Spraying Dispersion Analysis with Different Nozzle Types Using a UAV Spraying System in a Paddy Field

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Abstract

This study investigates the ability of Unmanned Aerial Vehicle (UAV) spraying systems to be used as an agriculture spraying method in Malaysia. The operating height of the UAV was 1.5 m with three different nozzles were investigated within a wind speed of 1.15 m/s to determine spray uniformity and dispersion in the paddy field conditions. The results from these samples were evaluated by using ImageJ software. The results show that the droplet distribution by using an electrostatic centrifugal nozzle has a high average droplet density, which is 134.03 deposits/cm2 for the top area and 153.93 deposits/cm2 for the bottom area. The electrostatic centrifugal nozzle also testified to the high value of total droplet deposit at 3478 for the top area and 3255 for the bottom area.

Keywords: UAV, Spraying System, Nozzles, Droplet Density, Average Coverage

1. Introduction

The Malaysian government has spent millions to develop the agricultural sector, mainly to enhance productivity, increase farmers' income, and provide employment [1]. Farmers have been using conventional techniques for seed planting, composting, pesticide application, etc. The traditional techniques used for pesticide and fertilizer spraying not only require more time but also are less effective, so there is a need for technological advancement in this field [2]. Manual spraying operations can be very difficult because of the crop's height.

Therefore, smart farms use drones for spraying, which reduces human contact with fertilizers, pesticides, and other harmful chemicals [3]. Alongside, [1] also reported that farmers' complaints of breathing difficulties during and after spraying of pesticides (51.5%), itchiness and soreness (26%), as well as rashes and peeling of skin on their hands (13.7%). To a more severe extent, there were incidences of farmers collapsing, experiencing stomach aches, vomiting, and being admitted to the hospital. Pesticide exposure was associated with respiratory symptoms such as coughing, wheezing, and airway inflammation [4].

Nowadays, the application of UAV spraying systems is growing at a very fast rate in agribusiness [2]. In this situation, the UAV spraying system is frequently utilized on farms to help farmers as a part of "Precision Agriculture" to modernize farming in developed countries [5]. Using the UAV spraying system for applying pesticides and fertilizer is an exuberant contraption. The UAV spraying system adequately reduces the rate of health dilemmas and the number of workers, which is quite an impressive landmark [6]. The proper selection of a nozzle type and size is essential for proper pesticide application. However, there have been issues reported with nozzle problems in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface, and the amount of potential drift. Nozzles are important not only to break the disposed liquid into droplets but also to form the spray pattern and to propel the droplets in proper directions [7].

In relation to the various problems of the nozzle, this study is aimed at determining the three different types of nozzles' application in the paddy area and estimating the droplet dispersion towards the paddy field to overcome these difficulties.

2. Materials and methods

2.1. *Testing method and data collection*

This study was conducted at the open field near the Centre of Excellence for Unmanned Aerial Systems (COEUAS), Universiti Malaysia Perlis (UniMAP), Malaysia (Latitude: 6.43744 N, Longitude: 100.18868 E) in June 2022. The UAV spraying system was tested at 1.5 m height with a wind speed of 1.15 m/sec, an average temperature of 33° C, and a humidity of 84%. The total area of the field was 140 m x 70 m.

The duration of this test was 2 weeks. The three different types of nozzles that were tested were flat fan, hollow cone, and electrostatic centrifugal with 100% openings. Water sensitive papers (WSP) (7.6 cm x 2.6 cm) were placed with a 1 m gap at the top area and bottom area of the paddy plant to evaluate the water droplets sampled received from the spraying nozzle, as shown in Figure 1.

The water-sensitive papers were placed in the middle of the paddy plant between the upper and lower leaf surfaces to see how far the droplets could penetrate.

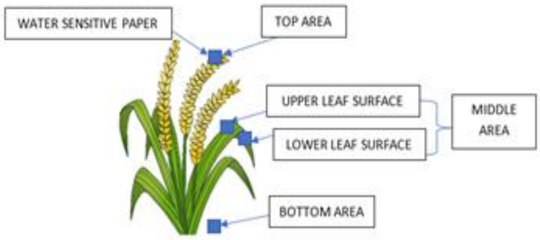

Fig. 1. Water sensitive paper placement

2.2. *Unmanned Aerial Vehicle (UAV) Spraying System Specifications*

In this study, the tested UAV spraying system is the HSSB10L-606 Sprayer Drone, as shown in Fig. 2, which has six arms, six motors, and three types of spray nozzles for this study. The complete specifications of this system are provided in Fig. 3. The spraying tank capacity was 10 liters, with a drone take-off payload capacity of 28 kg. This system had smooth take-offs and landings in its autonomous mode with a flying speed of 0–12 m/s. This UAV spraying system software interface used the IFLY application for instructions of flight height, spray span for overlapping or precise spraying, flight speed, and turn time.

Fig. 2. HSSB10L-606 sprayer drone

UAV part	Description
Number of arms	6
Tank capacity	10 Litres
Maximum take-off capacity	28 kg
Flying time	10-15 minutes
Flying height	0-30m
Flying speed	0-12 m/s
Spray speed	0-8 m/s
Spray width	>4-6m
Spray flow	1-1.15 L/min
UAV size	2.0m*1.3m*0.45m

Fig. 3. UAV spraying system specification

3. Results and discussions

Spray uniformity and dispersion were tested with different nozzles at the same height. The spraying dots imprinted on the water-sensitive paper were scanned using a scanner and uploaded to DepositScan software to determine the average number of droplets on the sample data. Uniformity at 1.5 m altitude with 100% nozzle opening was observed. The results of the deposition analysis for the flat fan nozzle, hollow cone nozzle, and electrostatic centrifugal nozzle are provided in Fig.4 and Fig. 5 below.

Based on Fig. 4, the electrostatic centrifugal nozzle had the highest average droplet density on water-sensitive paper, which was 134.03 deposit/cm² at the top area and 153.93 deposit/cm² at the bottom area, with an average coverage of 24.31 % at the top area and 21.91 % at the bottom area. Then, the total deposit count, which represents the total droplet deposition distribution in the target area, is the highest, which is 3478 at the top area and 3255 at the bottom area.

The penetration index was the lowest value amongst nozzles for droplets to reach from the top to bottom area, at 8%, which was considered that the droplet could penetrate easily to the ground and lower leaf surface that had difficult areas to reach. According to Fig. 4, the electrostatic centrifugal nozzle showed excellent droplet distribution from the top to bottom area for paddy plants because of the smallest mist. [8] proposed that electrostatic forces on tiny droplets are more prominent than gravitational forces; thus, the electrostatic charge of mist droplets can lead to better deposition with less drift.

Next, the test on the flat fan nozzle demonstrated less spray distribution on top but received lots of droplet density on the bottom, which is 1313.5 at the top area and 2629.8 at the bottom area. This nozzle can be rated as defective at all nozzle heights compared to the hollow cone nozzle. The result also revealed the highest penetration index between the top area and bottom areas at 33%, indicating that the bottom area reached more droplets during the spraying process. This process is also similarly stated in [9] research paper that a flat fan nozzle needed improvement in penetration into the crop canopy at an 80-degree nozzle angle.

However, the hollow cone nozzle showed the middle percentage index of penetration between the top area and bottom area, which is 26% with an average droplet density of 48.12 deposit/cm² at the top area and 26.32 deposit/cm² at the bottom area. The total deposit is determined by the lowest number between the nozzles, which is 816 at the top area and 469.8 at the bottom area, indicating that the droplet cannot be distributed evenly or penetrated to the ground area due to the faulty height. [9] also stated that the hollow cone nozzle is suitable for spraying the plant at the early growing stage from the emergence till tillering stage as the plant is still not too high and the density is medium, but after this stage, the hollow cone nozzle is not suitable for use.

Nozzles	Height (meter)	Sampling Site	Average Droplet Density (Deposits/ cm²)	Average Coverage (%)	Penetration index between upper and lower (%) *PI = (U/L)x100%	Total Deposit Counted	Review penetration on Middle area
Flat Fan Nozzle	1.5	Top area	81.63	43.64	33%	1313.5	Yes
		Bottom area	49.08	52.79		2629.8	No
Hollow Cone Nozzle		Top area	48.12	19.17	26%	816	Yes
		Bottom area	26.32	10.48		469.8	Medium
Electrostatic Centrifugal Nozzle		Top area	134.03	24.31	8%	3478	Yes
		Bottom area	153.93	21.91		3255	Yes

Fig. 4. UAV spraying system dispersion by using three different nozzles

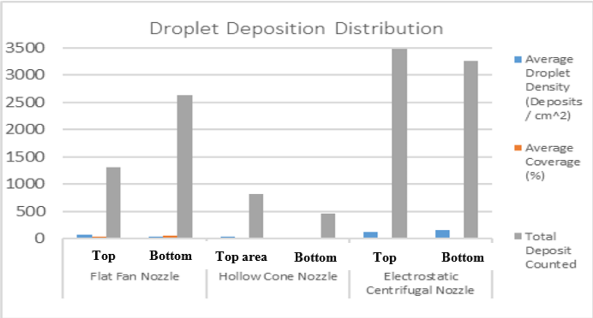

Fig. 5. Droplet deposition distribution

4. Conclusion

In this study, three types of spraying nozzle tests with the same height and same flow rate in a paddy field were carried out. The average droplet density, average coverage, total deposit distribution, and penetration index of droplets in the target area between top and bottom were compared and analyzed in this research. The conclusions are shown as follows:

1. The average droplet density and penetration results of droplet distribution in the target area were influenced by the type of nozzle, height, and flow rate. There were significant differences in the droplet distribution rate in the target area between the three nozzle tests. The average droplet density rate with an electrostatic centrifugal nozzle of 134.03 deposits/cm² at the top area and 153.93 deposits/cm² at the bottom area was the lowest and excellent penetration of the droplet, which is 8%. The droplet distribution rate from the top to bottom of the rice canopy was improved in the target area by using the better type of nozzle.
2. The average coverage results of droplets did not increase the total droplet distribution due to an increase in droplet density, and that of the droplets by using an electrostatic centrifugal nozzle with an average coverage of 24.31% for the top area and 21.91% for the bottom area was the lowest difference and greatest for droplet distribution starting from the rice canopy until to the ground area.
3. The highest total deposit counted of the droplets in the target area by using an electrostatic centrifugal nozzle was 3478 for the top area and 3255 for the bottom area, which indicated that the better droplet distribution was successfully distributed to the target area because of the smallest mist.

The experiment demonstrated that droplet size is one of the most important factors affecting droplet distribution and drift for pesticide spraying. For the application of UAV spraying systems with better spraying, to reduce droplet drift and improve the droplet distribution, the use of nozzles at an appropriate height should be considered downwind of the spraying field to avoid harm to the plant caused by pesticide drift. Furthermore, the shape of the spray pattern profile of a nozzle depends on the type and capacity of the nozzle utilized, which in turn is influenced by the pressure at the nozzle, the height of the nozzle from the spray surfaces, and the angle at which the nozzle is oriented. These should be studied to achieve precision agricultural aerial spraying in the future.

Acknowledgment

The authors would like to thank the Universiti Malaysia Perlis (UniMAP) for providing the facilities and financial support under Pre-Commercialisation Grant, Grant No: 9001-00639.

References

1. Fuad, M. J. M., Junaidi, A. B., Habibah, A., Hamzah, J., Toriman, M. E., Lyndon, N., Er, A. C., Selvadurai, S., & Azima, A. M.,"The Impact of Pesticides on Paddy Farmers And Ecosystem", Advances in Natural and Applied Sciences, 6(1), pp. 65–70, 2012.
2. Hafeez, A., Husain, M. A., Singh, S. P., Chauhan, A., Khan, M. T., Kumar, N., Chauhan, A., & Soni, S. K.," Implementation of drone technology for farm monitoring & pesticide spraying", A review. In Information Processing in Agriculture. China Agricultural University., 2022.
3. Pathak, H., Kumar, A.K., Mohapatra, S.D., Gaikwad, B.B., "Use of Drones in Agriculture: Potentials, Problems and Policy Needs", ICAR-NIASM 12(2), pp. 12-23, 2020.
4. Rudzi, S. K., Ho, Y. bin, Tan, E. S. S., Jalaludin, J., & Ismail, P., "Exposure to Airborne Pesticides and Its Residue in Blood Serum of Paddy Farmers in Malaysia", International Journal of Environmental Research and Public Health, 19(11), 2022.
5. Debangshi, U., "Drone-Applications in Agriculture Drones-Applications in Agriculture", 2021.
6. Rahman, M. F. F., Fan, S., Zhang, Y., & Chen, L.; "A comparative study on application of unmanned aerial vehicle systems in agriculture", In Agriculture (Switzerland), Vol. 11, Issue 1, pp. 1–26, 2021.

7. Johnson, M. P., Swetnam, L. D., & Engineering, A. (n.d.), “Sprayer nozzles: selection and calibration”, Agricultural Engineering.
8. M. Ahmed and M. S. Youssef, “Characteristics of mean droplet size produced by spinning disk atomizers,” J. Fluids Eng. Trans. ASME, Vol. 134, No. 7, 2012.
9. Mairghany, M., Yahya, A., Adam, M., Suhaizi, A., Su, M., & Elsoragaby, S., “Evaluation of Pesticide Spraying Quality in Wetland Rice Cultivation in Malaysia”, 2019.

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