had a significantly lower coverage rate, managing only 0.082 ha/h. The drone spraying system exhibited highly effective pesticide utilization, reaching up to 85%, whereas the Knapsack spraying system had a maximum utilization of only 30%. Also, the drone system showed potential water savings of up to 94.51% compared to the Knapsack system.

This study emphasizes the trade-offs between the two methods, showcasing that the knapsack sprayer excels in terms of field efficiency but has a significantly lower area coverage compared to the drone sprayer. Additionally, it consumes more time, liquid, and labor resources.

References

Anonymous (2022a). *How Does Drone Technology Impact Crop Spraying*? Available at https://www.xagaustralia.com.au/post/how-does-drone-technology-impact-cropspraying#:~:text=There%20are%20several%20reasons%20why,more%20ground%20in%20less%20time accessed on 1st April, 2023.

Chen, H., Lan Y., Fritz B.K., Hoffmann W.C. and Liu S. (2021). Review of agricultural spraying technologies for plant protection using unmanned aerial vehicle (UAV). *Int. J. Agricult. Biolog. Engg.*, **14(1)**, 38-49.

Dengeru, Y., Ramasamy K., Allimuthu S., Balakrishnan S., Kumar A.P.M., Kannan B. and Karuppasami K.M. (2022). Study on Spray Deposition and Drift Characteristics of UAV Agricultural Sprayer for Application of Insecticide in Redgram Crop (*Cajanus cajan* L. Millsp.). *Agronomy*, **12(12)**, 3196.

Gaadhe, S.K. and Tiwari V.K. (2022). Carrot Harvesting Methods: A Review. *Int. J. Plant Soil Sci.*, pp.7-16.

Gaadhe, S.K., Chavda S.K., Bandhiya R.D., Gojiya D.K. and Chavda D.B. (2023). Optimizing Carrot Harvesting Machine Design: Incorporating Soil and Crop Parameters. *Int. J. Environ. Clim. Change*, **13(10)**, 3680-3689. DOI: 10.9734/IJECC/2023/v13i103039

Nandaniya, J.V., Mehta T.D. and Gaadhe S.K. (2022). Development and Performance Evaluation of Lucerne Harvesting Machine. *Int. J. Res. Appl. Sci. Engg Technol.*, **10(7)**, 4013-4020. DOI: 10.22214/ijraset.2022.45568

Shaw, K.K. and Vimalkumar R. (2020). Design and development of a drone for spraying pesticides, fertilizers and disinfectants. *Engg. Res. Technol. (IJERT)*, **09(5)**, 1181-1185.

Shilin, W., Jianli S., Xiongkui H., Le S., Xiaonan W., Changling W., Zhichong W. and Yun L. (2017). Performances evaluation of four typical unmanned aerial vehicles used for pesticide application in China. *Int. J. Agricult. Biolog. Engg.*, **10(4)**, 22-31.

Vala, Ravi, Yadav Rajvir and Gaadhe S.K. (2023). Operator workplace design compatibility: A study on mini tractor. *Int. J. Agricult. Sci.*, **19(1)**, 51-60. DOI:10.15740/HAS/IJAS/19.1/51-60.

Wang, C., Liu Y., Zhang Z., Han L., Li Y., Zhang H., Wongsuk S., Li Y., Wu X. and He X. (2022). Spray performance evaluation of a six rotor unmanned aerial vehicle sprayer for pesticide application using an orchard operation mode in apple orchards. *Pest Manage. Sci.*, **78(6)**, 2449-2466.