

Study of Spray Fogging Performance Using a Combination of Fogging Machine, Electric Sprayer, and Air Blower

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ABSTRACT

This study aims to determine and analyze the parameters of spray fogging performance for the application of pesticide fog. Air blower spraying performance can be increased by regulating the type of fan and type of air blower. Setting the type of fan in air blower is axial fan and centrifugal combined with cone of 4, 6, and 8 holes. The most optimum combination of the test treatment is the combination of axial fan air blower and 4-hole cone. Spray fogging can be increased by adjusting the combination spray angle between fogging machines and air blowers at various observation distances. The combination spray angle setting is angle of 15°, 30°, and 45° and the observation distance of 1 meter to 4 meters. The results of the analysis and determination of spray fogging performance parameters produce an angle of 45° as the most optimum spray angle from the observation distance of 1 meter to 4 meters. This is indicated by the average value of the droplet diameter of 78.74 µm, a 70 droplet/cm² droplet density, an air flow speed of 1.97 m/s, and the temperature of the flocking of 31.8°C.

1. INTRODUCTION

Palm oil is one of the main commodities in the plantation sector which has a strategic role in the Indonesian economy, both as a source of foreign exchange and as a provider of jobs. According to BPS (2022), palm oil production in Indonesia in 2022 reached 45.58 million tons. As the world's leading producer of palm oil, all stakeholders of palm oil plantations in Indonesia continue to strive to increase palm oil productivity. According to Nurmala & Setiawan (2020), oil palm is a tree whose height can reach 24 meters and oil palm plants begin to mature at the age of planting three years marked by the appearance of male or female flowers. However, in the process of cultivating oil palm, there are challenges in the form of pest attacks and plant diseases.

Pest and disease attacks have the potential to reduce crop yields by 70% and also increase the additional costs required to restore affected plants (Nurhasnita *et al.*, 2020). According to Lubis & Lubis (2022), the aspect of pest control plays an important role in achieving increased palm oil production. The application of good cultivation technology and effective pest control efforts can maintain and increase palm oil productivity sustainably. This point showed that efforts to maintain the productivity of oil palm plants not only involve understanding the factors that influence plant growth, but also the use of appropriate technology in pest control.

Pest control on oil palm plants can be done using pesticides (Simanjuntak *et al.*, 2020). Pesticide application plays an important role in the success rate of pest control. Conventionally, pesticide application to oil palm plants is carried

out using a fogging machine. Fogging machines are used to apply liquid pesticides in the form of fog/smoke due to the very small particle size (Lusmaniar *et al.* 2022). However, the fogging machine has several weaknesses, including weak adhesion and fogging penetration, high fumigation temperature, and relatively low fogging flow rate, so efforts are needed to improve the quality of pesticide application. The quality of pesticide application can be improved by using a combination of a fogging machine, electric sprayer, and air blower. The fogging machine produces smoke with a very fine smoke droplet diameter. The electric sprayer produces pressurized liquid in the form of droplets that will form a mist when bound to the fogging so that it can increase adhesion and penetration. The air blower blows out pesticide mist to reach high oil palm leaves. This study is intended for further examine the performance parameters of spray fogging using a combination of fogging machine, electric sprayer, and air blower on pesticide mist application, so that it can determine the best performance parameters to increase efficiency.

2. MATERIALS AND METHODS

The research was conducted at the Agricultural Machinery and Infrastructure Testing Laboratory (LAMPP), Department of Mechanical Engineering and Biosystems, Faculty of Agricultural Engineering and Technology, IPB University, Bogor. Tools used in the form of portable fogging machine, electric sprayer, air blower, nozzle, stopwatch, patternator, concord paper, mobile spray fogger, ImageJ application, and microsoft excel. The materials used are ink, diesel oil, and gasoline. The function of every these tools and materials can be seen in the Table 1.

Table 1. Function of each tool and material

Tools and materials	Function
Fogging machine	Produces and emits smoke
Electric sprayer	Generates and sprays droplets
Air blower	Blowing out the liquid that comes out of the electric sprayer
Nozzle	Breaking liquid into droplets
Stopwatch	Measuring time
Patternator	Measuring height, width and spray range
Concord paper	Media for capturing droplets and liquid density
Mobile spray fogger	Performance testing tool for combination of fogging machine, electric sprayer, and air blower
ImageJ application	Analyzing droplet diameter and density
Microsoft excel	Processing data obtained from the ImageJ application
Ink	Clarifying droplet fog
Diesel oil	As a tested material
Gasoline	As fuel for fogging machines

2.1. Research Procedures

2.1.1. Component Performance Testing in the Laboratory

The study began with a performance test of each component, namely the fogging machine, electric sprayer, and air blower. The fogging machine was tested to determine the range and effectiveness of fumigation based on the following parameters: air flow speed, fumigation temperature, width, and reach of fogging.

Electric sprayer and air blower were tested with variations in fan types (axial and centrifugal) and nozzle types (4, 6, and 8 holes). Each fan type was combined with nozzle types, resulting in 6 treatments. The observation included liquid pressure and discharge, droplet flow velocity, spray angle, spray width and distance, droplet diameter and density.

2.1.2. Laboratory Data Analysis

Data analysis was carried out by weighting the parameters for each treatment combination to determine the most optimum air blower performance from the air blower performance test data with fan type and nozzle type settings in the laboratory. Each parameter was given a percentage of weight value according to the priority when applying pesticide mist. The weighting parameters for air blower performance test are shown in Table 2 – 7 (Rafidah, 2021; Pramuhadi *et al.*, 2019; Fahri, 2022).

Table 2. Air blower performance test weighting parameters (Rafidah, 2021)

No.	Weighting parameters	Percentage weighting (%)
1.	Total spray coverage	30
2.	Droplet diameter	25
3.	Droplet density	20
4.	Effective spraying width	15
5.	Total spraying discharge	10

Table 3. Total spray range limit class value (Rafidah, 2021)

Class No.	Total spray coverage (m)	Mark
I	2.00 – 2.49	1
II	2.50 – 2.74	2
III	2.75 – 2.99	3
IV	3.00 – 3.49	4
V	3.50 – 3.74	5
VI	3.75 – 4.00	6

Table 4. Droplet diameter limit class value (Pramuhadi *et al.*, 2019)

Class No.	Droplet diameter (μm)	Mark
I	99.12 – 128.30	6
II	128.31 – 158.08	5
III	158.09 – 186.81	4
IV	186.82 – 214.72	3
V	214.73 – 243.49	2
VI	249.50 – 272.48	1

Table 5. Droplet density limit class value (Pramuhadi *et al.*, 2019)

Class No.	Droplet diameter (μm)	Mark
I	68.28 – 97.28	1
II	97.29 – 126.05	2
III	126.06 – 155.10	3
IV	155.11 – 183.95	4
V	183.96 – 211.32	5
VI	211.33 – 239.87	6

Table 6. Effective spraying width limit class value (Fahri, 2022)

Class No.	Droplet diameter (μm)	Mark
I	46 – 51	1
II	52 – 57	2
III	58 – 63	3
IV	64 – 69	4
V	70 – 75	5
VI	76 – 81	6

Table 7. Total spray discharge limit class value (Fahri, 2022)

Class No.	Droplet diameter (μm)	Mark
I	1.10 – 1.20	6
II	1.21 – 1.30	5
III	1.31 – 1.40	4
IV	1.41 – 1.50	3
V	1.51 – 1.60	2
VI	1.61 – 1.70	1



Figure 1. Mobile spray fogger

Specification	Mark (m)
Overall length	1.80
Overall width	0.75
Steering width	0.60
Pole height	3.00
Steering height	1.10
Front wheel diameter	0.30
Rear wheel diameter	0.46



Figure 2. Specification of mobile spray fogger and illustration of α (angle of the air blower nozzle and the fogging muffler)

2.1.3. Performance Testing

Performance the combination of air blower and fogging machine produces fog from mixing droplet and smoke. According to Fahri (2022), fog is formed when air with different temperatures meet and causes condensation of water vapor to form water droplets. In this study, testing the performance of the combination of fogging machine and air blower was carried out using a mobile spray fogger. The mobile spray fogger consists of several supporting components such as a fogging machine, electric sprayer, and air blower. Electric sprayers were chosen because they have advantages such as quieter sound, no pollution, easy to use, and more stable spray pressure compared to power sprayer (Safitri 2021). The mobile spray fogger tool used is as shown in Figure 1. The tool specifications are in Table 2.

The fogging machine is located at the bottom of the air blower and the electric sprayer is located on the base frame. In the air blower, the type of fan and type of nozzle used are the result of a combination of settings that have the most optimum spraying performance with the largest weighting value in the air blower performance test. In this test, the combination settings used are in the form of observation distance and the angle setting of the air blower nozzle to the fogging machine as shown in Figure 2. Performance testing of the combination of fogging machine, electric sprayer, and air blower was carried out by setting a combination of spraying angles of 15°, 30°, and 45° at an observation distance of 1 meter, 2 meters, 3 meters, and 4 meters. The parameters observed in this test are droplet diameter and density, air flow velocity, and fogging temperature.

3. RESULTS AND DISCUSSION

3.1. Fogging Machine Performance Test Results

Fogging machine performance testing was conducted to determine the optimal parameters in the fumigation process. The test was conducted in a closed room (indoor testing) to avoid environmental influences. The parameters tested included air flow velocity, fogging temperature, fogging width, and fogging range. The results of the air flow velocity and fogging temperature tests are shown in Table 8.

Table 8. Air flow rate and smoking temperature test results

No.	Performance Test Parameters	Smoking Distance						
		1 m	2 m	3 m	4 m	5 m	6 m	7 m
1.	Air flow rate (m/s)	2.9	1.9	1.1	0.2	0	0	0
2.	Smoking temperature ($^{\circ}C$)	41.7	39.9	37.8	37.2	36.2	35.3	34.9

Air flow speed plays a role in determining how far the smoke can spread. The measurement results show that the further the observation distance from the fogging machine, the lower the airflow speed due to air resistance. The fogging temperature affects the photosynthesis process of plants. Juanda *et al.* (2020) state that the optimal temperature for chlorophyll formation process ranges between 30–40 $^{\circ}C$ with the best temperature range between 26–30 $^{\circ}C$, so that smoking temperatures that are too high can have a negative impact on the plant photosynthesis process.

The smoking width is calculated from the outermost side of the smoke produced by the fogging machine. The test results show that the average smoking width is 0.5 meters. Fogging coverage divided into effective and total range. Effective range, which is the distance of smoke that is still concentrated in a short time reaches 1 meter, while total range, which is the furthest point that is still affected by fogging reaches 4 meters.

3.2. Electric Sprayer and Air Blower Performance Test Results

The performance testing of electric sprayers and air blowers was carried out to determine the most optimum spraying capability based on the predetermined treatment, namely the setting of the fan type and air blower nozzle. The parameters tested included spraying pressure, droplet flow velocity, spraying angle, effective spraying width, effective spraying height, spraying range, spraying discharge, diameter, and droplet density. The test results of the electric sprayer and air blower performance are presented in Table 9.

Based on the data in Table 9, the pressure values obtained are almost constant for each type of fan. Electric sprayers based on their pressure source are divided into three, namely those that use air pressure, liquid pressure, and a combination of both (Rukmana 2018). The largest liquid pressure value is produced from the use of an axial fan air blower with a 4-hole nozzle, which is 2.45 kg/cm². The smallest liquid pressure value is produced from the use of an axial or centrifugal fan air blower with an 8-hole nozzle, which is 1.45 kg/cm². The same liquid pressure value in various treatments shows that the electric sprayer has a constant spray pressure. The liquid pressure produced is in accordance with SNI 8485:2018 on the minimum pressure requirements of 1 kg/cm² for the electric sprayer (BSN, 2018a).

The largest droplet flow velocity value is produced by an axial fan with a 4-hole nozzle type, which is 5.4 m/s . The smallest droplet flow velocity value is produced by a centrifugal fan with a 6-hole nozzle type, which is 2.1 m/s . The droplet flow velocity value is relatively low when using an air blower with a centrifugal fan because the wind gust from the fan is weaker than the axial fan. According to Ayu (2022), the droplet flow velocity value must be greater than the environmental wind speed value so that the distribution of droplet spread is right on target and the application of insecticides in the field becomes more effective.

Table 9. Electric sprayer and air blower performance test results data

No	Test Parameters	Air blower Axial fan			Air blower Centrifugal fan		
		4-holes nozzle	6-holes nozzle	8-holes nozzle	4-holes nozzle	6-holes nozzle	8-holes nozzle
1.	Spray pressure (kg/cm ²)	2.85	1.85	1.45	2.40	1.90	1.45
2.	Droplet flow velocity (m/s)	5.40	4.70	3.10	2.70	2.10	2.30
3.	Spray angle ($^{\circ}$)	95	64	71	70	50	65
4.	Effective spraying width (m)	0.80	0.72	0.48	0.80	0.48	0.48
5.	Effective spraying height (m)	0.36	0.58	0.51	0.57	0.51	0.38
6.	Effective spraying range (m)	0.48	0.64	0.72	0.56	0.64	0.88
7.	Total spraying range (m)	3.92	3.44	3.52	2.48	2.64	2.56
8.	Spraying rate (liters/minute)	1.16	1.52	1.82	1.14	1.37	1.69
9.	Droplet diameter (μm)	100.92	138.19	118.34	264.62	267.02	133.51
10.	Droplet density (droplet/cm ²)	155	73	68	108	155	72

The largest spraying angle is obtained from the axial fan air blower with a 4-hole nozzle of 95° and the smallest spray angle is produced by the centrifugal fan air blower with a 6-hole nozzle of 50°. The spray angle value is one of the factors that affect the effective spray height value. The greater the spray angle value, the smaller the effective spray height value. If the spray angle value and the effective spray height are both large, it will cause overlapping and spraying becomes wasteful and not optimal. Based on the [SNI 7640:2011](#), the spray angle value obtained from the measurement is in accordance with the performance requirements of the spray angle with a minimum spray angle value of 45° and a maximum spray angle value of 180°.

The effective spraying height value needs to be known so that there is no waste of pesticide solution and the spraying can be distributed optimally. The effective spray height value is influenced by the size of the spraying angle and the effective spraying width. The largest spray height value is produced by an axial fan air blower with a 6-hole nozzle, which is 0.58 m and the smallest spray height is produced by an axial fan air blower with a 4-hole nozzle, which is 0.36 m. Other factors that affect the spray height value are the shape and number of nozzle holes. A large spray height value causes spraying to be less effective because the resulting droplet density will be lower due to the nozzle position being too far from the spray target ([Ayu, 2022](#)).

The effective spraying width (ESW) value is obtained from the intersection distance of the original curve (pure data from direct spraying results) and several overlapping curves that have the smallest coefficient of variation (CV) values. The smallest effective spray width value is produced by an air blower with a centrifugal fan using an 8-hole nozzle, which is 0.48 m. The largest effective spray width value is produced by an air blower with an axial fan or a centrifugal fan using a 4-hole nozzle, which is 0.80 m. The use of an axial and centrifugal fan air blower with a 4-hole nozzle will produce optimum spraying because it has the largest ESW value. An axial fan is a type of fan that circulates air along the axis of rotation of the shaft and the air pressure comes from the rotation of the propeller contained in the fan. Centrifugal fans utilize an impeller that rotates to produce airflow ([Dewangga & Yamin 2020](#)). The greater the ESW value, the more optimal the pesticide spraying will be. This is due to the high effective spray width value show a spread spray pattern so that pesticide application is more even.

The spraying range value is directly proportional to the value of the droplet flow velocity because the greater the value of the droplet flow velocity produced, the spraying range will be further away ([Ayu, 2022](#)). This parameter is measured by spraying directly on the patternator from a horizontal direction in a closed room to prevent the influence of environmental wind speed. Furthermore, the volume of liquid contained in the glass is measured. The value of the volume of liquid contained in each glass is then graphed by dividing the volume value of the X axis so that the result will be $\frac{1}{2}$ the volume of the glass (positive Y) and $-\frac{1}{2}$ the volume of the glass (negative Y). The graph of the spraying range of the air blower using axial fans and centrifugal fans is shown in Figure 3, from which is then re-analyzed to determine the total spraying range and effective spraying range. Effective spraying range (ESR) is the furthest distance with the largest spraying width produced by an electric sprayer and air blower. Total spraying range (TSR) is the length of the total spraying range produced from the end of the blower to the end of the sprayed area. Referring to the Indonesian National Standard SNI 8650: 2018, the minimum total spraying distance is 5 m ([BSN, 2018b](#)).

Based on the data in Table 9, it can be concluded that the total spraying range value is directly proportional to the droplet flow velocity because the higher the droplet flow velocity, the further the total spraying range will be. Based on the total spraying range value, the most optimum spraying range is by using an axial fan air blower with a 4-hole nozzle. The range of effective spraying range is inversely proportional to the speed of the droplet flow because the higher the droplet flow velocity, the effective spraying range value will be lower.

The spray discharge value on all types of nozzles with axial fan air blowers is greater than the spray discharge using centrifugal fan air blowers. The highest spray discharge value is produced by axial fan air blowers with 8-hole nozzles, which is 1.82 L/min. The lowest spray discharge value is produced by centrifugal fan air blowers with 4-hole nozzles, which is 1.14 liters/minute. According to [Blake \(2017\)](#), the characteristics and performance of centrifugal fans depend on the type and shape of the fan as well as the fan blades. The spray discharge value is influenced by the number of nozzle holes and the wind speed produced by the air blower fan.

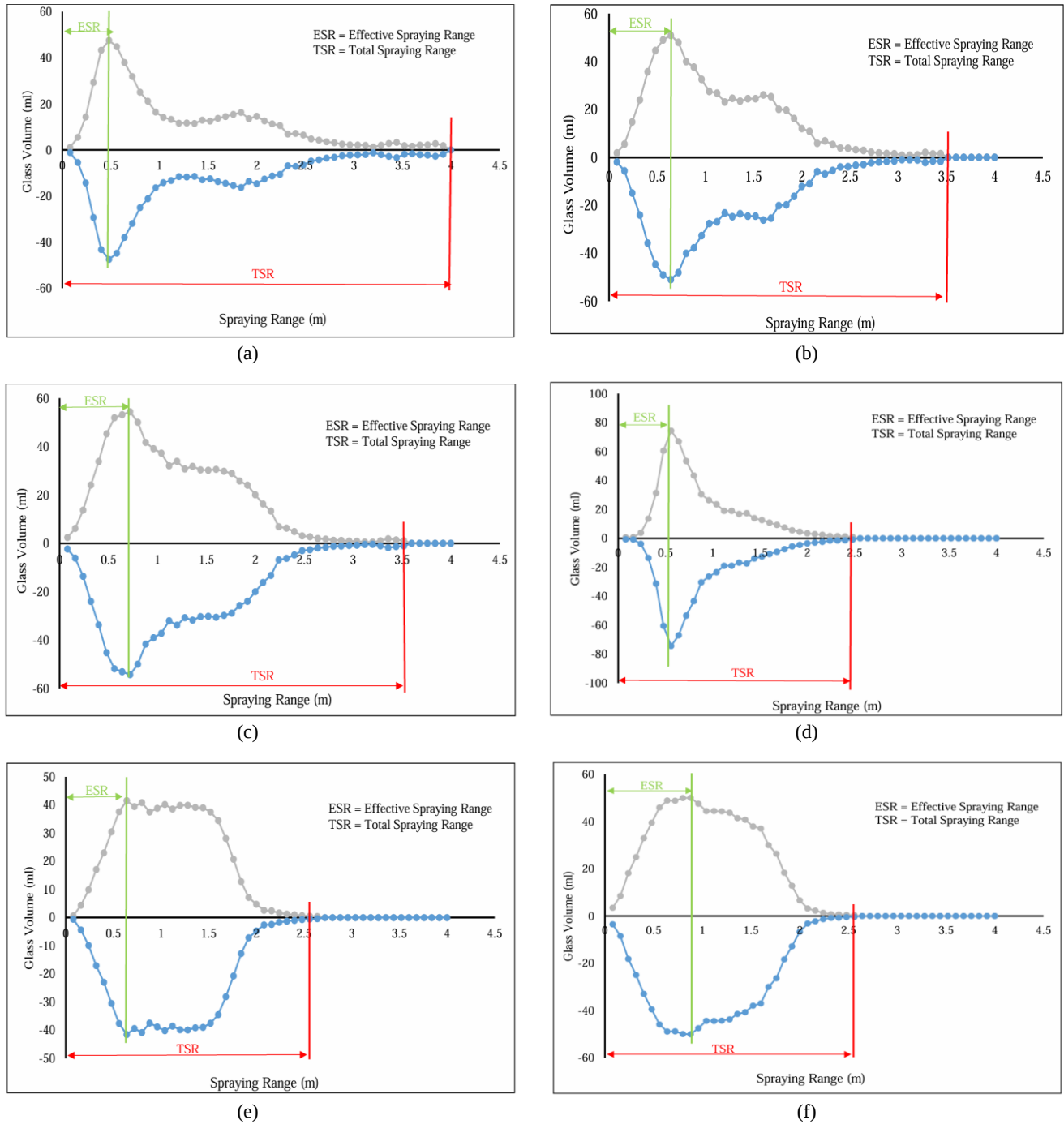


Figure 3 Fogging range of electric sprayer and air blower graph, (a) axial fan with 4-hole cone nozzle; (b) axial fan with 6-hole cone nozzle; (c) axial fan with 8-hole cone nozzle; (d) centrifugal fan with 4-hole cone nozzle; (e) centrifugal fan with 6-hole cone nozzle; and (f) centrifugal fan with 8-hole cone nozzle

Based on the data in Table 9, the measurement of the axial fan air blower with a 4-hole nozzle produces a small droplet diameter and high droplet density due to the influence of the number of nozzle holes and the wind speed produced by the air blower. The cone nozzle used has a varying number of holes and produces a spray pattern resembling a cone with fine droplets (Rizal, 2018). The wind speed produced by the axial fan causes the droplets output from the air blower to be more uniform and the 4-hole nozzle breaks the droplets into finer pieces compared to other types of nozzles.

3.3. Laboratory Data Analysis

Laboratory data analysis is needed to determine the best treatment combination from the performance test data of electric sprayers and air blowers with fan type and nozzle type settings. The performance of the most optimum treatment combination is selected based on five main parameters, namely the largest total spraying range, the smallest droplet diameter, the largest droplet density, the largest effective spraying width, and the smallest spraying discharge. The selection of the best treatment combination is obtained by means of a percentage of parameter weighting as in Table 10 with the assignment of values depending on the class limit value for each parameter. The results of the performance weighting of electric sprayers and air blowers for each treatment are shown in Table 10.

Table 10. Results of weighting of air blower performance test parameters for each treatment

No.	Test Parameters	Percentage	Weighted Value					
			AN4	AN6	AN8	SN4	SN6	SN8
1.	Total spraying coverage	30%	1.8	1.2	1.5	0.3	0.6	0.6
2.	Droplet diameter	25%	1.5	1.25	1.5	0.25	0.25	1.25
3.	Droplet density	20%	0.6	0.2	0.2	0.4	0.6	0.2
4.	Effective spraying width	15%	0.9	0.9	0.15	0.9	0.15	0.15
5.	Spraying discharge	10%	0.6	0.2	0.1	0.6	0.4	0.1
Amount			5.40	3.75	3.45	2.45	2.00	2.30
Ranking			1	2	3	4	6	5

Note: AN = axial fan air blower; SN = centrifugal fan air blower; (4, 6, 8) = number of hole cone nozzles

Based on the weighting results in Table 10, the most optimum treatment (the highest weighted value) was obtained, namely the axial fan air blower with a 4-hole cone nozzle (AN4). The combination of treatments that has the smallest value is the air blower with a centrifugal fan with a 6-hole cone nozzle (SN6). The combination of air blower treatments with the most optimum weighting value will be used for testing the performance of the spray fogger using a mobile spray fogger.

3.4. Spray Fogging Performance Test Results

Performance test parameters are the diameter of fog droplet, fog droplet density, fogging temperature, and air flow velocity obtained from research in the laboratory. The results of the fog droplet each treatment are in Figure 4, fog droplets are displayed as black, while the background is white. Based on the results of the spray atomizer performance test presented in Table 11, the fog droplet diameter value and the droplet density value are directly proportional because the values of these two parameters increase as the observation distance increases. The air flow velocity value and the fogging temperature value are directly proportional because the values of these two parameters decrease as the observation distance increases.

The following discussions explain spray fogger performance based on the relationship between the independent and dependent variables analyzed from the coefficient of determination (R^2). The coefficient of determination is one of the statistical values used to determine the influence between the independent variable (X) and the dependent variable (Y) (Rica *et al.*, 2016).

3.4.1. Air Flow Rate

Based on Figure 5, the lower the air flow velocity value as the observation distance increases. This is caused by the air resistance force so that the further the observation distance, the lower the measured air flow velocity value. Air resistance is a drag force caused by the flow of fluid against a moving object (Desi *et al.*, 2020). The air flow velocity value at a spraying angle of 45° is the highest value at each observation distance and has an R^2 value of 0.99. This is caused by the droplet flow velocity from the air blower binding the fogging which has a low flow velocity and then increasing the air flow velocity. The lowest air flow velocity value at each distance is obtained from a combination spraying angle of 15° which has an R^2 value of 0.95. This is caused by the droplets coming out of the air blower not touching the fogging temperature from the fog machine so that there is no increase in air flow velocity.

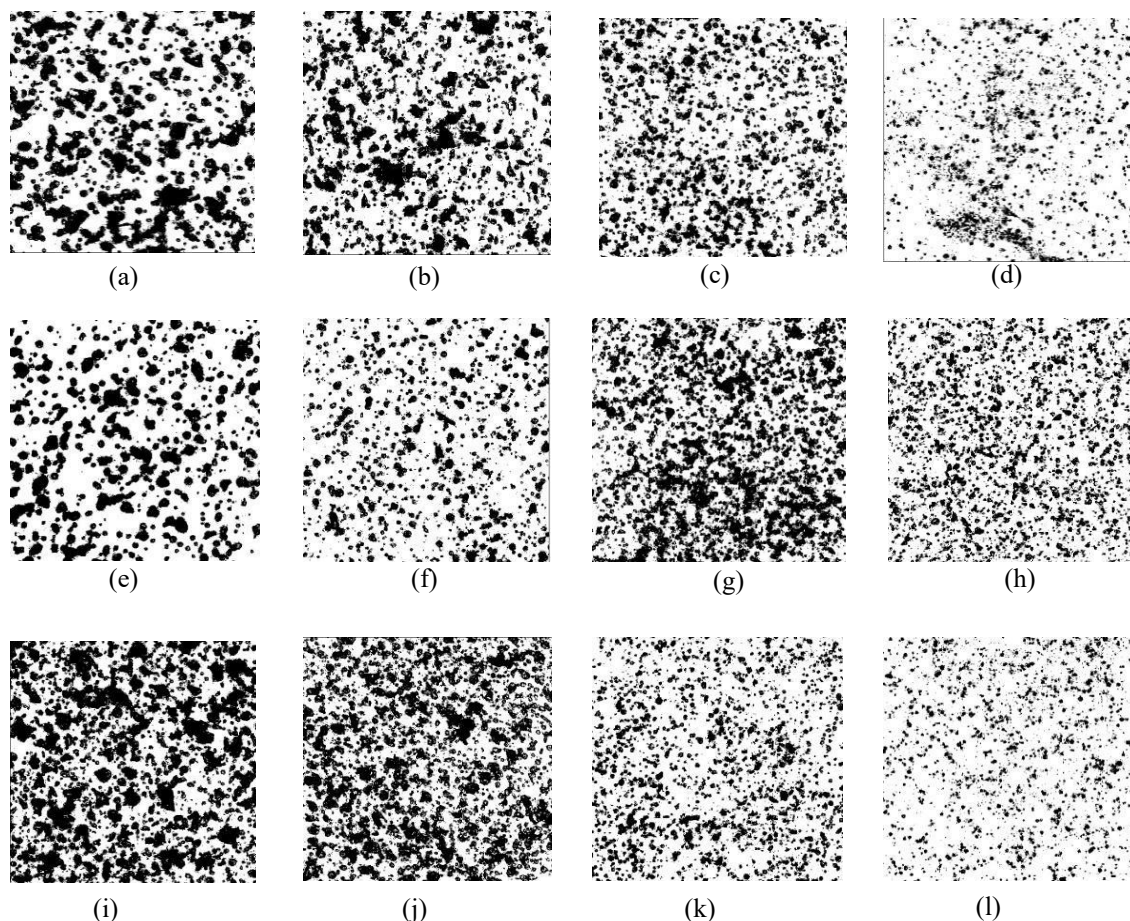


Figure 4. Distribution of spray droplets based on the angle of air blower nozzle and the muffler (α) and distance (d). (a) $\alpha = 15^\circ$, $d = 1$ m; (b) $\alpha = 15^\circ$, $d = 2$ m; (c) $\alpha = 15^\circ$, $d = 3$ m; (d) $\alpha = 15^\circ$, $d = 4$ m; (e) $\alpha = 30^\circ$, $d = 1$ m; (f) $\alpha = 30^\circ$, $d = 2$ m; (g) $\alpha = 30^\circ$, $d = 3$ m; (h) $\alpha = 30^\circ$, $d = 4$ m; (i) $\alpha = 45^\circ$, $d = 1$ m; (j) $\alpha = 45^\circ$, $d = 2$ m; (k) $\alpha = 45^\circ$, $d = 3$ m; (l) $\alpha = 45^\circ$, $d = 4$ m;

Table 11. The results of the performance test of the spray atomizer with a spraying angle of 15°

Angle α Test Parameters	Fogging Distance				Average
	1 meter	2 meters	3 meters	4 meters	
$\alpha = 15^\circ$					
Mist droplet diameter (μm)	61.80	61.80	79.78	71.36	68.68
Density of fog droplets (droplets/cm ²)	44.00	58.00	73.00	82.00	65.00
Air flow velocity (m/s)	1.80	1.30	0.70	0.30	1.02
Fogging temperature ($^\circ\text{C}$)	37.6	34.0	33.0	31.2	33.6
$\alpha = 30^\circ$					
Mist droplet diameter (μm)	71.36	71.36	71.36	79.78	73.46
Density of fog droplets (droplets/cm ²)	32.00	66.00	62.00	87.00	62.00
Air flow velocity (m/s)	2.50	2.30	0.70	0.40	1.47
Fogging temperature ($^\circ\text{C}$)	36.2	34.0	32.0	31.2	33.4
$\alpha = 45^\circ$					
Mist droplet diameter (μm)	61.80	71.36	94.40	87.40	78.74
Density of fog droplets (droplets/cm ²)	46.00	69.00	73.00	91.00	70.00
Air flow velocity (m/s)	4.50	2.00	0.90	0.50	1.97
Fogging temperature ($^\circ\text{C}$)	35.0	32.6	29.8	29.6	31.8

3.4.2. Droplet diameter

Based on Figure 6, the relative droplet diameter value is obtained the larger the distance of observation the further away. The droplet diameter value at a spray angle of 15° is almost the largest value at each observation distance and has an R^2 value of 0.97. This is because the droplets from the air blower at a combination angle of 15° do not touch the smoke from the fogging machine so that the droplets cannot bind the fogging properly. The droplet diameter value at an angle of 45° is the smallest value at almost every observation distance and has the highest R^2 value, which is 0.99, which means that the independent variable (observation distance) can explain the dependent variable (droplet diameter) by 99% and the remaining 1% is explained by other factors. This is because the air blower droplets from a spray angle of 45° touch and intersect the fogging from the fogging machine so that they are able to bind the fogging and form fog properly.

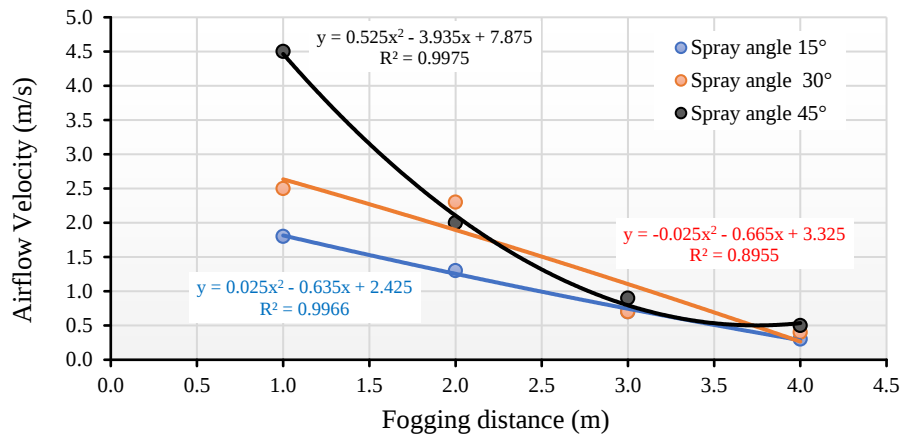


Figure 5. The coefficient of determination (R^2) and the trendline of airflow velocity at each angle and observation distance

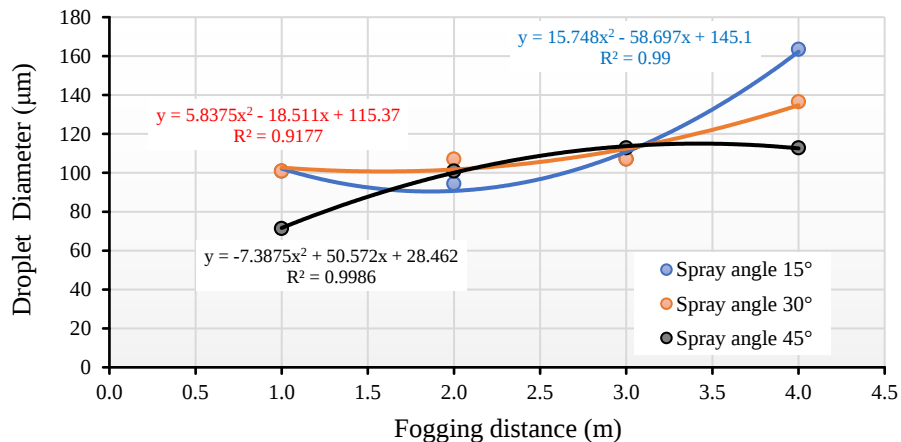


Figure 6. The coefficient of determination (R^2) and the trendline of the fog droplet diameter at each angle and observation distance.

Fahri (2022) used an air blower with a combination of 6 propellers on the air blower fan and an 8-hole cone nozzle type, and obtained the fog droplet diameter of 109.61 µm. This value is greater than the average droplet diameter value of a spray angle of 15° (68.68 µm), spray angle 30° (73.46 µm), and a spray angle of 45° (78.74 µm). This is due to the number of holes in the nozzle. Using a nozzle with fewer holes at constant pressure will break the droplets from the electric sprayer into finer pieces compared to using a nozzle with more holes (Ayu, 2022). This shows that the combination of the axial fan type on the air blower and the 4-hole cone nozzle is better than the combination of the number of 6 propellers on the air blower fan and the 8-hole cone nozzle because it produces finer droplets.

3.4.3. Droplet density

Based on Figure 7, the droplet density value is obtained which is getting higher as the observation distance is getting further. This is caused by the wind speed that pushes the droplets so that the particles are more focused at a long distance (Pramuhadi *et al.*, 2019). The droplet density value at a spray angle of 30° is the lowest value at observation distances of 1 and 4 meters but has an R^2 value of 0.98. The droplet density value at a spray angle of 15° is the lowest value at an observation distance of 3 meters and has the lowest R^2 value, which is 0.94. This is because the measured density is not the density of the fog droplets but the density of the liquid droplets from the air blower because the fog is not formed properly. The droplet density value at a spray angle of 45° is the highest value at each observation distance and has the highest R^2 value, which is 0.99. This is because the droplets from the air blower bind the smoke from the fogging machine so that the fog is formed properly at a spray angle of 45°.

Fahri (2022) used an air blower with a combination of 6 propellers on the air blower fan and an 8-hole cone nozzle type, and obtained the fog droplet density of 326 droplets/cm². This value is higher than the average droplet density value of a spray angle of 15° (65 droplets/cm²), spray angle 30° (62 droplets/cm²), and a spray angle of 45° (70 droplets/cm²). This shows that the combination of the number of 6 propellers on the air blower fan and the 8-hole cone nozzle is better than the combination of the axial fan type on the air blower and the 4-hole cone nozzle because it produces a higher droplet density. The higher the droplet density, the more droplets will stick to the leaf surface so that the pesticide application process will be more optimal (Pramuhadi *et al.*, 2019).

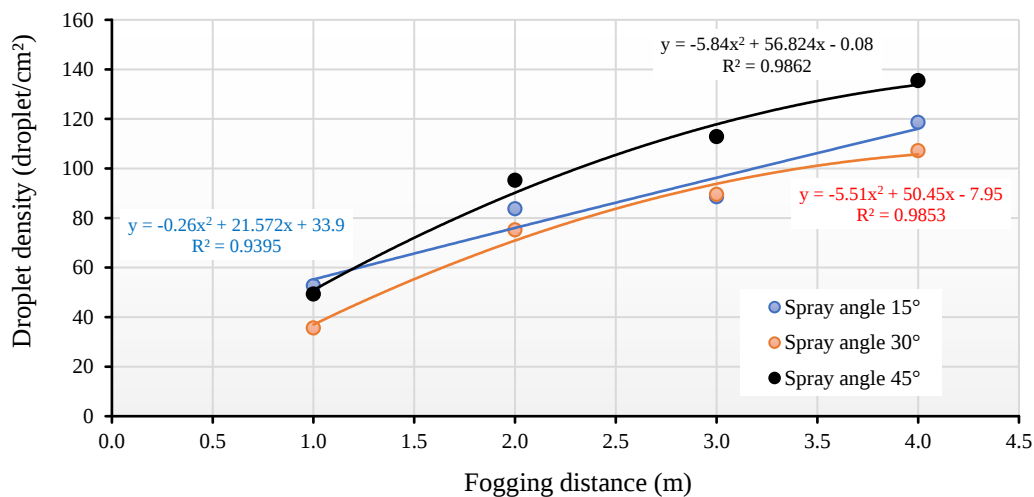


Figure 7. The coefficient of determination (R^2) and the trendline of fog droplet density at each angle and observation distance.

3.4.4. Fogging temperature

Based on Figure 8, the lower the fogging temperature value as the observation distance increases. This is due to the ambient air temperature so that the further the observation distance, the lower the measured fogging temperature value. Fahri (2022) said that the fogging temperature is influenced by the level of fog density, which means that the further the observation distance, the lower the level of fog density, causing the measured temperature to be lower. The fogging temperature value at a spray angle of 45° is the lowest value at each observation distance and has an R^2 value of 0.98. This is because the droplets from the air blower reduce the high fogging temperature from the fogging machine so that the fogging temperature does not damage the surface of the plant leaves. The highest fogging temperature value at each distance is obtained from a combination spray angle of 15° which has an R^2 value of 0.97. This is because the droplets coming out of the air blower do not touch the fogging temperature from the fogging machine so that there is no decrease in the fog temperature.

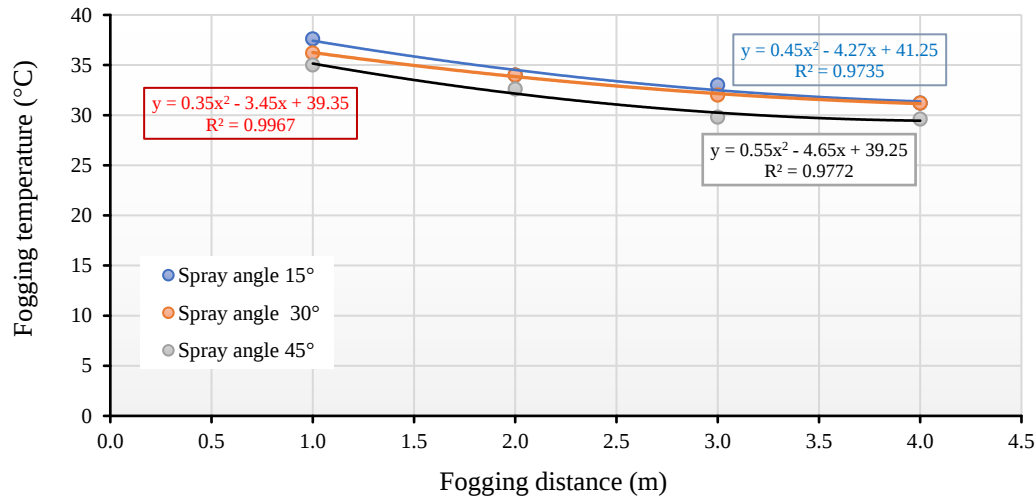


Figure 8. The coefficient of determination (R^2) and the trendline of the fogging temperature for each angle and observation distance.

4. CONCLUSION

The results of the analysis and determination of the performance parameters of the spray fogging with a combination of axial fan type, 4-hole cone nozzle on the air blower, a combination spray angle of 45°, and an observation distance of 1 meter to 4 meters produced an average droplet diameter value of 78.74 μm , a droplet density of 70 droplets/ cm^2 , an air flow speed of 1.97 m/s and a fogging temperature of 31.8°C. The combination of an axial fan with a 4-hole cone nozzle produces finer droplet diameter values, lower droplet density, and lower fogging temperature compared to the combination of 6 blades on the air blower fan and an 8-hole cone nozzle..

5. RECOMMENDATION

The practical application form that can be done is combining a fogging machine, air blower, and electric sprayer using a combination of 45° spray angle settings. This research can be continued by comparing its performance with the performance of a cold fogger to obtain better pesticide fogging results.

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