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Analysis of the Performance of Liquid Fertilization in Cucumber Cultivation

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ABSTRACT

Liquid fertilization can be applied to cucumber plants, including using electric sprayers, electric sprayers and air blowers, and using the mist blower. The three sprayer units are capable of producing fine granules (droplets) that can enter the stomata of cucumbers. This study aims to compare the results of spraying performance using the three methods of liquid fertilization in cucumber cultivation. The research method used is indoor testing in the Sprayer Laboratory to determine the value of the performance parameters of each method of liquid fertilization and outdoor testing to apply liquid fertilizer droplets to cucumbers and determine their effect on the growth and production of cucumbers. The results showed that the first fastest appearance of the flower and the first fruit was in the treatment using electric sprayers and air blowers at 24.6 days after planting (DAP) and 31.5 DAP. This treatment also produces cucumbers with the largest diameter, length, and weight of the fruit of 2.97 cm, 26.10 cm, and 298.28 grams. The accuracy of the dose of liquid fertilization application using an electric sprayer and air blower is 63.41%, an electric sprayer of 59.56%, and the mist blower of 29.90%.

1. INTRODUCTION

Cucumbers (*Cucumis sativus* L.) is one of the vegetable plants that has many health benefits. Data from the Central Statistics Agency for the production of cucumbers in the last 5 years has always increased. In 2017 Indonesia was able to produce 424,917 tons of cucumbers and in 2021 could produce 471,941 tons of cucumbers. This production, however, is much lower than Indonesia's production in 2012 which produced more than 500 thousand tons of cucumbers (BPS, 2021). The decline in cucumber production in Indonesia can be caused by several factors involving climate factors, land conversion, and plant cultivation techniques including fertilization (Tiyandara *et al*., 2020).

Fertilization activities are very important in producing plant growth and crops production. Manure or granules can be given to plants through the soil that will be absorbed by the roots, while liquid fertilizer is applied using a sprayer to produce a fine spray (droplet) that can enter the plant stomata (Purba *et al*., 2021). In addition, liquid organic fertilizer is also considered fast to provide nutrients and does not damage the soil even though it is used routinely (Alex, 2015).

Sprayer is an equipment that functions to break the liquid into fog or droplet distributed evenly to the object. At present, sprayers that are widely used by the community are still of manual types, so it takes a long time. In addition, the intensity and spraying distance is limited. As a result, the distribution of droplets becomes uneven (Rahman & Yamin, 2014).

Droplets can be produced based on the principle of fluid pressure and air pressure. The working principle of fluid pressure is a liquid compressed by the pump, then passing through the nozzle and forming droplets. The working principle of air pressure is that air flow produced by the blower causes liquid drops pushed by air through the nozzle so that forming droplets (Jamaluddin *et al*., 2018). Some types of sprayers that use air pressure working principle include electric sprayers, air blowers, and mist blowers.

Electric sprayers have a constant liquid pressure, the mist blower has a large range of spraying distance, while air blowers have a considerable range of spraying (Pramuhadi *et al*., 2019). The performance of the three sprayers can be assessed based on applying liquid fertilizer droplets to plants and plant growth responses from each treatment after fertilization. The performance parameter of the tool include spraying discharge, effective spraying width, and size (diameter), and the resulting droplet density. Plant growth response parameters include flower appearances, fruit appearance, and fruit dimensions (diameter, length, and fruit biomass weight). In order to determine the performance of liquid fertilization in cucumber cultivation, it is necessary to do research to analyze and compare the results of spraying performance using three methods of fertilizing liquid, namely using an electric sprayer, mist blower, and a combination of electric sprayer and air blower.

2. MATERIALS AND METHODS

The research activity was carried out from March 2018 to October 2018 at the Agricultural Machinery and Infrastructure Testing Laboratory and in experimental field in the Siswadhi Soepardjo Field Laboratory, Leuwikopo, Bogor Agricultural University. This study used three treatments, namely spraying methods using (1) electric sprayers (ES), (2) electric sprayers and air blowers (ESAB), and (3) mist blower (MB). Tools and measuring instruments used for testing the sprayer innvolved a patternator, measuring tapes, measuring cups, stopwatch, arc, scales, and Sharpdevelop software designed to read the number and extent of the test results. The materials used are clean water, ink solution, liquid organic fertilizer, and cucumber seeds. Other supporting materials were also used such as sensitive paper types of concords, supporting bars, mulch plastic, as well as other tools and materials commonly used in cucumber cultivation. Research activities included the performance testing activities of three treatments in the laboratory, cucumber cultivation in dry land, as well as the application of liquid fertilizer using three experimental treatments.

2.1. Sprayer Performance: Laboratory Test

Sprayer performance testing in the laboratory was used as a reference for carrying out testing of liquid fertilization performance in the experimental field. The research parameter consisted of spraying discharge, effective spraying width, as well as the diameter and density of the droplets. According to BSN (2018) spraying discharge is measured using a measuring container and stopwatch by operating a sprayer within a certain period of time and measured volume of liquid that comes out. Spraying discharge was calculated from a measured liquid volume divided by the spraying time.

Effective spraying width (ESW) is determined by spraying liquid fertilizer (with a particular dose of application that has been set) at height of 60 cm above the surface plane of the patternator. The volume of liquid filled the cups was measured and the original chart of droplet volume was made. The chart was then overlapped each other in such a way that the lowest coefficient of variation (CV) was resulted. The ESW was the horizontal distance of the intersection of the points between the original graph and the selected overlapping chart that has the lowest CV value.

Effective spraying height (ESH) becomes the basis or reference for determining the optimum spraying distance to plants. This value is determined based on the width of the ESW and the raying angle which is calculated using equation 1.

$$ESH = \frac{½\ ESW}{\tan\ (½\ \alpha)} \tag{1}$$

where *ESH* is the effective spraying height (m), *ESW* is the effective spraying width (m), and α is spraying angle (^{o}).

Measurement of the diameter and density of the droplet is carried out by spraying the test solution (a mixture of clean water and ink solution) vertically and perpendicular to the test paper (concord type sensitive paper) at a spraying distance of the ESH. Test papers are photographed using a scanner and was analyzed using a SharpDevelop 4.4 computer program which in principle calculates the number of pixels on the test paper and comparing with a number of samples of each item. The pixel points are then converted to the diameter of the droplet in the micron unit (µm). Droplet density is determined by calculating the number of droplet points per unit of area (droplet/cm^2) (Pramuhadi *et al*., 2019).

2.2. Cucumber Cultivation

Cucumber cultivation activities in principle were the same as vegetable cultivation in general. Soil preparation activities were carried out by making a bed of 1.2 m width and a height of 30 cm to 50 cm. Bed soil was given basic fertilizer in the form of manure of 1 kg/m^2 (10 tons/ha). Bed soil was then covered with mulch plastic as a prevention for the growth of weeds around the main plants. Mulch was perforated with a spacing of 30 cm x 60 cm as planting holes. Cucumber seeds were sowed directly on the planting holes. Maintenance of cucumbers included replanting which is carried out in 5 days to 7 days after planting (DAP). Died plants were replaced with new seedlings that have been prepared. Irrigation was carried out routinely twice a day (morning and afternoon), especially in the initial phase of growth. At 5 DAP bamboo rods were arranged to make “ajir” as a support for cucumbers to grow up and maximize the intake of sunlight in plants (Amin, 2015).

Application of liquid fertilizer was conducted using three types of sprayers to be tested and was given every week since the plant was two weeks old after planting up to two weeks before the harvest time (Jumini *et al*., 2012). During maintenance the plant was also observed to record when the appearance of flowers and the appearance of fruit. The appearance of flower shoots was characterized by brownish protrusions on the armpit of leaves. Over time, the bulges grow elongated and the bud will be more clearly visible. After some time the flowers bloom and pistils are ready for pollination. After the pollination process is complete, the flower crown (petals) start to fall out and leaves an ovary (Hamim *et al*., 2019).

Observation of harvesting data was performed twice. The first harvest was carried out after the cucumber plant is 1.5 months old after planting. The second harvest was done one week after the first harvest. The harvest parameter consisted of the length, diameter, and weight of each cucumber fruit.

2.3. Sprayer Performance: Field Measurement

Measurement of sprayer performance on the field was carried out when the sprayer is operated for the application of liquid fertilizer in plants. Liquid fertilizer application to cucumber plants used a concentration according to the instructions in the package of 0.3% (3 cc of liquid fertilizer in 1 liter of clean water) and the target dose of the application was 5 L/ha. The research parameter consisted of effective field capacity, throughput capacity, and the accuracy of fertilizing applications for each treatment. According to Pramuhadi (2012) effective field capacity of fertilization (ha/h) was calculated based on the sum of area of liquid fertilizer applications divided by the time elapsed during the application process. The throughput capacity (L/ha) was calculated based on the amount of spraying discharge (L/h) divided by the effective field capacity of fertilization (ha/h). Spraying discharge was measured in the laboratory by measuring the amount of liquid that comes out of the nozzle of each sprayer of spraying time. The accuracy of the dose of liquid fertilization application (%) was calculated based on the amount of output capacity (L/ha) divided by the specified liquid fertilizer application dose (L/ha) multiplied by 100%. Equation 2 to equation 4 presented the formula to calculate effective field capacity, thoughput capacity, and accuracy of fertilizing applications. In Figure 1, fertilization activities were shown using three methods of application of liquid fertilizer spraying in cucumber cultivation field.

$$EFC = \frac{A}{T} \tag{2}$$

where *EFC* is the effective field capacity (ha/h), *A* is field area of liquid fertilizer applications (ha), and *T* is time elapsed during the application process (h).

$$TC = \frac{SD}{EFC} \tag{3}$$

where *TC* is the throughput capacity (L/ha), and *SD* is spraying discharge (L/h).

$$ADA = \frac{TC}{DOS} 100\% \tag{4}$$

where *ADA* is accuracy of the dose of liquid fertilization application (%), and *DOS* is specified liquid fertilizer application dose (L/ha).

Figure 1. Application of liquid fertilizer in cucumber cultivation field

3. RESULTS AND DISCUSSION

3.1. Sprayer Performance: Laboratory Test

The spraying treatment using an electric sprayer and air blower (ESAB) has a spraying discharge (SD) relatively larger than those of the electric sprayer (ES) and the mist blower (MB). The pressurized air from the air blower pushes the liquid that comes out of the nozzle relatively faster than the electric sprayer which only presses the liquid from the liquid pump. Mist blower spraying discharge is the lowest, lower than that of electric sprayer because the liquid from the mist blower tank drops (exit) gravitationally and then blown by the pressurized air from the blower. The amount of spraying discharge is also influenced by the type of nozzle used, as shown in Table 1.

Table 1. Performance of three spraying methods in the laboratory

Spraying methods*	Nozzle type	Performance parameters			
		Spraying discharge (L/h)	Effective spraying width (m)	Droplet diameter (µm)	Droplet density (droplet/cm^2)
ES	Double	99.78	0.72	768.24	46.68
	Shower	137.16	0.48	589.30	41.42
	Solid cone	106.14	0.64	670.64	45.80
	Flat fan	103.62	1.20	598.26	48.04
	Hollow	133.92	0.72	584.92	62.32
ESAB	Shower 5 H	141.06	0.80	330.97	76.67
	Shower 8 H	137.76	0.64	332.04	63.86
	Solid cone	103.38	0.56	382.04	58.16
MB	-	65.16	0.64	357.95	294.99

* ES = electric sprayer; ESAB = electric sprayer and air blower; MB = mist blower

Spraying discharge is basically influenced by the type of nozzle and spraying pressure (Dharmawan & Soekarno, 2020). The size of the hole and the number of holes in the nozzle affect the amount of spraying discharge. In addition, the water pressure on the sprayer increases the speed of the water flow, so that the spraying discharge increases. Nozzle with a large number of holes as in the shower nozzle causes the amount of spraying discharge increase. The presence of air flow in air blowers also causes greater spraying discharge. While the low value of spraying discharge on the mist blower can occur because the flow of water on the sprayer hose only relies on the influence of gravity.

The amount of effective spraying width (ESW) in Table 1 is influenced or determined by the type of nozzle. Flat fan type nozzle shows the largest ESW value because the distribution of droplets forms a flat shape like a fan where the major diameter is much larger than the minor diameter. Cone type nozzles, such as solid cone, shower, or hollow cone, produce ESW that are lower than the flat fan type nozzle. The shape of the droplet distribution of the cone type nozzles produce a droplet spray pattern that approaches the circle where the major diameter and the minor diameter are almost the same.

Information regarding the width of the nozzle spray is important for the operator to adjusts to the area to be sprayed. For example, to spray the plant close to the media, a nozzle that has a long spray width can be selected, so that the main plants are exposed to spray solutions well (Sari & Prasetio, 2021).

The success of spraying is largely determined by the level of coverage, namely the number of spray particles that cover the target field (droplet density). The more number of spray particles in each unit of the target area, the more likely regarding the object being sprayed and the greater the success of spraying (Prabaningrum, 2017). Small (smooth) droplet with large droplet density will easily enter stomata in large quantities. Both of these parameters will greatly determine the quality of spraying liquid fertilizer to crops and become the basis for determining or selecting the type of nozzle used in the sprayer (Hermawan, 2014).

Table 1 also shows that the hollow type cone nozzle in the electric sprayer has the smallest droplet diameter of 584.92 µm and has the largest droplet density of 62.32 droplet/cm^2 so that it can be selected for the application of liquid fertilizer in the cucumber cultivation. The 5-holes shower type cone nozzle in the electric sprayer and air blower also has the smallest droplet diameter of 330.97 µm and has the largest droplet density of 76,67 droplets/cm^2 so that it can also be selected for the application of liquid fertilizer in cucumber cultivation. Mist blower only has one type of nozzle with a 357.95 µm droplet diameter and a droplet density 294.99 droplet/cm^2, so that the use of the mist blower is directly applied to the plant without considering the type of nozzle used.

3.2. Cucumber Production

The application of liquid fertilizer in cucumber cultivation is carried out with three types of sprayers using different nozzles. The selection of the nozzle is based on the number and size of the resulting droplet. Hollow type cone nozzles are used in electric sprayers (ES), 5-holes shower type cone nozzles are used in electric sprayers and air blowers (ESAB), and the mist blower (MB) uses only one type of nozzle installed on the mist blower pipe output channel.

Time when the emergence of flowers and fruits is important to assess the ability of plants in managing nutrients so that the generative phase of cucumbers goes well. The day of the first emergence of flowers indicates the generative phase in plants begins (Marhaeni *et al*., 2018). This phase is strongly influenced by the number of nutrients possessed by plants, including fertilizer that is supplied by sprayer. The results of liquid fertilization performance using three spraying methods show that the first flower appearance and the first fruit appearance gives different results, as shown in Table 2.

Table 2. Observations of the appearance of flowers and cucumbers

Spraying method treatments	Nozzle type	First Appearance (DAP)	
		Flower	Fruit
Electric sprayer	Hollow	25.5 a	32.5 a
Electric sprayer and air blower	Shower 5-holes	24.6 a	31.5 a
Mist blower	-	33.5 b	40.3 b
F calculated		11.38*	10.46*
F table		3.35*	3.50*

*Analysis of variation (α = 0.05) using Duncan's Multiple Range Test

The growth of cucumbers was analyzed using the ANOVA and the Duncan's Multiple Range Test (DMRT). This observation was carried out using three spraying treatments, but the results of the control treatment were not displayed because in the control treatment there were several samples died. The results of cucumber growth parameters indicate that F calculated is greater than the F table, meaning it is necessary to do further tests using DMRT. The results of the DMRT analysis show that the treatment using the mist blower is significantly different from the treatment using an electric sprayer and treatment using an electric sprayer and air blower.

The results of the study (Table 2) show that the fastest appearance of the first flower and the first fruit are found in the treatment of electric sprayers and air blowers which is 24.6 days after planting (DAP) and 31.5 DAP. Based on the DMRT test the first flower appearance and the first fruit emergence in the electric sprayer (ES) is not significantly different from that the electric sprayer and air blower (ESAB). The both treatments use ES and ASB indicates a better value than spraying using the mist blower (MB). The treatment of electric sprayers and air blowers has a smaller droplet diameter and a greater droplet density so that the droplet is easier to enter the stomata in large quantities and causes the response to the growth of cucumbers to be faster.

Other observations of other cucumber growth include the dimensions or sizes of cucumber fruits (diameter, length, and weight). According to Zulkarnain (2013) a good cucumber should have 100 g up to 200 g with a diameter of 2 cm up to 4 cm and length of 7 cm up to 10 cm. Table 3 shows the results of observations and the ANOVA analysis of the sizes of cucumbers.

Table 3. Observation results of the dimension of Cucumber fruit

Spraying method treatments	Nozzle types	The average size of cucumbers		
		Diameter (cm)	Length (cm)	Weight (g)
Electric sprayer	Hollow	2.89 a	23.13 b	231.42 b
Electric sprayer and air blower	Shower 5-holes	2.97 a	26.10 a	298.28 a
Mist blower	-	2.79 a	22.95 b	230.00 b
Control		2.68 a	20.98 b	196.03 b
F calculated		1.48	5.71*	4.89*
F table		2.72	2.72*	2.72*

*Analysis of variation (α = 0.05) using Duncan's Multiple Range Test

Table 3 shows that in the diameter the results of the F calculated are smaller than the F table, which shows that there is no significant difference of the three treatment methods of spraying to the control treatment, or among the three treatments of spraying methods used. Thus, it cannot be stated that one treatment is better than other treatment. From Table 3 it can be showed that the spraying method using ESAB (electric sprayer and air blower) gives the largest diameter of cucumbers of 2.97 cm (but not statistically different with the others).

The results of the DMRT analysis show that the treatment of spraying methods using electric sprayers and air blowers (ESAB) is significantly different from the treatment of spraying methods using electric sprayers, using a mist blower, and control. The DMRT test display the length (26.10 cm) and weight (298.28 g) of the average cucumber in the treatment using ESAB are significantly greater than those of the other three treatments.

3.3. Sprayer Performance: Field Measurement

Performance of the three spraying methods can be assessed and compared based on the results of measurement and calculation of effective field capacity, throughput capacity, and accuracy of the dose of liquid fertilizer application. Table 4 shows the results of spraying performance in the experimental field using three spraying methods.

Table 4. Spraying performance in experimental field

Treatment parameters	Unit	Spraying methods*		
		ES	ESAB	MB
Effective field capacity	ha/h	0.0145	0.0148	0.0142
Throughput capacity	L/ha	2.98	3.17	1.49
Accuracy of the dose of liquid fertilizer application**	%	59.56	63.41	29.90

* ES = electric sprayer; ESAB = electric sprayer and air blower; MB = mist blower
** = Dosage of defined liquid fertilizer application = 5 L/ha

Effective field capacity is the total operating time of a tool or machine to complete work on a particular field area. The magnitude of this field capacity is influenced by the operator's skills, the type and condition of the machine used, the type of vegetation applied, and the soil condition (Gunawan, 2014). The main factor that is the basis of this research is the type of tool used. Effective field capacity in the spraying method using an ESAB (electric sprayer and air blower) shows the largest value of 0.0148 ha/h because this method is capable of producing ESW (0.80 m), higher as compared to other treatments (Table 1). The different spraying width causes the area of the land to be sprayed using an ESAB is larger than the other treatments, so that spraying activities can run faster. This is in line with the statement of Karimah *et al*. (2020) that the width of work affects the effective field capacity.

Large spraying discharge also affects the amount of output capacity and accuracy of the dose of liquid fertilizer application. Spraying method using an electric sprayer and air blower has the largest spraying discharge of 141.06 L/h (Table 1). This condition results in the amount of throughput capacity and accuracy of the dose of liquid fertilizer application to be the largest of 3.17 L/ha and 63.41% as shown in Table 4.

4.CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

The used of spraying methods using an electric sprayer and air blower (ESAB) resulted in the fastest appearance of the first flower and the first fruit, which is at 24.6 DAP and 31.5 DAP. This treatment also produces cucumbers with the largest diameter, length, and weight of the fruit of 2.97 cm, 26.10 cm, and 298.28 g, respectively. The accuracy of the dose of liquid fertilization application using an electric sprayer and water blower (ESAB) is 63.41%, an electric sprayer (ES) is 59.56%, and the mist blower (MB) is 29.90%.

4.2. Recommendations

Research like this can still be continued and developed in order to be more complete by involving the study of engineering economy analysis so that it can eventually be used as a reference in cucumber cultivation in Indonesia.

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