SUGISAKA MASANORI

Journal of Advances in Artificial Life Robotics
Vol. 4(1); June (2023), pp. 41–45
ON LINE ISSN 2435-8061; ISSN-L 2435-8061
https://alife-robotics.org/jallr.html

Research Article

Analysis of Nozzle Effects on Droplet Adhesion in Rice Cultivation Using A Hexacopter Unmanned Aerial Vehicle

Hazry Desa, Muhammad Azizi Azizan, Nurfadzillah Ishak, Tan Yew Tian
Centre of Excellence for Unmanned Aerial Systems (COE-UAS), Universiti Malaysia Perlis (UniMAP), Malaysia

ARTICLE INFO

Article History
Received 09 October 2022
Accepted 05 September 2023

Keywords
UAV
Spraying system
Nozzles
Droplet density
Average coverage

ABSTRACT

This study investigated the potential of a hexacopter unmanned aerial vehicle (UAV) spraying system as one of the agricultural spraying methods in Malaysia. The altitude of the UAV he operated at 1.5 meters and under a wind speed of 1.15 meters per second he tested three different nozzles. The uniformity and spread of application in paddy field conditions were evaluated. ImageJ software was used for evaluation. The results showed that using an electrostatic centrifugal nozzle for droplet dispersion resulted in remarkable average droplet densities, especially 134.03 deposits/cm2 in the upper region and 153.93 deposits/cm2 in the lower region. Furthermore, in the electrostatic centrifugal nozzle, it was confirmed that 3478 droplets were deposited in the upper region and 3255 droplets were deposited in the lower region.

1. Introduction

The Malaysian agricultural sector has received significant investment from the government, primarily to improve productivity, increase farmers' incomes and create jobs [1].

Traditional methods such as manual seed planting, composting, and pesticide spraying are popular among farmers. Spraying pesticides and fertilizers is time-consuming and less effective, so technological advances are essential in the agricultural field [2]. The height of the crop can make manual spraying operations very difficult. As crops grow taller, uniform application of chemicals becomes difficult and inefficient, which can reduce yields. Variation in crop height within a field can lead to uneven application and taller crops can be physically demanding, costly and unsafe for workers. Spraying sparsely can result in poor crop growth and quality, while spraying too much can lead to wasted resources. To address many challenges, the use of mechanized sprayers and drones is increasing to optimize spray application and reduce the burden of manual labor. Therefore, modern agriculture is employing drone technology to reduce direct contact with fertilizers, pesticides, and other potentially harmful chemicals in an effort to keep humans safe. [3].

Correspondingly, findings from [1] revealed significant concerns among farmers, including breathing difficulties during and after pesticide spraying (51.5%), itchiness and irritation (26%), and skin issues like rashes and peeling (13.7%). More severe instances involved farmers collapsing, experiencing stomach discomfort, vomiting, and requiring hospitalization. Pesticide exposure was linked to respiratory symptoms like coughing, wheezing, and airway inflammation [4].

Presently, the adoption of UAV spraying systems is burgeoning within the agribusiness sector [2]. This trend is particularly prevalent on farms as part of "Precision

Corresponding author's E-mail: hazry@unimap.edu.my

"Agriculture", a movement aimed at agricultural modernization in developed countries [5]. The introduction of his UAV spraying system for pesticide application has brought enormous benefits. This technology can reduce health and working conditions [6]. For effective pesticide spraying, selecting an appropriately sized nozzle is most important, but it is also important to quantify the amount of spray, ensure uniform spraying, It is essential to solve the problem of nozzle function, such as minimizing the amount of spray. The nozzle is important not only for breaking up the liquid into droplets, but also for establishing the spray pattern and ejecting the droplets accurately [7]. Given the array of nozzle-related problems, this study aimed to address these challenges by investigating the application of his three different types of nozzles in paddy fields to improve the spread of droplets throughout the paddy field area. It is intended for analysis.

This study aims to address these issues by applying three different types of nozzles in paddy fields and analyzing the droplet spread over the entire paddy field area.

2. Experimental Approach

2.1. *Testing approach and data acquisition*

The research was conducted in an open field near the Center for Unmanned Air Systems Research (COEUAS) at Universiti Malaysia Perlis (UniMAP) in Malaysia. Specifically, latitude: 6.43744 N, longitude: 100.18868 E point. This study was conducted on his June 2022. The UAV spray system was tested at a height of 1.5 meters and a wind speed of 1.15 meters/second. The environmental conditions were an average temperature of 33°C and a humidity level of 84%. The total area of the field is 140m x 70m. The test is for 2 weeks. Three different nozzle types (flat fan, hollow cone, and electrostatic centrifugation) were experimented, all operated at 100% aperture ratio. A 7.6 cm x 2.6 cm water-sensitive paper (WSP) was used to evaluate the distribution of water droplets dispensed from the spray nozzle. Water-sensitive paper was placed at both the top and bottom of the rice field with a gap of 1 meter. This evaluation is shown in Fig. 1.

Water-sensitive papers were positioned within the paddy plants, precisely between the upper and lower leaf surfaces, with the intention of assessing the extent to which the droplets could permeate.

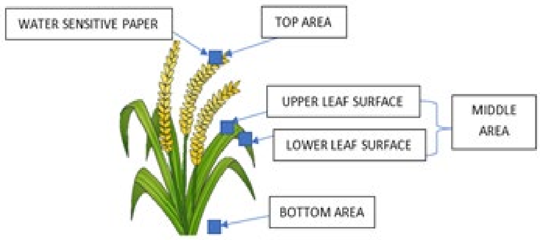

Fig. 1. Arrangement of water sensitive paper

2.2. *Specifications for the UAV Agricultural Spraying System*

This study examines the HSSB10L-606 hexacopter sprayer drone, designated as the tested UAV spraying system, as depicted in Fig. 2. The hexacopter sprayer drone features six arms, six motors, and incorporates three distinct types of spray nozzles for the purposes of this investigation. Fig. 3 contains the comprehensive specifications of this system.

The drone's spraying tank could hold up to 10 liters of liquid, and it had a maximum take-off payload capacity of 28 kg. In autonomous mode, the system exhibited seamless take-offs and landings while maintaining a flying speed ranging from 0 to 12 m/s. The software interface of this UAV spraying system was facilitated by the IFLY application, which provided instructions for parameters such as flight height, spray span to ensure proper overlap or precise spraying, flight speed, and turn time.

Fig. 2. HSSB10L-606 hexacopter sprayer drone

Hexacopter sprayer drone	Specification
Quantity of arms	6
Volume of the tank	10 Litres
Maximum take-off capacity	28 kg
Duration of flight	10-15 minutes
Flying height	0-30m
Flying speed	0-12 m/s
Spraying speed	0-8 m/s
Spraying width	>4-6m
Spraying flow	1-1.15 L/min
Sprayer drone size	2.0m*1.3m*0.45m

Fig. 3. Hexacopter sprayer drone system specification

3. Results and discussions

Various nozzles were assessed for their ability to achieve consistent and widespread spray distribution at a uniform height. The dots created by the sprayed liquid on water-sensitive paper were captured through scanning and subsequently processed using the DepositScan software to calculate the mean droplet count within the sample data. The uniformity of spray dispersion at a height of 1.5 meters was noted when using the nozzle at full 100% opening. The outcomes of the analysis regarding deposition for the flat fan nozzle, hollow cone nozzle, and electrostatic centrifugal nozzle can be found in Fig.4 and Fig. 5 presented below.

Referring to Fig. 4, it is evident that the electrostatic centrifugal nozzle exhibited the most elevated average droplet density on water-sensitive paper. Specifically, this density measured 134.03 deposits/cm² at the upper region and 153.93 deposits/cm² at the lower region. Furthermore, the nozzle achieved an average coverage of 24.31% at the top and 21.91% at the bottom. The total count of deposited droplets, which provides an overall representation of droplet distribution in the targeted area, reached its peak at 3478 in the upper region and 3255 in the lower region.

The penetration index registered the minimum value across all nozzles, standing at 8%. This signifies that droplets could readily permeate through to the ground and lower surface of leaves, even accessing hard-to-reach regions. As indicated by Fig. 4, the electrostatic centrifugal nozzle demonstrated exceptional uniformity in droplet dispersion from the upper to the lower areas in paddy plant applications. This can be attributed to its finely dispersed mist. A previous study [8] suggested that electrostatic forces exert a more pronounced influence on minute droplets compared to gravitational forces. Consequently, the electrostatic charge carried by mist droplets can result in enhanced deposition while minimizing drift.

Subsequently, the examination of the flat fan nozzle showcased diminished spray dispersion on the upper part, while exhibiting substantial droplet concentration on the lower region, measuring 1313.5 on the upper section and 2629.8 on the lower portion. In comparison to the hollow cone nozzle, this particular nozzle's performance can be deemed subpar across all nozzle heights. Additionally, the outcomes unveiled a notably elevated penetration index of 33% between the upper and lower areas, underscoring that a greater number of droplets reached the lower section throughout the spraying procedure.

This procedure aligns with the findings from a study mentioned in [9] where it was indicated that enhancing the penetration of a flat fan nozzle into the crop canopy was necessary, particularly when employing an 80-degree nozzle angle.

Nonetheless, the hollow cone nozzle displayed an intermediate penetration percentage index between the upper and lower regions, measuring 26%. This

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. Dispersion variation in hexacopter sprayer drone system utilizing three distinct nozzles

corresponded with an average droplet density of 48.12 deposits/cm² at the top and 26.32 deposits/cm² at the bottom. The total deposit count, the smaller of the two nozzle values, amounted to 816 at the top and 469.8 at the bottom. This highlights that the droplet distribution and penetration to the ground were hindered due to improper nozzle height. In line with this, [9] also highlighted that the hollow cone nozzle is well-suited for spraying plants during their early growth stages, from emergence until the tillering stage. This is attributed to the plants' relatively lower height and medium density during this period. However, beyond this stage, the hollow cone nozzle's suitability diminishes.

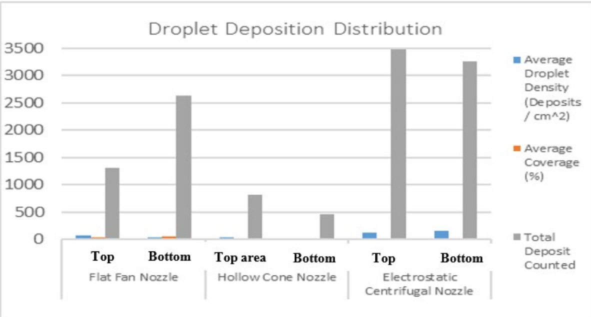

Fig. 5. Distribution of droplet deposition

4. Conclusion

In this study, a comprehensive evaluation involving three distinct spraying nozzle types was conducted within a paddy field, all operating at uniform heights and flow rates. The research encompassed a comparative analysis of various factors, including average droplet density, coverage, total deposition distribution, and droplet penetration index across the target area. The ensuing conclusions are detailed below:

1. The outcomes for both average droplet density and penetration, concerning the dispersion of droplets within the designated region, were notably influenced by variables such as nozzle type, nozzle height, and flow rate. Substantial variations in the rate of droplet dispersion within the designated region were observed across the three nozzle experiments. Notably, the employment of an electrostatic centrifugal nozzle resulted in a lower average droplet density, measuring 134.03 deposits/cm² at the upper region and 153.93 deposits/cm² at the lower region. This configuration also demonstrated exceptional droplet penetration, achieving a rate of 8%. The application of an improved nozzle type effectively enhanced the droplet distribution rate from the upper to the lower portions of the rice canopy within the designated region.

2. The augmentation in droplet density did not result in a corresponding escalation of total droplet dispersion, as evidenced by the average coverage findings. Interestingly, when employing an electrostatic centrifugal nozzle, the discrepancy in coverage was minimal, with 24.31% for the upper region and 21.91% for the lower region. This configuration notably exhibited the most substantial improvement in droplet distribution, extending from the upper reaches of the rice canopy down to the ground area.

3. Utilizing an electrostatic centrifugal nozzle resulted in the most significant total droplet deposition in the designated region, amounting to 3478 in the upper region and 3255 in the lower region. This outcome underscores the successful distribution of improved droplet dispersion within the target area, facilitated by the finer mist produced by this nozzle.

The experiment illustrated that the size of droplets holds significant importance in influencing the distribution and drift of droplets during pesticide spraying. In the context of enhancing the efficacy of UAV spraying systems, it is essential to minimize droplet drift and enhance droplet distribution. This can be accomplished by strategically situating nozzles at an appropriate downwind height relative to the spraying area, thus preventing potential harm to plants due to pesticide drift. Additionally, the configuration of the nozzle's spray pattern profile is contingent upon factors like nozzle type, capacity, pressure, height from the sprayed surfaces, and orientation angle. Investigating these variables is crucial for achieving precise aerial spraying in future endeavors related to agricultural precision.

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.

Authors Introduction

Prof. Dr. Hazry Desa

He received a Bachelor of Mechanical Engineering from Tokushima University, Japan. He was also a senior design engineer at R&D Sony Technology Malaysia, and Tamura Electronics Malaysia and as a researcher at Artificial Life and Robotics Laboratory, Oita University, Japan. He was a Dean at the Center for Communication Skills and Entrepreneurship and the School of Business Innovation and Technopreneurship and later, served as Dean for the Faculty of Engineering Technology at Universiti Malaysia Perlis. He is the director at the Center of Excellence for Unmanned Aerial Systems (COE-UAS) His research interests are in mobile robotics, unmanned systems, and aerial robotics, resulting in notable achievements such as journal publications, patents, and prototype developments in Unmanned Aerial Systems (UAS). He is registered are professional Chartered Engineer (CEng), Professional Engineer (Ir.), Professional Technologist (Ts.), and also as senior memberships in IEEE and IET.

Dr. Muhammad Azizi Azizan

He received his PhD degree in Civil Engineering from Universiti Malaysia Perlis and is currently working as a Senior Lecturer at the same institution. He is also co-founder and director of Haas Solutions Sdn Bhd, a technology startup company of Universiti Malaysia Perlis

Dr. Nurfadzillah Binti Ishak

She received her PhD in Building Engineering from the Universiti Malaysia Perlis. She is currently a Senior Lecturer in the same institution. She is Head of Built Environment Intelligent (BELL) at Centre of Ecellence for Unmanned Aerial System (COEUAS), Universiti Malaysia Perlis.

Ms. Tan Yew Tian

She received her Bachelor’s Degree in Mechatronic Engineering in 2022 from the Faculty of Electrical Engineering Technology from Universiti Malaysia Perlis (UniMAP), Malaysia.