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Modification of Power Sprayer as a Pest Spraying Tool for Citrus Plants (*Citrus* sp.)

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Abstract
This study, titled "Modification of Power Sprayer into a Pest Spraying Tool for Citrus Plants (*Citrus Sp*)," was conducted in Gunuang Omeh Sub-district, Lima Puluh Kota Regency, from September to October 2024. The objective was to assess the efficiency of a power sprayer and the effectiveness of pest control on citrus plants. The research involved modifying the nozzle of the power sprayer and conducting field tests on a 20 x 20 meter plot. Observations included flow rate, insecticide output capacity, spray distribution, operator walking speed, theoretical field capacity, effective field capacity, spraying efficiency, wind speed, and operator power. In addition, the performance of the power sprayer was compared with that of a knapsack sprayer. Based on the results, the average flow rate was 0.008874 L/s; average droplet size from the power sprayer was 0.3611 mm; average operator walking speed was 0.0413 m/s; average theoretical field capacity was 0.076764 ha/h; average effective field capacity was 0.058789 ha/h; average wind speed was 1.22 km/h; and average operator power was 0.227 kW. The average spraying efficiency of the power sprayer and knapsack sprayer was 76.66% and 60.66%, respectively. These findings indicate that the power sprayer is more efficient than the knapsack sprayer, as it requires less time, less physical effort, and delivers a comparable spray output. Furthermore, the power required by the operator when using the power sprayer is lower than that of the knapsack sprayer.

Keywords: *Citrus*; Efficiency; Knapsack Sprayer; Pest; Power Sprayer

Introduction

Citrus sp. is one of the important horticultural commodities that faces pest control challenges, especially in hilly areas such as Payakumbuh, West Sumatra. The use of knapsack sprayers, which are common among farmers, often results in uneven pesticide distribution, oversized droplets, and operator fatigue, thereby reducing control effectiveness (Chen et al., 2023; Garcerá et al., 2017a). Previous studies have shown that factors such as nozzle type, nozzle position, spray pressure, and operator walking speed influence spray distribution and canopy penetration (Ou et al., 2024a). Innovations in spraying technology, including the application of fixed spraying systems or drones, have also shown the potential to improve efficiency and reduce pesticide use without compromising effectiveness.

Modifying a power sprayer is a promising alternative because it can produce a more uniform flow rate and droplet size, increase spray coverage, and reduce the operator's physical workload (Ou et al., 2024b). Adjustments in design, particularly in nozzle specifications and pressure settings,

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are necessary to adapt the tool for citrus plants, which are sensitive to high pressures. This study aims to develop and evaluate the technical performance and operational efficiency of a modified power sprayer compared to a knapsack sprayer, with the goal of enhancing productivity and sustainability in pest control for citrus plants..

Literature Review

Citrus (Citrus sp.) is a perennial plant native to East and Southeast Asia, with China as its primary center of origin. In Indonesia, citrus cultivation has been practiced since the Dutch colonial period, with various varieties such as sweet oranges, tangerines, and pomelos introduced from Europe and America (Garcerá et al., 2017b; Shanti, 2007). Citrus nobilis (Jeruk Siam) is the dominant variety due to its high productivity, although its quality varies. Citrus products are consumed fresh and processed into essential oils, pectin, alcohol, and traditional medicines (Chen et al., 2023).

Citrus plants are susceptible to various pests such as aphids, mites, thrips, leaf miners, fruit flies, and leaf-eating beetles (Bactrocera spp.), which can significantly reduce yield (Garcerá et al., 2017a). Pesticide spraying is a common control method, but its effectiveness is influenced by droplet size, spray distribution, and spray pressure (Ou et al., 2024b). Power sprayers have greater capacity and require less manual effort than knapsack sprayers, but excessively high pressure can damage citrus plants. Modifying nozzle design and pressure systems has been proven to improve spray penetration into the canopy and reduce drift.

The novelty of this research lies in developing a power sprayer specifically modified for spraying citrus plants in hilly areas, focusing on replacing the original nozzle with a low-pressure electric cone nozzle. This approach combines the high capacity and wide coverage of a power sprayer with the crop safety typically associated with a knapsack sprayer. Furthermore, this study directly compares the technical and ergonomic performance of both tools in field conditions, which is rarely conducted in previous studies, particularly in steep topographical contexts like Payakumbuh.

Research Method

This study employed an experimental method to evaluate the effectiveness of a modified power sprayer for pest control in citrus plants, particularly fruit flies. The experimental method was chosen because it allows direct field testing to quantitatively compare the performance of the tool before and after modification (Garcia-Ruiz et al., 2013; Nuyttens et al., 2013).

The research began with the preparation of tools and materials, including a steam-type Supernow power sprayer, a plastic drum containing an insecticide solution, and a 20-meter hose. The modification focused on the nozzle component by replacing the original nozzle with a low-pressure electric cone nozzle to reduce spray pressure, which could damage the citrus plants. This modification was expected to produce finer droplets and more uniform spray distribution (Lou et al., 2018).

The equipment was designed so that the power sprayer engine remained stationary while the operator only carried the hose and nozzle. This design reduced the operator's workload and increased mobility in hilly terrain (Chen et al., 2023). The performance of the modified power sprayer was compared to that of a knapsack sprayer using indicators such as spraying time, distribution uniformity, theoretical field capacity, effective field capacity, spraying efficiency, operator walking speed, and operator power output (Nuyttens et al., 2013).

The spray discharge rate was measured using the volumetric method, calculating the volume of liquid exiting the nozzle per unit of time. Operator walking speed was measured using a distance-time method, while field capacity was calculated using standard formulas as recommended by

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ASABE Standards. Efficiency was calculated as the ratio between effective field capacity and theoretical field capacity, while operator power output was measured based on workload per unit of time (Nurmianto, n.d.).

Discharge Rate

The spraying discharge rate was calculated based on the volume of liquid exiting the nozzle per unit of time. The process began by filling the drum with a measured mixture of water and insecticide. The time was recorded from the moment the liquid began to flow from the nozzle until it stopped. The volume of liquid used was calculated by subtracting the remaining liquid from the initial total volume.

The discharge rate was calculated using the following formula:

$$Q = V / t$$

Where:

Q = Discharge rate (liters/minute)

V = Volume of liquid (liters)

t = Time (minutes)

Operator Walking Speed

The walking speed of the operator was calculated using the following formula:

$$V = S / t$$

Where:

V = Walking speed (m/s)

S = Distance traveled by the operator (meters)

t = Time taken by the operator (seconds)Kapasitas lapang teoritis

Theoretical Field Capacity

The theoretical field capacity can be calculated using the following formula:

$$TFC = 0.36 \times (v \times l)$$

Where:

TFC = Theoretical Field Capacity (hectares/hour)

v = Average walking speed (m/s)

l = Spray width or plant spacing (meters)

0.36 = Conversion factor

Effective Field Capacity

The effective field capacity can be calculated using the following formula:

$$EFC = L / WK$$

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Where:

EFC = Effective Field Capacity (hectares/hour)

L = Area sprayed (hectares)

WK = Working time (hours)

Efficiency

The efficiency of insecticide distribution is expressed as the ratio between the effective field capacity and the theoretical field capacity:

Spraying Efficiency = (EFC / TFC) × 100%

Where:

EFC = Effective Field Capacity (hectares/hour)

TFC = Theoretical Field Capacity (hectares/hour)

Results and Discussion

Discharge Rate

The discharge rate measurement is used to determine the volume of water that can be delivered from the tank within a specific period of time. The discharge rate values are presented in Table 1.

Table 1. Discharge Rate Measurements

Replication	Discharge (Liters/second)	
	Power Sprayer	***Knapsack Sprayer***
1	0,009	0,005
2	0,008	0,004
3	0,009	0,005
4	0,009	0,005
5	0,009	0,005
Average	0,0089	0,0049

Based on the table above, the highest discharge rate was recorded for the power sprayer, with an average of 0.0089 liters/second, while the lowest was observed for the knapsack sprayer, with an average of 0.0049 liters/second. It is evident that the power sprayer produced a higher discharge rate compared to the knapsack sprayer. This difference can be attributed to the more stable pressure generated by the power sprayer.

Determination of Operator Walking Speed

One of the important factors to consider during spraying is the walking speed of the operator. Measuring the operator's walking speed helps determine how fast the operator moves when using both the power sprayer and the knapsack sprayer. The walking speed values for each sprayer type are presented in Table 2.

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Table 2. Operator Walking Speed

Track	Operator Walking Speed (m/s)	
	Power Sprayer	*Knapsack Sprayer*
1	0,042	0,038
2	0,043	0,029
3	0,043	0,032
4	0,042	0,035
5	0,037	0,031

Based on Table 2, the highest walking speed was observed with the power sprayer on tracks 2 and 3 at 0.043 m/s, while the lowest speed occurred with the knapsack sprayer on track 2 at 0.029 m/s. Several factors influence the operator's walking speed, with travel time being the most significant. The longer the time taken, the slower the walking speed. Additionally, the weight of the equipment also affects walking speed—the heavier the load, the quicker the operator becomes fatigued, increasing the time needed to complete the task. Lastly, the size of the plant being sprayed also plays a role; the larger the plant, the longer it takes to complete the spraying process.

Theoretical Field Capacity

Theoretical field capacity is used to determine the performance capability of a spraying tool when operating at its maximum working width. It can be calculated by measuring the operator's walking speed and the spray width or plant spacing. The values for theoretical field capacity are presented in Table 3.

Table 3. Theoretical Field Capacity

Replication	Theoretical Field Capacity (ha/h)	
	Power Sprayer	*Knapsack Sprayer*
1	0,077	0,068
2	0,078	0,058
3	0,076	0,063

Based on Table 3, the theoretical field capacity of the power sprayer is higher than that of the knapsack sprayer. The average theoretical field capacity for the power sprayer is 0.0768 ha/h, while for the knapsack sprayer, it is 0.063 ha/h. The difference in theoretical field capacity between the two sprayers is influenced by the spray width and the operator's walking speed. The greater the spray width and walking speed, the higher the resulting theoretical field capacity. Conversely, narrower spray width and slower walking speed will result in a lower theoretical field capacity.

Effective Field Capacity

Effective field capacity is used to determine the area that can be covered by the power sprayer and knapsack sprayer within one hour. The area used in this study was 0.04 hectares. The effective field capacity values are presented in Table 4.

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Table 4. Effective Field Capacity

Replication	Effective Field Capacity (ha/h)	
	Power Sprayer	*Knapsack Sprayer*
1	0,057	0,036
2	0,060	0,038
3	0,060	0,039

As shown in Table 4, the highest effective field capacity was recorded for the power sprayer at 0.060 ha/h, while the lowest was for the knapsack sprayer at 0.036 ha/h. This indicates that the power sprayer is more effective, as it can cover a larger area within the same amount of time compared to the knapsack sprayer. One of the reasons the knapsack sprayer has a lower capacity is due to time losses, such as turning time, refilling, equipment adjustments, and other interruptions.

Human labor field capacity is influenced by factors such as age, education, skill, experience, physical fitness, and environmental conditions. Recent studies confirm that human capital—including education, health, and experience—plays a crucial role in improving agricultural productivity and labor efficiency. Stated that agricultural operational capacity depends on the type and size of machinery, operator skills, available power sources, and working conditions. Modern research emphasizes the importance of operator skill and appropriate mechanization in enhancing operational efficiency and reducing manual labor burdens.

Efficiency

Spraying efficiency can be determined by calculating the ratio between effective field capacity and theoretical field capacity. The spraying efficiency values are presented in Table 5.

Table 5. Spraying Efficiency

Replication	Spraying Efficiency (%)	
	Power Sprayer	*Knapsack Sprayer*
1	74,60	53,43
2	76,94	65,60
3	78,44	62,63

Based on Table 5, the average spraying efficiency of the power sprayer was 76.66%, while that of the knapsack sprayer was 60.55%. These results show that the spraying efficiency of the power sprayer is higher than that of the knapsack sprayer. This difference may be influenced by the spray width achieved by the sprayer, the operator's walking speed, and the amount of time required to cover a given area.

Fieldwork efficiency is influenced by several interrelated factors, including theoretical field capacity, turning time, work pattern, field shape and size, as well as field and crop conditions (Al-Amin & Adams, n.d.; Bahmutsky et al., 2025; Griffel et al., 2020). Recent studies also highlight that optimizing headland turning, reducing overlap, and improving machine maneuverability can

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significantly increase operational efficiency in agricultural fieldwork (Evans et al., 2020; Li et al., 2022).

Ergonomics

Ergonomics is the study of human aspects in their working environment. In agriculture, ergonomic research is applied to design technologies that minimize physical strain and health risks for operators. Recent studies emphasize that optimizing tool design, workload distribution, and posture during pest control activities can significantly reduce operator fatigue and energy expenditure. In this study, observations were conducted to determine the energy required by the operator during pest spraying. The ergonomic values related to pest spraying are presented in Table 6.

Table 6. Operator Power Output

Operator Power Output (kW)		
Replication	*Power Sprayer*	*Knapsack Sprayer*
1	0,208	0,266
2	0,246	0,317
3	0,227	0,253

Based on Table 6, the operator power output for the power sprayer across three replications was 0.208 kW, 0.246 kW, and 0.227 kW, respectively. For the knapsack sprayer, the values were 0.266 kW, 0.317 kW, and 0.253 kW. The average operator power output after using the power sprayer was 0.227 kW, while for the knapsack sprayer it was 0.279 kW. According to Christensen, a workload within the range of 0.17 to 0.33 kW is categorized as light work.

Conclusion

Based on the results of the study on both power sprayers and knapsack sprayers, the following conclusions can be drawn:

1. The spraying process was effective in controlling pests on citrus plants. The effect of spraying using the power sprayer was observed on the 8th day after application, while for the knapsack sprayer, it was observed on the 10th day.
2. The pressure generated by the machine or human effort significantly affects the spray volume—the higher the pressure, the greater the discharge rate.
3. The average spraying efficiency of the power sprayer (76.66%) was higher than that of the knapsack sprayer (60.66%).
4. Operator walking speed was influenced by the load carried. The power sprayer allowed for an average speed of 0.041 m/s since the operator only carried the hose, while the knapsack sprayer had an average speed of 0.033 m/s due to the heavier tank.
5. The average operator power output after using the power sprayer (0.227 kW) was lower compared to the knapsack sprayer (0.279 kW).

Benefits to Science: This research contributes to the development of more efficient and ergonomic agricultural spraying technology, especially for horticultural crops in hilly areas. The findings can serve as a reference for researchers and agricultural engineers in designing spraying equipment that combines high capacity, wide coverage, and crop safety. Moreover, the low-pressure nozzle

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modification approach can be adapted to other crops to improve pest control effectiveness while reducing the environmental impact of excessive pesticide use.

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