Mist blower performance for liquid fertilizing on eggplant vertical culture cultivation system

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Abstract. The objective of the research was to test the performance of two types of knapsack mist blowers for liquid fertilizing on eggplant vertical culture cultivation system. The research was conducted from March to June 2019 at the Sprayer Laboratory, Leuwikopo, Bogor, West Java, Indonesia, to determine parameters of droplet diameter, droplet density, effective spraying width, and effective spraying debit. The research was also conducted on the field of Siswadhi Soepardjo Field Laboratory, Leuwikopo, to determine the harvested weight of eggplants. Spraying tools and material were knapsack mist blower type A (Shandong 3WF-3), knapsack mist blower type B (Tasco MD-160), and liquid fertilizer. Results of the research showed that mist blower type A had less wind speed and more nozzle vanes number than mist blower type B so that it influenced their liquid fertilizing performances. Mist blower type A produced smaller or finer droplet diameter, larger droplet density, and smaller effective spraying debit than mist blower type B, whereas mist blower type B produced larger effective spraying width than mist blower type A. Mist blower type A and type B produced droplet diameter, droplet density, effective spraying width, and effective spraying debit were 301.51 micronmeter, 64.63 droplet cm⁻², 64 cm, and 2.37 liter min⁻¹, and 331.12 micrometer, 181.28 droplet cm⁻², 72 cm, and 3 liter min⁻¹ in average respectively. Mist blower type A has produced maximum harvested eggplants weight of 96.22 g/fruit on average on the optimum walking speed of 0.92 m/s with 2 liter ha⁻¹ liquid fertilizer dosage. Mist blower type B has produced maximum harvested eggplants weight of 61.66 g/fruit on average on the optimum walking speed of 1 m s⁻¹ with 2 liter ha⁻¹ liquid fertilizer dosage.

1. Introduction
Conventional eggplants cultivation was commonly conducted by farmers on a seedbed dry land with 60-70 cm row spaces, so it must be planted on a large dry land area to get high eggplants production. Eggplants’ vertical culture cultivation system became a solution for small dryland areas. Vertical culture cultivation is a planting system on pots or polybags that arranged in a stack [1].

Maulana [2] described that plant production raising depends on its irrigation, fertilizing, pest control, and condition monitoring of the growing environment. Azhari [3] revealed that liquid fertilizing was a solution to get an optimum nutrition application for plants growing. The liquid fertilizing can be done by taking advantage principles of air and liquid pressures which is breaking the liquid to be fine particles or droplets so that it can be spread evenly and effectively to leaves surface or stomata.

Now many knapsack sprayers were used by farmers. It takes a long time to apply liquid fertilizer and has a constrain in limited spraying distance so that its liquid fertilizing become unevenly [4]. A knapsack mist blower was a sprayer that can spread liquid in the form of droplets with constant high air pressure and large reach of spraying.
Forward walking speed of mist blowing operation would become a factor that influenced its mist blowing performance. Lower walking speed would produce too much liquid fertilizer dosage and very high liquid fertilizer consumption, whereas higher walking speed would produce very poor liquid fertilizer dosage. So it must be arranged on an optimum forward walking speed to get an optimum liquid fertilizer dosage.

In Indonesia, there are many types of knapsack mist blowers. The knapsack mist blowers have their own performances in producing droplet size (droplet diameter), droplet density, spraying width, and spraying debit. Collaboration between forward walking speed and types of knapsack mist blower will produce different performances in producing eggplants fruits.

2. Materials and methods
The research was conducted from March to June 2019 at the Sprayer Laboratory, Leuwikopo, IPB University, Darmaga Campus, Bogor, Indonesia and in a dry field to determine parameters i.e. droplet diameter, droplet density, effective spraying width, effective spraying debit, and harvested fruit weight of eggplants. The materials used in this research were liquid fertilizer and clean water. Measuring instruments and machines that be used were a patternator, a protractor, a scanner, measuring cups, a stopwatch, concord papers, a computer, a knapsack mist blower type A (Shandong 3WF-3), and a knapsack mist blower type B (Tasco MD-160) as seen on Figure 1. Mist blower type A has a 12 liter tank capacity, 2.13 kW engine power, and engine rotation speed of 7500 rpm, while mist blower type B has a 15 liter tank capacity, 2.13 kW engine power, and 7000 rpm engine rotation speed. Determination of optimum liquid fertilizing performance was based on the ability of the two mist blowers to produce minimum droplet diameter, maximum droplet density, maximum effective spraying width, and minimum effective spraying debit.

![Figure 1](image1.jpg)

Figure 1. The two knapsack mist blowers: (a) type A, and (b) type B

Determination of mist blowing (liquid fertilizing utilized mist blower) parameters is important to do before it is applied in a dry field. In principle, mist blowing is filling all leaves stomata with liquid fertilizer droplet to fill nutrient inside stomata. Determination of optimum (effective and efficient) mist
blowing was based on the most effective and the most efficient mist blowing results. The flow chart of this analysis is shown in figure 2.

![Flow Chart](image)

**Figure 2.** An analytic chart for determining optimum mist blowing

Figure 2 showed that the determination of optimum mist blowing was based on minimum droplet diameter, maximum droplet density, maximum effective spraying width (ESW), and minimum effective spraying debit (ESD). These four parameters of mist blowing effectiveness and efficiency can be measured at the Sprayer Laboratory, Leuwikopo, IPB Darmaga Campus, Bogor, Indonesia, as shown in Figure 3.

![Sampling Activity](image)

**Figure 3.** Sampling activity in determination of effective spraying width and effective spraying debit using patternator
Determination of the four parameters was based on the droplet spreading on a patternator. Liquid volume accommodated in each measuring cup, spraying angle, and spraying time were measured to determine ESW and ESD, as seen in figure 4. Determination of spraying angle and ESW will produce effective spraying distance. Based on the value of the effective spraying distance, it can be used to determine droplet diameter and droplet density using concord papers, a scanner, and a computer.

**Figure 4.** Determination of the four parameters in the Sprayer Laboratory

ESW can be determined by replacing an original spraying pattern on several overlapping patterns. ESW was determined by calculating the coefficient of variation (CV) of each overlapping pattern. Finally, ESW can be calculated by determining minimum CV and measure the distance from both two cross-sections as seen in figure 5.

**Figure 5.** An example of an effective spraying width (ESW) determination

Effective spraying debit (ESD) was determined by calculating the total volume accommodated in each measuring cup on the range of ESW. ESD can be calculated by calculating the volume accommodated divided by spraying time, as expressed in equation 1.
\[ Q = \frac{V}{t} \]  
\hspace{1cm} (1)

Where  \( Q \) = effective spraying debit, liter \( \text{min}^{-1} \)
\( V \) = total volume accommodated on the range of effective spraying width, liter
\( t \) = spraying time, minute

Droplet diameter and droplet density were determined by using an image processing program, which was developed using “C-Language” of SharpDevelop 4.3 software. Its determination process can be seen in figure 6.

**Figure 6.** Determination process of droplet diameter and droplet density

First, the liquid fertilizer solution mixed with dark ink. The solution has the same characteristics as water, is not thick, not sandy, and does not settle to produce the shape and size of a fixed droplet and can be seen by the eye or scanner, and then it is sprayed onto concord paper surface perpendicular with droplet spraying direction from the nozzle on its effective spraying distance (50 cm for mist blower type A and 56 cm for mist blower type B). Scan and crop the 10 cm x 10 cm droplet picture, then conduct a major binary of it to determine the total area of paper and the total area of the droplet. Conduct a minor binary to determine the area of one droplet. Output data from the program is an area in pixels. Next, the output data are processed to determine droplet diameter (unit: micron meter) and droplet density (unit: droplet cm\(^{-2}\)).

On a dry field area, eggplants were planted on 84 polybags that arranged in a stack like a vertical culture cultivation system, as shown in Figure 7. Each polybag was irrigated using a drip irrigation system. There is no nutrient added to the drip irrigation system.

The two knapsack mist blowers are applied in the field by directing the nozzle to the plant as far as the effective spraying distance. There are two treatments applied during conducting mist blowing i.e. three forward walking speed of spraying and three dosages of liquid fertilizer solution, as seen in Table 1. Determination of the forward walking speed is based on the application dosage (application rate), effective spraying debit (flow rate), and effective spraying width. Srivastava et al. [5] described that sprayer calibration refers to adjusting the chemical application rate in terms of liter/ha. The application rate depends on the sprayer forward speed, effective sprayer width, and the nozzle flow rate. The following formula (equation 2) can be used to determine the required nozzle flow rating.
\[ Q_n = \frac{A_R S d_n}{600} \]  

where

- \( Q_n \) = nozzle flow rate (liter/min)
- \( A_R \) = application rate (liter/ha)
- \( S \) = sprayer speed (km/h)
- \( d_n \) = nozzle spacing (m)

Based on equation 2 above, it can be determined forward walking speed using equation (3).

\[ S = \frac{600 Q_n}{A_R d_n} \]  

Table 1. The two treatments that were applied during conduct mist blowing on the dry field area

| Mist blowing method | Forward walking speed (m s\(^{-1}\)) | Application dosage of liquid fertilizer (l ha\(^{-1}\)) | Note for the application dosage |
|---------------------|-------------------------------------|----------------------------------------------------|---------------------------------|
| **Method A**        |                                     |                                                    |                                 |
| A1                  | 0.62                                | 3.0                                                | More than the recommended application dosage |
| A2                  | 0.92                                | 2.0                                                | Equal with the recommended application dosage |
| A3                  | 1.22                                | 1.5                                                | Less than the recommended application dosage |
| **Method B**        |                                     |                                                    |                                 |
| B1                  | 0.75                                | 2.7                                                | More than the recommended application dosage |
| B2                  | 1.00                                | 2.0                                                | Equal with the recommended application dosage |
| B3                  | 1.25                                | 1.6                                                | Less than the recommended application dosage |

**Figure 7.** Sample of eggplants vertical culture installation on the dry field, Leuwikopo, Bogor

Optimum mist blowing can be obtained by conducting the two treatments i.e. spraying using mist blower type A and mist blower type B. Recommended application dosage for eggplants is 2 liters ha\(^{-1}\). Concentration of the liquid fertilizer solution is 0.3\% (3 ml of liquid fertilizer in 1 liter of water). During each spraying, the length of time for spraying for each polybag depends on the speed of
application. Mist blowing was applied on 7 days after planting, and then applied regularly every 7 days until harvesting on 77 days after planting. The eggplants were harvested to determine the weight of harvested eggplants fruits.

3. Results and discussion
Performance test results of the two mist blowing methods in the Sprayer Laboratory showed different values of the four parameters. It indicated that mist blowing effectiveness and efficiency of the two mist blowers were different, as shown in Table 2.

Table 2. Performance test results of the two mist blowing methods

| Mist blowing method | Value of the parameters (in average) |
|---------------------|-------------------------------------|
|                     | WS (m s⁻¹) | ESW的有效ECW (m) | ESD的有效ECW (liter min⁻¹) | Droplet diameter (micron meter) | Droplet density (droplet cm⁻²) |
| Method A (Mist blower type A) | 20.9 | 0.64 | 2.37 | 301.51 | 264.63 |
| Method B (Mist blower type B) | 33.8 | 0.72 | 3.01 | 331.12 | 181.28 |

Note: WS: wind speed produced by own mist blower, ES: effective spraying

Table 2 showed that Method A had a better result in spraying method than Method B because it had a value of droplet diameter was smaller than Method B, the value of droplet density was larger than Method B, and value of effective spraying debit was smaller than Method B. It would result in different eggplants growing. The finer the droplet diameter and the higher the droplet density would result in ease of liquid fertilizer droplet enter to eggplants stomata. As a consequence of that results so Method A will produce higher harvested eggplant fruits weight than Method B, especially when the application dosage of liquid fertilizer is equal with the recommended application dosage of 2.0 liter ha⁻¹ (method A2 and method B2) as seen on Figure 8. Method A2 and method B2 produced harvested eggplant fruits weight of 96.22 g/fruit and 61.66 g/fruit on average, respectively.

![Figure 8](image)

**Figure 8.** Average harvested weight of eggplant fruits using Method A and Method B

Table 2 also told us that Method B had a larger effective spraying width and effective spraying debit than Method A. It may result in excessive liquid fertilizer droplet application that too many liquid fertilizer droplets, which it did not enter to stomata so that it would result in dissipation droplet
outside stomata. This case is caused by the higher wind speed produced by mist blower type B than mist blower type A.

The difference in that results above (Table 2 and Figure 8) is also caused by the difference in spraying mechanism between the two methods. Method A and Method B described that droplet production was influenced by wind speed and nozzle design of the two mist blowers. The difference in that spraying mechanism of the two methods has resulted in droplet performance, i.e. droplet diameter and droplet density. Method B produced higher wind speed than Method A, but it had fewer nozzle vanes number (8 vanes) than Method A (12 vanes) so that it produced larger effective spraying width, larger droplet diameter, and smaller droplet density than Method A. Design of nozzle vanes and droplet pattern of the two mist blowers can be seen on Figure 9.

![Figure 9. An example of droplet pattern formed by mist blower nozzle type A and type B](image)

**4. Conclusion**

Mist blowing Method A had less wind speed and nozzle vanes number than Method B so that it influenced their liquid fertilizing performances. Method A produced smaller or finer droplet diameter, larger droplet density, and smaller effective spraying debit than Method B, whereas Method B produced larger effective spraying width than Method A. Mist blowing Method A and Method B produced droplet diameter, droplet density, effective spraying width, and effective spraying debit were 301.51 micrometer, 64.63 droplet cm\(^{-2}\), 64 cm, and 2.37 liter min\(^{-1}\), and 331.12 micrometer, 181.28 droplet cm\(^{-2}\), 72 cm, and 3 liter min\(^{-1}\) in average respectively. Mist blowing Method A has produced maximum harvested eggplants weight of 96.22 g/fruit on average on the optimum walking speed of 0.92 m/s with 2 liter ha\(^{-1}\) liquid fertilizer dosage. Mist blowing Method B has produced maximum harvested eggplants weight of 61.66 g/fruit on average on the optimum walking speed of 1 m s\(^{-1}\) with 2 liter ha\(^{-1}\) liquid fertilizer dosage.

**5. Acknowledgments**

The authors say thank you to the PD Karya Mitra Usaha, Bogor, West Java and the PT Agrindo Maju Lestari, Cikupa, Banten, the companies in Indonesia that has prepared knapsack mist blowers of Shandong 3WF-3 and Tasco MD-160.

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