Influence of Spray Parameters of UAV Sprayer on Droplet Size in Paddy Spraying

Abstract

Unmanned aerial vehicles (UAVs) have emerged as a promising technology for agricultural applications, including pesticide spraying in paddy fields. Droplet size is a critical factor influencing the effectiveness and efficiency of pesticide application. This study investigates the impact of various spray parameters of UAV sprayers on droplet size in paddy spraying. The experimental setup involved a UAV equipped with different nozzle types (flat fan nozzle, hollow cone nozzle and spinning disc nozzle), operating at varying forward speed (2, 3, 4, 5 and 6 m s^{-1}) and spray height (l, 1.5, 2, 2.5 and 3 m above crop canopy). The results demonstrated that among three operational parameters type of nozzle had significant effect on droplet size, where forward speed and height of spray found non-significant. The larger droplet size was obtained for flat fan nozzle followed by hollow cone and spinning disc nozzle. These findings provide valuable insights for optimizing UAV sprayer settings to achieve desired droplet size distributions and improve pesticide application efficiency in paddy fields.

Key words: UAV sprayer, Paddy, Type of nozzle and Droplet size.

Introduction

Pesticide application is a crucial aspect of paddy cultivation, aimed at controlling pests and diseases. Traditional methods of pesticide application, such as manual spraying or tractor-mounted sprayers, can be labour-intensive, time-consuming, and inefficient. In recent years, unmanned aerial vehicles (UAVs) have emerged as a promising alternative for pesticide spraying in paddy fields. UAVs offer several advantages, including increased efficiency, precision, and reduced environmental impact.

Droplet size is a critical factor influencing the effectiveness and efficiency of pesticide application. Smaller droplets can penetrate the dense canopy of paddy plants more effectively, reaching target pests and diseases. However, excessive droplet drift can lead to off-target pesticide deposition, environmental contamination, and reduced pesticide efficacy. Larger the droplet size leads to runoff and pesticide wastage. Therefore, understanding the factors influencing droplet size in UAV-based paddy spraying is essential for optimizing pesticide application practices. This study investigates the impact of various spray parameters of UAV sprayers such as type of nozzle, forward speed and height of spray on droplet size in paddy spraying.

Materials and Methods

UAV sprayer

Unmanned aerial vehicles are classified into three major types: quadcopters, hexacopters and octocopters. The quadcopter of the four arms has less stability during flight. It is small in size and has less payload capacity. Compared with all available technologies, octocopters are bulky and more expensive. Hence, it is suggested to use a hexacopter equipped with a sprayer system, as it is more stable during the spraying process than a quadcopter and is more economical than an octocopter (Susitra *et al.*, 2020). The hexacopter (Fig.1) can be selected and modified for pesticide application. The components of UAV sprayer is shown in Table 1.

Fig. 1: Hexacopter UAV sprayer

Table 1. Components and their images of selected UAV sprayer

Sl. No.	Components	Images
1	Fuselage	

2	Landing gear	
3	Arms	
4	Lithium polymer battery	
5	Propeller	
6	Brushless DC (BLDC) motor	
7	Electronic speed controller	
8	Power distribution board	
9	Remote controlled transmitter	

10	Receiver	
11	Flight controller	
12	Global positioning system	
13	Pump motor	
14	Nozzles	
15	Chemical tank	

Experimental Setup

The study was conducted at the farmer's field (Hosur village, Raichur District), a 1000 m^2 area was marked in paddy field to carry out the trials (Fig.2). A hexacopter UAV sprayer was used for the experiments. The three different types of nozzles that were tested were flat fan, hollow cone, and spinning disc nozzle (Table 2) with 100% openings. The forward speed and height of spray of the UAV sprayer were varied during the experiments according to Taguchi L-25 orthogonal experimental design (Table 3).

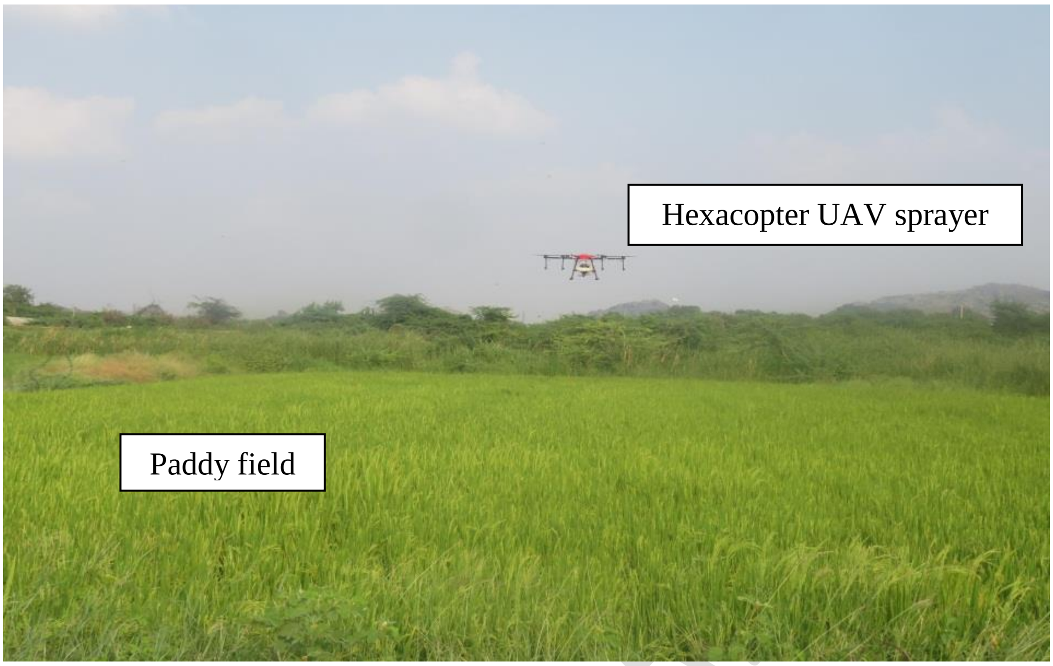
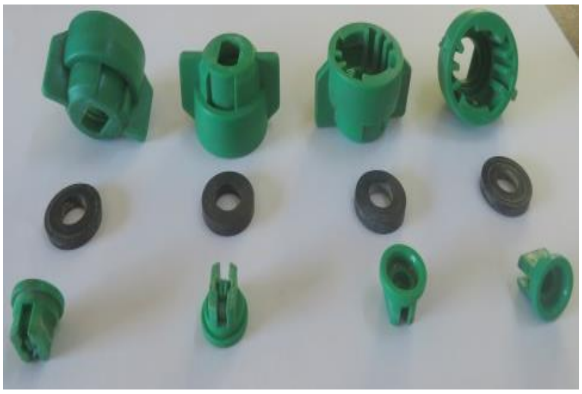


Fig.2: Operating UAV sprayer over paddy crop in the farmer's field to record droplet size

Table 2. Three types of nozzles selected for the study

Sl. No.	Type of nozzle	Nozzle view
1	Flat fan nozzle	

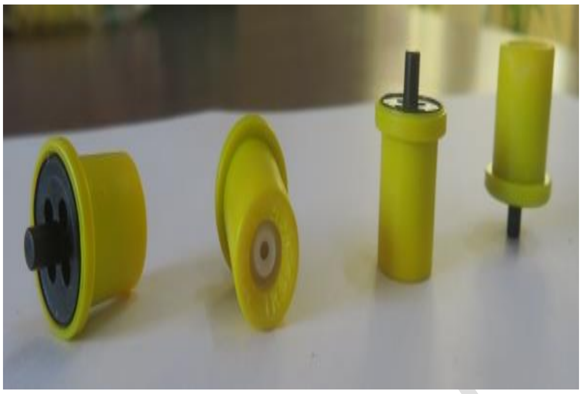
2	Hollow cone nozzle	
3	Spinning disc nozzle	

Table 3. Taguchi L-25 orthogonal experimental design for recording droplet size produced by various nozzle types attached to an UAV sprayer

Experiment No.	Type of nozzle	Forward speed (m s^{-1})	Height of spray (m)
1	Flat fan nozzle	2	1
2	Flat fan nozzle	3	1.5
3	Flat fan nozzle	4	2
4	Flat fan nozzle	5	2.5
5	Flat fan nozzle	6	3
6	Flat fan nozzle	2	1.5
7	Flat fan nozzle	3	2
8	Flat fan nozzle	4	2.5
9	Flat fan nozzle	5	3
10	Flat fan nozzle	6	1
11	Hollow cone nozzle	2	2

12	Hollow cone nozzle	3	2.5
13	Hollow cone nozzle	4	3
14	Hollow cone nozzle	5	1
15	Hollow cone nozzle	6	1.5
16	Spinning disc nozzle	2	2.5
17	Spinning disc nozzle	3	3
18	Spinning disc nozzle	4	1
19	Spinning disc nozzle	5	1.5
20	Spinning disc nozzle	6	2
21	Spinning disc nozzle	2	3
22	Spinning disc nozzle	3	1
23	Spinning disc nozzle	4	1.5
24	Spinning disc nozzle	5	2
25	Spinning disc nozzle	6	2.5

Droplet size measurement

Nozzles produce droplets of various sizes ranging from very fine (<60 µ) to ultra-coarse (>665 µ). It is essential to choose the right nozzle to reduce spray drift and get maximum coverage simultaneously. Droplet sizes are usually measured in microns (micro meters). One micron equals 0.001 mm. The micron is a useful unit of measurement because it is small enough that whole numbers can be used in drop size measurement. By cutting a droplet size in half, we can produce eight times the number of droplets. Hence, with the same amount of chemical we can increase the area of coverage by reducing the droplet size. A nozzle with a coarse or very coarse droplet is usually selected to minimize off target spray drift, while a nozzle with a fine droplet is required to obtain maximum surface coverage of the target plant.

Size of spray droplet is represented as volume median diameter (VMD). The volume median diameter (VMD), which is the midpoint droplet size, where half of the volume of spray contains droplets larger than the VMD in µm and the other half contains droplets smaller than the VMD. To reduce experimental error, Water sensitive papers (7.6 cm x 2.6 cm) were placed at upper and under leaf surfaces at top, middle and bottom canopy of paddy plant to record droplet size received from the spraying nozzle.

Total three paddy plants (three replications) were selected for each trial and WSPs were carefully placed on paddy leaves (Fig. 3). In particular, six WSPs were used per paddy plant. The droplets result in blue deposits when deposited on the WSPs. The WSPs were

carefully removed with clean tweezers and sealed in Ziploc bags after spraying. The collected WSPs were qualitatively analysed for determining droplet size (Tang *et al.*, 2018).

Fig.3: Placement of water sensitive paper to collect spray droplets for measuring droplet size

Data processing

The WSPs were scanned into a digital image with a high pixel resolution (600 dpi × 600 dpi). The droplet size on the WSPs was evaluated via Deposit Scan software (Tang *et al.*, 2018).

Statistical analysis

A Taguchi L-25 orthogonal experimental design was used to evaluate the effects of nozzle type, forward speed and spray height on droplet size. Different combinations of these factors were tested to assess their interactions. Minitab 19 was used for analysing the data (Yang and Tang, 1998). The pareto chart was generated to indicate most significant parameter among selected independent variables based on the standardized effect values at 5% level of significance.

Results and Discussion

Influence of type of nozzle, forward speed and height of spray on droplet size collected from paddy leaves

Pareto chart determine the magnitude and the importance of the effects of operational parameters on performance parameters. On the pareto chart, bars that cross the reference line (2.09) are statistically significant at the 0.05 level. The pareto chart for droplet size at top upper, top under, middle upper, middle under, bottom upper and bottom under surfaces of paddy leaves are presented in the Fig 4, 5, 6, 7, 8 and 9, respectively.

Influence of nozzle type

From pareto chart (Fig. 4 to 9), it was found that nozzle type significantly influenced droplet size. The spinning disc nozzle produced the smaller droplets, followed by hollow cone nozzles and flat fan nozzles .This was due to fact that flat fan, hollow cone and spinning disc nozzles have varying orifice size and discharge rates, which mainly affect the droplet size produced from the nozzle. Similar results were obtained for droplet size at upper and under surfaces of top, middle and bottom canopy of paddy leaves.

Effect of forward speed

The droplet size was not changed significantly as the forward speed. This was in concurrence with the results of Martin *et al.* (2019). Similar results were observed for droplet size at upper and under surfaces of top, middle and bottom canopy of paddy leaves.

Effect of spray height

The droplet size on paddy leaves was found non-significant with the height of spray above the crop canopy at upper and under surfaces of each canopy. However, downwash air flow of drone mounted sprayer break up the droplets into smaller sizes. This may be due to the when height of spray increases it leads to increased air turbulence, longer travel distances and greater exposure to air currents but it does not significantly change the average droplet size.

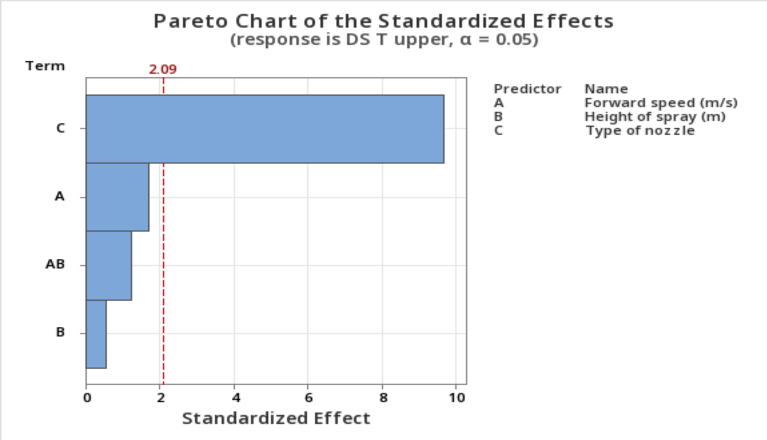


Fig. 4. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at top upper surface of paddy leaves

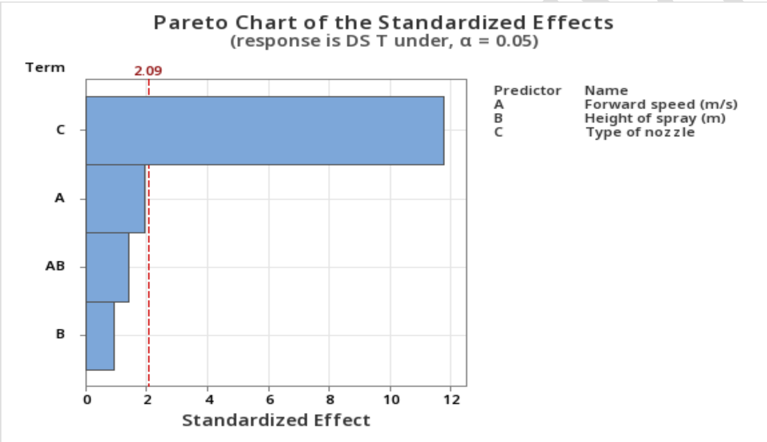


Fig. 5. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at top under surface of paddy leaves

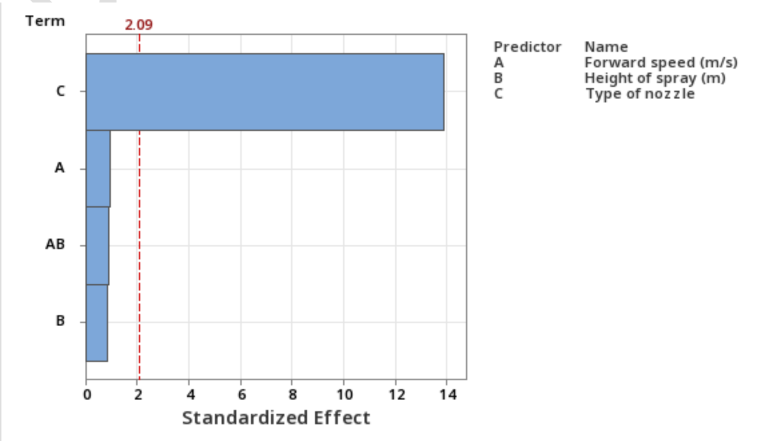


Fig. 6. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at middle upper surface of paddy leaves

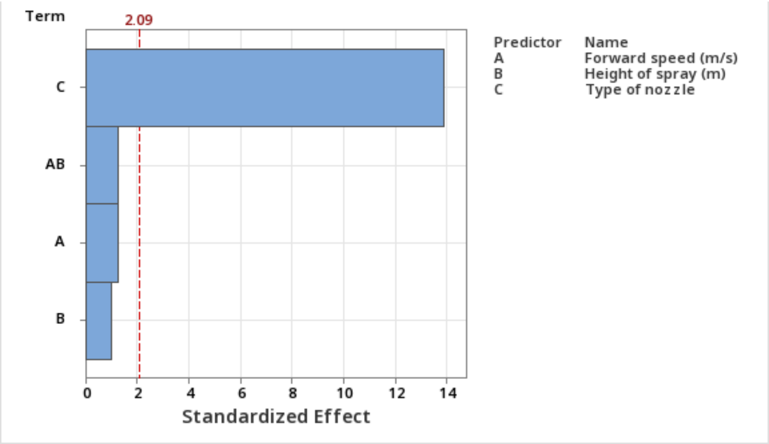


Fig. 7. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at middle under surface of paddy leaves

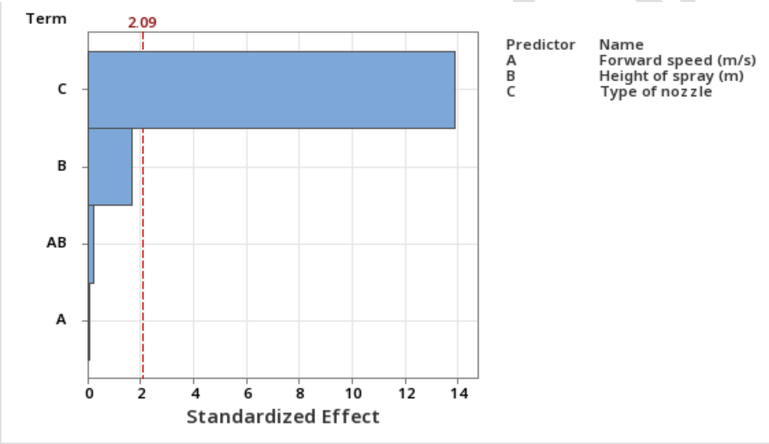


Fig. 8. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at bottom upper surface of paddy leaves

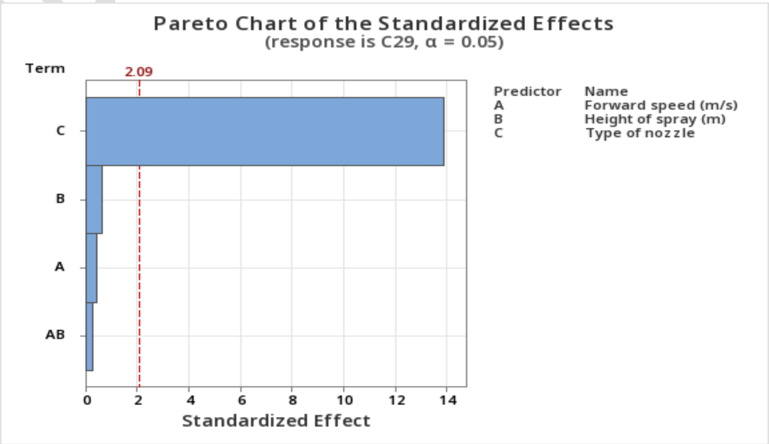


Fig. 9. Pareto chart of the standardized effect of type of nozzle, forward speed and height of spray on droplet size at bottom under surface of paddy leaves

Main effects plot for means

The main effects plot for means (Fig. 10 to 15) describes the mean values of the performance parameter along with the individual response of operational parameters. It was presented that the highest mean value of droplet size on top upper leaves of paddy (Fig.10) was observed at combination of flat fan nozzle, 2 m s^{-1} forward speed and 1.5 m height of spray whereas, the lowest mean value of droplet size on top upper leaves of paddy crop was observed at combination of spinning disc nozzle, 6 m s^{-1} forward speed and3 m height of spray. The main effects plots for droplet size at top under, middle upper, middle under, bottom upper and bottom under surfaces of paddy leaves are presented in the Fig 11, 12, 13, 14 and 15 respectively.

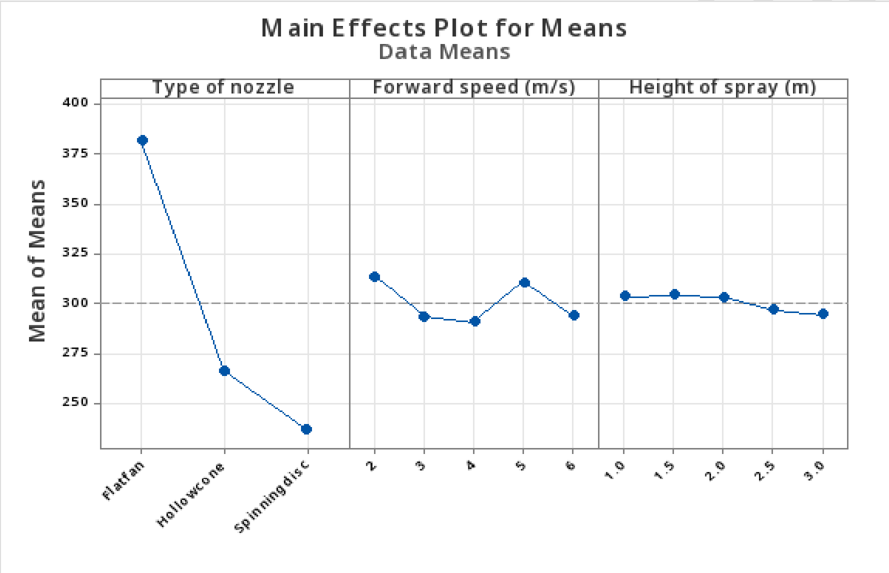


Fig. 10. Main effects plot for means of operational parameters on droplet size at top upper surface of paddy leaves

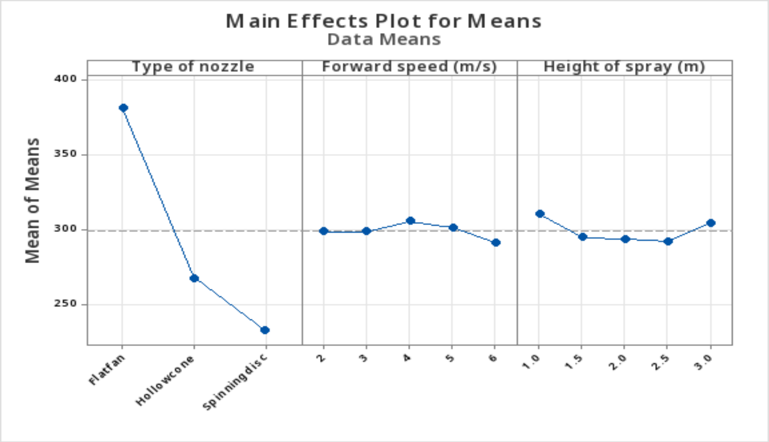


Fig. 11. Main effects plot for means of operational parameters on droplet size at top under surface of paddy leaves

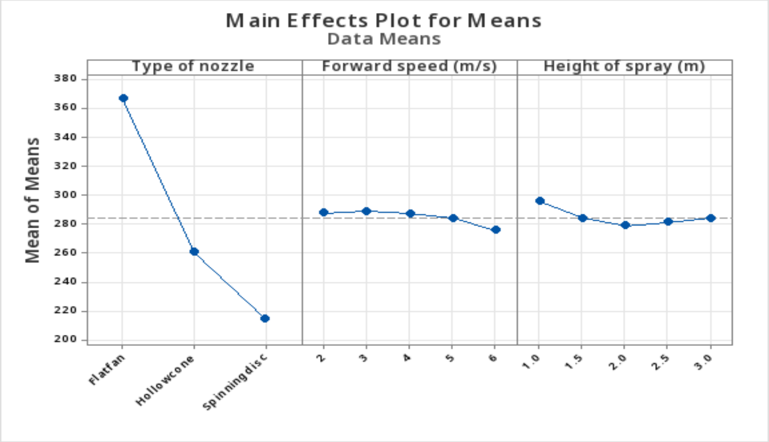


Fig. 12. Main effects plot for means of operational parameters on droplet size at middle upper surface of paddy leaves

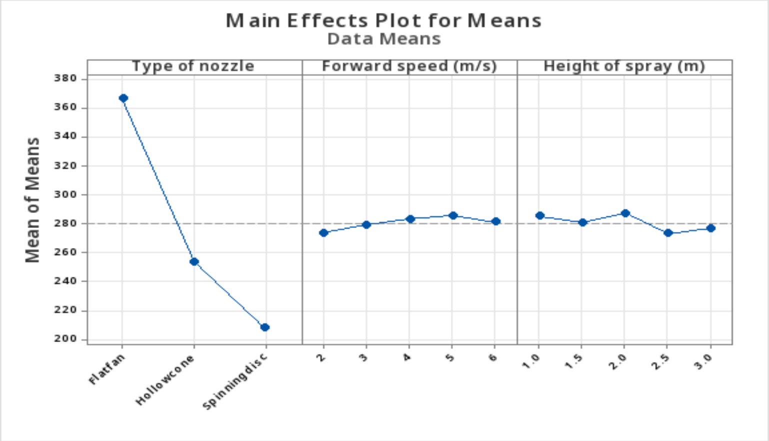


Fig. 13. Main effects plot for means of operational parameters on droplet size at middle under surface of paddy leaves

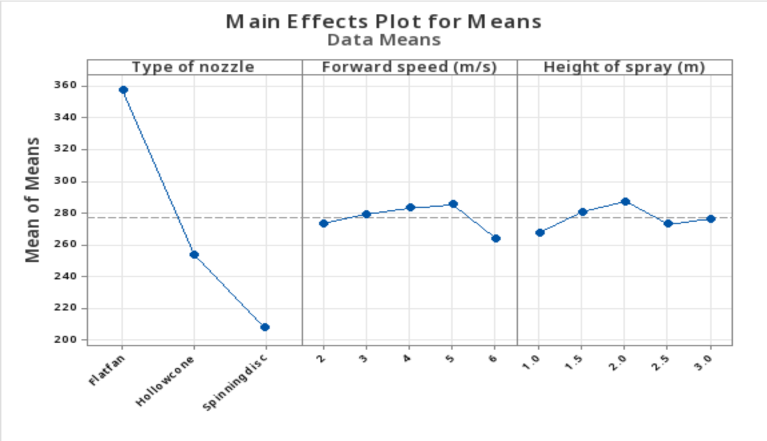


Fig. 14. Main effects plot for means of operational parameters on droplet size at bottom upper surface of paddy leaves

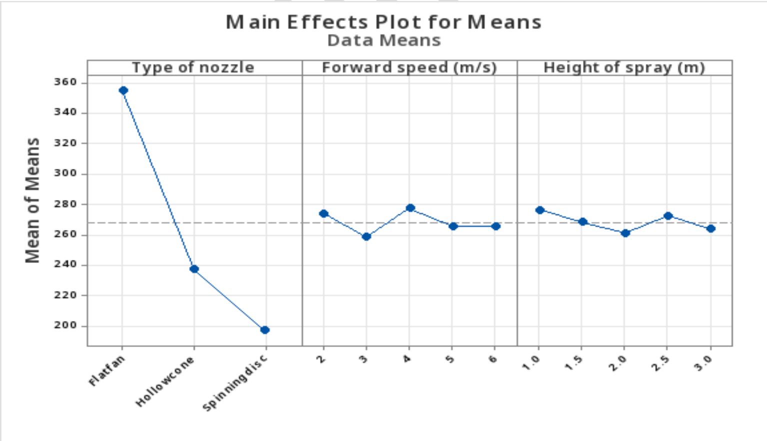


Fig. 15. Main effects plot for means of operational parameters on droplet size at bottom under surface of paddy leaves

Conclusion

The experiments were conducted to know the impact of operational parameters (nozzle type, forward speed and spray height) of UAV sprayer on droplet size in paddy field. This study concludes that the type of nozzle used on the UAV sprayer significantly influence the droplet size during paddy spraying, with flat fan nozzles producing the largest droplets, followed by hollow cone and spinning disc nozzles. In contrast, forward speed and spray height had no significant effect on droplet size. These findings suggest that selecting the appropriate nozzle type is crucial for optimizing pesticide application efficiency and minimizing drift in paddy fields.

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