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Research Article

Experimental Analysis of Flight Altitude for Enhanced Agricultural Drone Spraying Performance

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ABSTRACT

Effective rice field management and the proper application of agricultural chemicals are crucial for ensuring agricultural product quality. These chemicals control weeds and protect against insect pests, which can harm crop yields and quality. This research explores the relationship between the altitude at which agricultural drones spray chemicals, spray uniformity, and chemical dispersion. The study assesses drone operations at heights of 1m, 1.5m, and 2m above hollow cone nozzles in 2.8m/s wind conditions. It aims to evaluate droplet uniformity and dispersion on water-sensitive paper placed on paddy plants, analyzed with ImageJ software. Results show that at 1.5m height, there's a significantly higher average droplet density, with 162.7 deposits/cm² in the upper region and 161.8 deposits/cm² in the lower region. Additionally, coverage is notably increased, at 55.21% for the upper region and 51.4% for the lower region. This research highlights the importance of optimal drone altitude for efficient chemical application in rice fields, improving crop protection and yield.

1. Introduction

In line with the Food Security Policy Malaysia 2021-2025 and 12th Malaysia Plan 2021-2025, Malaysia has been actively pursuing paddy and rice sector development. Conventional pesticide spraying has been used, but without considering variations in plant populations and canopies [1] resulting in substantial pesticide usage worldwide [2]. These chemicals combat pests and weeds, affecting crop yield and quality [3]. The World Health Organization also reported that manual pesticide spraying poses health risks [4].

On the other hand, agriculture drone spraying systems have found application in crop monitoring and pesticide application, but there is a need to explore the appropriate spraying altitude and nozzle aperture. This inquiry is crucial due to various issues in the field, including uneven spraying or delayed application [5], as well as challenges related to penetration and uniform distribution among the crops. Research conducted by [6] demonstrated that agriculture drone spraying systems have the potential to boost efficiency by over 60%, while also reducing pesticide usage by 20-30%. Additionally, the autonomous routing capabilities of drones can substantially minimize pesticide wastage and improve fertilizer application, as highlighted in another study [7]. [8] recommended that thorough testing of agriculture drone spraying systems is essential to guarantee precise application. Furthermore, a suggestion was made to maintain a low flight altitude within the 1 to 5-meter range to mitigate the potential for spray drift.

Nonetheless, there is currently a lack of research regarding various flight configurations involving altitude and spray nozzle openings, which could offer valuable insights to farmers seeking to enhance the efficiency of their agriculture drone spraying systems. Conducting such studies could mitigate the potential risks associated with excessive pesticide use, such as external drift and the overlapping of sprayed areas [1].

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In this present study, we have endeavored to assess the dispersion of spray achieved by the agriculture drone spraying system at varying altitudes, with a particular focus on estimating droplet dispersion, particularly in paddy fields.

The results obtained from this study will prove valuable in suggesting optimal spraying techniques for paddy fields utilizing agriculture drone spraying systems, and they also offer an alternative approach to establishing standardized guidelines for the integration of drones in precision agricultural practices.

2. Experimental approach

2.1. *Testing procedure and data gathering*

The study was conducted in an open field located at Universiti Malaysia Perlis (UniMAP) in Malaysia, specifically at the geographical coordinates of Latitude: 6.43744 N and Longitude: 100.18868 E. The field encompassed a total area measuring 140 meters in length and 70 meters in width.

The evaluation of the agriculture drone spraying system's sprayer took place at three different altitudes: 1 meter, 1.5 meters, and 2 meters above ground level. The testing parameters encompassed a wind velocity of 2.8 meters per second, coupled with an average temperature of 33 degrees Celsius and humidity levels at 84%. During the testing, a hollow cone nozzle with full 100% openings was employed. Water-sensitive paper strips, sized 7.6 cm x 2.6 cm, were strategically placed at two distinct locations on the paddy plant. The "upper region" denotes the highest part of the plant, whereas the "lower region" is positioned within 20 cm from the ground. The aim is to evaluate the water droplet sample obtained from the spray nozzle, as illustrated in Fig. 1.

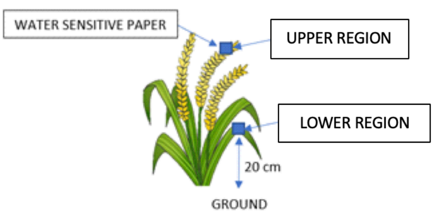

Fig. 1. Positioning of water-sensitive paper

Particular attention was given to the exact positioning of water-sensitive papers, ensuring a 30 cm separation between the left and right sides of the central paddy plant, in order to capture the drone spray markings, as depicted in Fig. 2 and Fig. 3 below. A comparable testing approach to that presented in Fig. 2 was recommended by [9].

The agricultural drone spraying system was set in motion at a speed of 12 meters per second during its journey from point A to B, and its operation was controlled using the IFLY application software. This procedure was repeated 10 times with the hollow cone nozzle. Afterwards, the samples were gathered, and the paper was inspected for dryness before proceeding with the next step. The same methods were employed on various nozzle heights. A total of 300 samples were tested.

The ImageJ software (DepositScan) was utilized to examine the imprints of spray droplets on water-sensitive paper. The count of spray dots per square centimeter was tabulated. When the count of fine spray dots equaled or exceeded 100, the spray was categorized as uniform. The requirement for achieving uniformity in spraying necessitates a spray dot count of 100 or more per square centimeter, which varies based on nozzle height, wind speed, and nozzle opening. This count of 100 is the recommended threshold for achieving uniform spraying. Conversely, if the spray count falls below 100, it signifies that the selected nozzle height, wind speed, and nozzle opening are not suitable for achieving uniform spraying. In such cases, non-uniform spraying may occur, resulting in a waste of resources [9]. The assessment of spray dispersion involved the examination of three key parameters: (i) the evaluation of average droplet concentration on water-sensitive paper was conducted by tallying the number of droplets within a given unit area (measured in deposits/cm^2), (ii) average coverage, which represents the proportion of the water-sensitive surface area covered by the droplets, expressed as a percentage (%), (iii) total deposit counted, which represents the total of droplet deposition distribution in the target area.

Fig. 2. Configuration of the water-sensitive paper sampling area

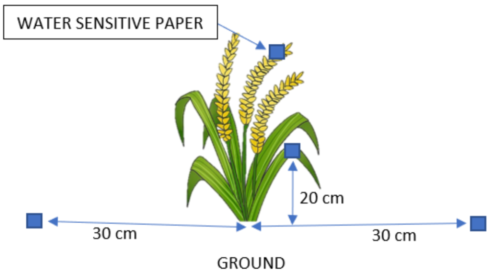

Fig. 3. Segregation of water-sensitive papers from the main plant

2.2. *Specifications for the Agriculture Drone Spraying System*

In this study, the examined agriculture drone spraying system is the HSSB10L-606, illustrated in Fig. 4, which has six arms with six motors, and employs a hollow cone-style spray nozzle. Full details regarding this system's specifications can be found in Fig. 5 below. The spraying tank had a capacity of 10 liters, and the agriculture drone had a take-off payload capacity of 28 kg. In its autonomous mode, this system exhibited seamless take-offs and landings, maintaining a flying speed within the range of 0–12 m/s. The software interface for this drone spraying system relied on the IFLY application to provide instructions for flight height, spray span to ensure overlap or precision in spraying, flight speed, and turn time.

Fig. 4. HSSB10L-606 agriculture drone

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

Fig. 5. Agriculture drone sprayer specification

The hollow cone spray nozzle is used to analyze the effect of spraying dispersion at different heights. The hollow cone spray pattern forms a ring-shaped area, and the spraying angles range from 51 to 144 degrees. This nozzle creates droplets that vary in size from tiny to medium. Smaller droplets offer better coverage and greater penetration potential.

3. Results and discussions

Uniformity and dispersion of the spray were assessed using hollow cone nozzles at various elevations. The spray dots, which left impressions on the water-sensitive paper, were scanned using a scanner and then analyzed with DepositScan software to calculate the average droplet count in the collected data. The tests were conducted at altitudes of 1 m, 1.5 m, and 2 m, employing nozzles fully open at 100% and a wind speed of 2.8 m/sec. As depicted in Fig. 6 below, the spray dots left on the water-sensitive paper exhibit variations in their working heights. The outcomes of the deposition analysis corresponding to this observation can be found in Fig. 7 and Fig. 8 below.

Fig. 8 illustrates a bar graph representing the distribution of droplet density concerning the working height from the nozzle. According to Fig. 7, the hollow cone nozzle positioned at a height of 1.5 meters exhibited the highest average droplet density on the water-sensitive paper. Specifically, it recorded 162.7 deposits/cm² at the upper region and 161.8 deposits/cm² at the lower region. Additionally, it achieved an average coverage of 55.2% at the upper region and 51.4% at the lower region. Subsequently, the total deposit count, indicative of the overall droplet distribution within the designated area, reached its peak at 1003 for the upper region and 885 for the lower region. Notably, the percentage difference in average coverage was minimal across different working heights, measuring at just 0.9%. This observation suggests that droplets effectively penetrated from the upper region to the lower region.

Subsequently, the hollow cone nozzle tested at a height of 2 meters displayed an uneven or diminished spray distribution pattern in terms of droplet density, recording 79.0 deposits/cm² at the upper region and 63.7 deposits/cm² at the lower region. The total deposit count was at its lowest, with 214 for the upper region and 171 for the lower region. Due to the unsuitable altitude setting, there was a 6.9% disparity in the average coverage, signifying an inability to achieve uniform droplet distribution or adequate penetration to the ground area.

The findings also revealed the most significant variance in average coverage, with a margin of 15.5%, indicating that the upper region had a notably higher droplet density compared to the lower region. At a working height of 1 meter, the spray dispersion had a suboptimal impact. Excessive dripping resulted in the saturation of the water-sensitive paper. While this may be suitable for water applications, it is unsuitable for pesticide use. Excessive application of pesticide chemicals may potentially harm the rice crops and result in resource wastage.

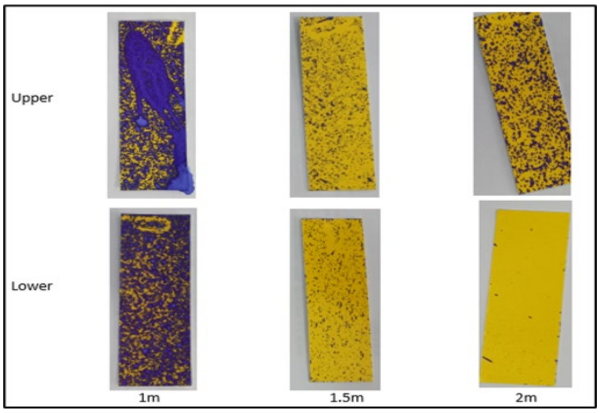

Fig. 6. Distribution of spray at three different operational heights

Nozzles	Height (meter)	Sampling Site	Average Droplet Density (Deposits/ cm²)	Average Coverage (%)	Total Deposit Counted	Average coverage differences (%)
Hollow Cone Nozzle	1	Top Area	79.2	29.71	369	15.5
		Bottom Area	63.7	24.53	320	
	1.5	Top Area	162.7	55.21	1003	0.9
		Bottom Area	161.8	51.4	885	
	2	Top Area	45.7	12.58	214	6.9
		Bottom Area	38.8	3.46	171	

Fig. 7. The dispersion of an agriculture drone spraying system with a fully open nozzle (100%) and a wind speed of 2.8 meters per second

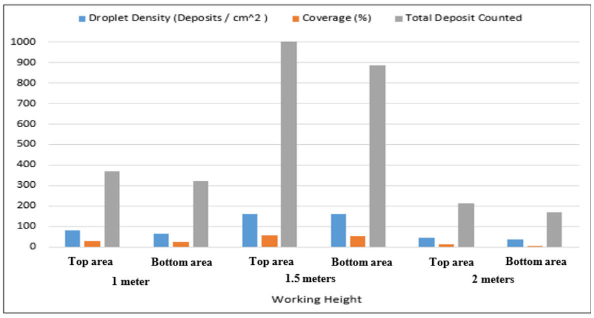

Fig. 8. Distribution of droplet deposition

4. Conclusion

In this study, we employed three different flight heights for the spraying nozzles, utilizing hollow cone nozzles with 100% flow rate openings while taking into account wind conditions in a paddy field. Our research focused on comparing and analyzing three key parameters: the average droplet density, average coverage, and the distribution of deposited droplets in the target area between the upper and lower regions. The findings and conclusions are presented as follows:

1. The average droplet density within the target area was influenced by factors such as nozzle height, wind speed, and flow rate. Significant variations in droplet distribution were observed among the three flight heights. Notably, the average droplet density was highest and yielded excellent results at a flight height of 1.5 meters, with a deposit density exceeding 100

deposits/cm². This finding aligns with the research conducted by [9]. Additionally, the percentage difference in average droplet density between the upper and lower regions was minimal, measuring only 0.9%. This suggests successful penetration of droplets from the upper to the lower area.

2. The average coverage outcomes for the droplets were affected by the overall distribution of droplets, which, in turn, was contingent on the flight height. At a flight height of 1.5 meters, the droplet dispersion exhibited the highest average coverage percentage, reaching 55.21% for the upper region and 51.5% for the lower region.

3. At a height of 1.5 meters, the highest total count of deposited droplets in the dispersion target area was recorded, with 1003 for the upper region and 885 for the lower region. This finding signifies that this nozzle height is well-suited for achieving improved droplet distribution.

The experiment demonstrated that the flight height of the nozzle stands as one of the most pivotal factors influencing droplet distribution and drift in the context of pesticide spraying using agriculture drones. The experimental findings elucidated that, at a flight altitude of 1.5 meters, along with a fully open nozzle (100%) and wind speeds of 2.8 m/s, uniform spraying outcomes were achieved. Recognizing the importance of the matter and thoughtfully choosing a hollow cone nozzle at the right spraying height is crucial for improving the spread of spraying and the even distribution of droplets, while also minimizing the risk of environmental and human harm caused by pesticide drift. Hence, it is essential to explore diverse nozzle types at varying flight altitudes, nozzle angles, and orientations to improve the accuracy of aerial agricultural spraying.

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References

1. Faical, B.S., H. Freitas, P.H. Gomes, L.Y. Mano, G. Pessin, A.C. deCarvalho, B. Krishnamachari and J. Ueyama., "An adaptive approach for UAV-based pesticide spraying in dynamic environments", pp. 210-223, 2017.
2. Pimentel, D., "Pesticides and pest control. In: R. Peshin and A.K. Dhawan (eds.), Integrated Pest Management: Innovation-development process", 2005.
3. Tudi, M., Daniel Ruan, H. Wang. L., Lyu. J., Sadler. R., Connell. D., Chu. C., Phung. D.T., "Agriculture Development, Pesticide Application and Its Impact on the Environment", Int. J. Environ. Res. Public Health, pp. 2-23, 2021.
4. Mogili, R.U.M., B.B.V.L. Deepak, "Review on application of drone system in precision agriculture", International Conference on Robotics and Smart Manufacturing (RoSMa2018), Procedia Comput. Sci., pp. 502-509, 2018.
5. Hussain, S., Cheema, M. J. M., Arshad, M., Ahmad, A., Latif, M. A., Ashraf, S., & Ahmad, S, "Spray uniformity testing of unmanned aerial spraying system for precise agro-chemical applications", Pakistan Journal of Agricultural Sciences, Vol 56, No 4, pp. 897–903, 2019.
6. Qin, W., X. Xue, S. Zhang, W. Gu and B. Wang., "Droplet deposition and efficiency of fungicides sprayed with small UAV against wheat powdery mildew", Int. J. Agric. Biol. Eng. pp. 27-32, 2018.
7. Faical, B.S., F.G. Costa, G. Pessin, J. Ueyuma, H. Freitas, A. Colombo, P.H. Fini, L. Villas, F.S. Osorio, P.A. Vargar, T. Braun, "The use of unmanned aerial vehicles and wireless sensor networks for spraying pesticides", J. Syst. Architect, pp. 393-404, 2014.
8. Gao, Y., "Study on distribution of pesticide droplets in gramineous crop canopy and control effect sprayed by unmanned aerial vehicle, Northeast Agric. Univ. Harbin, China", 2013.
9. Yanliang, Z., L. Qi, Z. Wei. "Design and test of a six-rotor unmanned aerial vehicle (UAV) electrostatic spraying system for crop protection", Int. J. Agric. Biol. Eng, pp. 68-76, 2017.

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