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Implementation of Insect Pest Control Innovation with Raindrop Sensor using Solar Energy Source in Shallots Farming

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ABSTRACT

Spodoptera exigua, commonly known as the beet armyworm, is a major pest affecting shallot (Allium ascalonicum L.) plants, leading to significant damage and economic losses for farmers. Traditional pest control methods, such as manual caterpillar removal and pesticide application, have proven ineffective and costly. In response, this study aims to develop an environmentally friendly and sustainable solution by designing a pest control system powered by solar energy, equipped with high-voltage wires, UV lamps, and a raindrop sensor for automatic operation. The system works by converting solar energy into electrical power, which then supplies the pest control unit. The UV lamps attract moths, while the high-voltage wire eliminates them. A raindrop sensor is used to ensure the system operates efficiently by shutting off during rainfall. The method involved discussions with local farmers, design and assembly of the device, followed by field implementation and monitoring in shallot farms. The results show that the device successfully trapped between 40 to 80 moths per day, significantly reducing pest populations and lowering production costs for farmers, as the use of chemical pesticides was minimized. Additionally, the quality of shallot crops improved, leading to higher market value. The solar-powered pest control system is an effective, eco-friendly alternative for managing pest infestations in shallot farming. It offers a cost-efficient solution, reducing the need for pesticides while improving crop quality and yield.

Keywords*: High-voltage Light trap, Shallot pest control, Solar energy, Spodoptera exigua, UV lamp.*

1. INTRODUCTION

Shallots (Allium ascalonicum L.) are one of the horticultural agricultural commodities classified as spice vegetables. Shallots are used as the main ingredient for basic cooking spices or as a flavoring **(Suprayoga et al., 2023)**. Not only do shallots serve as a flavoring, but they also contain nutrients that can improve blood circulation and are used as a herbal or traditional medicine **(Aryanta I Wayan Redi, 2019)**. Plosorejo Village, located in Gampengrejo District, Kediri Regency, East Java Province, is situated on a plateau, where most of the soil is gray alluvial, consisting of fertile clay and sand deposits. The Dewi Sri II Farmers Group, chaired by Mr. Imam Masruri, has 58 members and was founded in 2016.

A common problem faced by farmers is the presence of caterpillar pests, which damage the quality of shallot plants **(Pratiwi et al., 2022)**. The caterpillar pest, a metamorphosis of a moth that is attracted to light, damages shallot plants **(Yuniarti et al., 2021)**. The damage caused by caterpillars eating the leaves results in poor-quality shallots, leading to lower sales prices and potential crop failure **(Rahim et al., 2022).**

The Dewi Sri II Farmers Group has been attempting to eradicate these pests through pesticide spraying. However, the use of chemical pesticides has been deemed ineffective and inefficient, as the caterpillars attached to the leaves do not die completely, and the quality of the leaves is contaminated with chemicals **(Andani & Nasirudin, 2021; Setiyoko et al., 2017)**. Moreover, farmers still need to manually remove caterpillars from the leaves twice a day, which hinders the optimal growth of shallots expected to be of high quality.

An innovative solution to this problem is a pest trap using high-voltage wires and UV lights to attract moth pests (Spodoptera exigua), which lay eggs on the leaves of shallot plants and develop into caterpillars **(Yuniarti et al., 2021)**. The system is equipped with a protection mechanism, namely a raindrop sensor, to detect rainfall. By utilizing solar panels as an alternative energy source, the costs associated with electricity can be minimized. Through the application of this science and technology, it is hoped that this solution will address the issue of shallot pests among the Dewi Sri II Farmers Group in Plosorejo Village, Gampengrejo District, Kediri Regency, East Java Province.

2. IMPLEMENTATION METHOD

2.1 Condition of Existing Partners

The dry season is the period when caterpillars breed extensively and attack shallot plants. Caterpillar pest infestations significantly reduce the quality of shallots, leading to lower selling prices. Partners in the Dewi Sri II Farmers Group still rely on traditional methods, manually removing caterpillars from the shallot leaves twice a day, and use expensive pest control chemicals.

The following outlines the background of the partners' problems:

a. Identifying the condition of existing farmer
   1. Dewi Sri II Farmers Group is located in Plosorejo Village, Gampengrejo District, Kediri Regency.
   2. The dry season is when caterpillars reproduce rapidly, attacking the shallot plants.
   3. During the dry season, only 1/4 of the total available land is used for shallot planting.
   4. Shallots are a high-profit crop for the Dewi Sri II Farmers Group, making a successful harvest highly desired.

b. Latest Partner Solutions
   1. Farmers manually remove caterpillars from the shallot leaves twice a day.
   2. Pesticides are used, but they are expensive.

c. Cost of maintaining shallot plants
   1. Pesticides are priced at IDR 350,000 for 100 ml, sufficient for 10 sprays over 10 days. Since planting lasts 65 days until harvest, 7 bottles are required. Therefore, the total pesticide cost is 7 x IDR 350,000 = IDR 2,450,000.

2. The initial costs for land preparation and shallot seeds amount to IDR 8,825,000.

d. The harvest obtained

The selling price of shallots is determined by wholesalers based on the condition of the shallot leaves and the size of the bulbs. Shallots with healthy leaves and large bulbs fetch a higher price. Partners expect a return of twice their initial investment, but due to poor leaf quality, profits often amount to no more than half the capital, with selling prices ranging from IDR 10 million to IDR 15 million per 1,400 m² of rice fields, from an initial investment of IDR 8,825,000. In cases of crop failure early in the planting season, losses occur, and planting and maintenance may not continue.

2.2 Tool Design as a solution

The tool design integrates a solar-powered system using a high-voltage module and UV lamp to attract and kill pests, along with a raindrop sensor for protection. Solar panels convert sunlight into electrical energy, which is stored in a battery and regulated by a charge controller. The tool operates for 9 hours, controlled by a digital timer, and shuts off automatically when the raindrop sensor detects rain, safeguarding the high-voltage components. When dry, the system resumes, trapping pests with the UV lamp and high-voltage wire, which kills them upon contact. The overall setup ensures efficient and automated pest control. The schematic diagram of the tool design is shown in Figure 1.

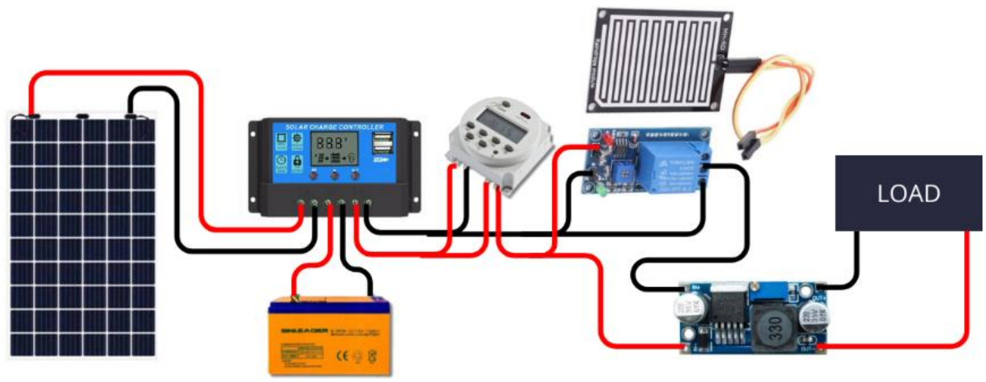

Figure 1. Tool Design Schematic Diagram

Table 1. Calculation of Component Requirements

Type	Calculation	information
Energy Requirements	Load x Hours of Use 10 Watts x 9 Hours = 90Wh	The total power of 10 watts is obtained from 3 watts of lamp power, 5 watts of high voltage circuit, 2 watts of Modul Raindrop Sensor. The system lasts for 9 hours and has an energy requirement of 90 Wh.
System Loss	PV Module Loss = 10 % SCC Loss = 3 % Cable Loss = 2 % Battery Loss = 10 % Total Loss = 25 %	According to the calculation, the total loss in the system is 25%.
Total Energy Module	$\frac{Energy\ Requirements}{100\% - System\ loss}$ $\frac{90\ Watt}{100\% - 25\%} = 120\ W$	The minimum power required for the module capacity is 120 watts

Module Capacity	30 Wph x 4 jam = 120 W	The PV capacity that will be used is 30 Wp with effective charging for 4 hours, which can produce 120 watts of power
Battery Capacity	$Ah = \left(\frac{Module\ Capacity}{Vb}\right) : DOD(\%)$ $Ah = \frac{120}{12} : 80\% = 12{,}5\ Ah$	Based on calculations, the battery capacity to be used is 12Ah

From the calculations in Table 1, the specifications required for the tool are determined. Solar panels are expected to charge the battery during the day, within a 5-hour period between 9:30 AM and 2:30 PM. The battery can then power the tool for 9 hours. The cost for each tool is IDR 1,493,000, and one piece of land requires approximately three tools. Each tool covers about 500 m², and the equipment is installed in the center and at the edges of the rice field.

2.3 Product Design

Figure 2 presents the schematic diagram of the tool design used for solar-powered pest control. The system is composed of various components: a 30Wp photovoltaic panel (1) that captures sunlight and converts it into electrical energy, a raindrop sensor (2) to detect rainfall, and a UV lamp (3) used to attract pests. High-voltage wires (4) are integrated to exterminate the pests upon contact. All components are housed in a box panel (5), with a receptacle (6) for connections. Inside the control box, the system features a solar charge controller (SCC) (7) for managing the charging of the battery (13), a timer (8) to regulate operating hours, and a buck converter (9, 12) to manage the voltage levels. The module for the raindrop sensor (10) and the high-voltage kit (11) ensure that the system operates efficiently under varying environmental conditions. This setup is designed to automate pest control through solar power while incorporating a protective mechanism against rain.

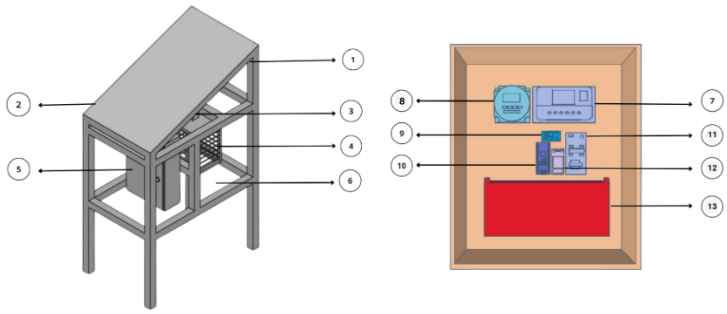

Figure 2. Tool Design Diagram schematic

Description:

1. Photovoltaic 30Wp
2. Raindrop Sensor
3. UV Lamp
4. High Voltage Wire
5. Box Panel
6. Receptacle
7. SCC
8. Timer
9. Buck Converter
10. Modul Raindrop Sensor
11. High Voltage Kit
12. Buck Converter
13. Battery

2.4 Economic Analysis

Before using the tool, it is estimated that the yield does not exceed 800 kg and may even be as low as half that amount. This is because many shallot leaves are eaten by caterpillars if pest removal is not performed every afternoon, and continuously purchasing pesticides will increase production costs. Moreover, spraying pesticides does not prevent leafhoppers from eating the leaves at night.

After using the tool, while the difference in production costs is not drastically reduced, the pest control tool can be used for multiple harvests. Applying this pest control tool is likely to reduce caterpillar pests during the night, which may help lower production costs for subsequent harvests. The shallots harvested after using the tool are better protected from chemicals, and the fresh shallot leaves can be sold as well. By selling fresher shallots with minimal chemical exposure, the economic value for farmers can increase. To analyze the data collected from farmers, a break-even point (BEP) analysis can be applied. The objective is to determine the BEP of the shallot farming business. Based on this data, the BEP of shallot farming can be calculated using the formula (1):

$$Q = \frac{TFC}{P - AVC} \tag{1}$$

Information:
Q : Total Production in Farming (Kg)
TFC : Total Fixed Cost (Rp)
P : Price per Unit (Rp)
AVC : Variable Cost (Rp)

Revenue is determined by production quantities and sales prices. The higher the output sold, the greater the revenue. Similarly, as the selling price increases, revenue grows accordingly. Before proceeding with the calculations, it is important to determine the variable cost (AVC) so that it can be fully calculated**(A. A. Rahim, 2015)**. To calculate AVC, multiply the total variable cost (TVC) by the production result in equation (2).

$$AVC = \frac{TVC}{Production} \tag{2}$$

Information:
AVC : Total Production in Farming (Kg)
TVC : Total Variable Cost (Rp)
Production : Production result

3. RESULTS AND ANALYSIS

3.1 Science and Technology Products

This program applies science and technology by utilizing sunlight as a source of electricity through solar panels or photovoltaic (PV) cells. During the day, the solar panel absorbs sunlight and converts it into DC electrical voltage, which is connected to a solar charge controller (SCC). The SCC regulates battery charging, ensuring it does not overcharge or discharge excessively **(Syahadhah et al., 2021)**. The stored voltage powers the DC ultraviolet (UV) lamp and the pest control wire. High-power lamps previously used by the community have been replaced with 3-watt LED lamps, which are more energy-efficient.

The system is protected by a DC miniature circuit breaker (MCB) to safeguard the PV and battery. The current capacity of the MCB and KHA cables is set at 125% of the total current flowing through the system to ensure protection. Additionally, a raindrop sensor has been integrated into the system to detect rain and automatically cut off the power supply to the high-voltage wire, preventing potential hazards.

Figure 3. Handover of equipment to partners & Implementation of the developed tool

3.2 Testing and Implementation Results

In Figure 3, the images show the implementation of the developed solar-powered pest control tool in a shallot farm. The left image illustrates the outdoor setup with solar panels mounted on the device, which captures sunlight to generate electrical energy for the system. The tool is placed on the field and is constructed to be durable in outdoor conditions. The right image shows the internal mechanism of the device under operation. The ultraviolet (UV) lamp emits light to attract pests, and a high-voltage wire traps and exterminates them. A basin is placed below to collect the pests. This system ensures that pests are effectively controlled while minimizing the use of chemical pesticides.

Measurements of several units of voltage and current were taken using a digital multimeter. Solar panel measurements were conducted in the morning for 5 hours, from 09:30 to 14:30, and at night. The results of the solar panel measurements varied because the intensity of sunlight during the day differs by hour and region. The measurement results for daytime and nighttime are as follows:

1. Daylight Measurements

Table 2. Measurement In the Daylight

Time	V (Voltage)	I (Ampere)	P (Power)
9:30	14.58	0.95	13.85
10:00	14.98	1.68	25.17
10:30	14.70	1.3	19.11
11:00	15.64	1.46	22.83
11:30	16.02	1.84	29.48
12:00	15.21	1.52	23.12
12:30	16.17	1.97	31.85
13:00	15.40	1.23	18.94
13:30	15.35	1.18	18.11
14:00	14.94	1.04	15.54
14:30	14.17	0.84	11.90

Table 2 shows that the values from the measurements during the day vary significantly. From these values, it can be concluded that the area where the solar panels are installed is highly suitable for charging the battery. The battery is adequately charged so that the tool can supply power for more than 9 hours during the night.

2. Night Measurement

Table 3. Measurement In the Night

Time	V (Voltage)	I (Ampere)	P (Power)
17:00	13.5	0.93	12.56

Time	V (Voltage)	I (Ampere)	P (Power)
18:00	13.36	0.92	12.29
19:00	13.29	0.88	11.70
20:00	13.15	0.89	11.70
21:00	13.02	0.86	11.20
22:00	12.96	0.8	10.37
23:00	12.89	0.83	10.70
0:00	12.83	0.84	10.78
1:00	12.76	0.82	10.46
2:00	12.7	0.8	10.16

Table 3 shows that the values from the night measurements are very stable, unlike the day measurements. This stability is because the battery only supplies 10W of power from the total system load. With this load, the battery has sufficient remaining power to last for more than 9 hours.

3. Trapped pests

Tabel 4. Calculation of Trapped Pest Results

No. of Days	Moth	green ladybugs	fruit flies
1	40	3	1
2	58	4	2
3	49	1	0
4	63	0	0
5	71	2	2
6	80	2	3
7	57	3	1
8	68	2	0
9	61	4	1
10	54	1	1

Table 4 shows that the pest trap is highly effective in controlling shallot crop pests. Not only moths, but also green ladybugs and fruit flies are trapped and killed by the device. These results demonstrate the success of the tool in mitigating pest damage to the shallots, as shown in figure 4.

Figure 4. Implementation Results

This tool will work again to trap pests with UV lights and high voltage wire. High voltage wire is used to kill pests when they touch the wire and fall into the basin container. A basin filled with water functions to trap pests that are still alive after being exposed to a high voltage electric shock. Figure 4 shows several examples of traps that receive various pests from different days so that they do not only catch one type of pest.

3.3 Calculation of Profits Using the Developed Tools

The planting process uses the same quantity of seeds, namely 125 kg, with the price of 1 kg of seeds being IDR 27,000. Fixed costs (FC) are costs that remain constant regardless of the production volume, while variable costs (VC) vary based on production needs **(Yuni et al., 2021)**. The table 5 below outlines the costs required from the start of planting to harvest.

Table 5. Costs required from the start of planting to harvest

No	Description	Price	Quantity	total
1	With out tool			
	Shallot seeds (VC)	Rp 27.000	125 Kg	Rp 3.375.000
	Planting and harvesting labor (VC)	Rp 1.500.000	1 Period	Rp 1.500.000
	Preza Pesticide (VC)	Rp 350.000	7 bottle	Rp 2.450.000
	Fertilizer (VC)	Rp 500.000	1 pcs	Rp 500.000
	Sprayer 15 L (FC)	Rp 500.000	2 pcs	Rp 1.000.000
Total				Rp 8.825.000
2	With tool			
	Shallot seeds (VC)	Rp 27.000	125	Rp 3.375.000
	Planting and harvesting labor (VC)	Rp 1.500.000	1 period	Rp 1.500.000
	Fertilizer (VC)	Rp 500.000	1pcs	Rp 500.000
	Pest exterminator (FC)	Rp 1.493.000	3pcs	Rp 4.479.000
	M&O Cost (FC)	Rp 2.488	1 period	Rp 2.488
Total				Rp 9.856.488

From the harvest obtained, Kediri shallot farmers experience a larger yield after using the pest control equipment. During the 65-day period from planting to harvest, the quality of the onions improves, reducing damage caused by pest attacks. The harvest yield of 1,400 m² increases from around 600 kg without the tool to approximately 800 kg with the tool. The shallots also grow larger and healthier compared to before.

1. Before Using the Tool

   By planting 125 kg of seeds, farmers obtain a harvest of 600 kg. With the selling price of shallots set at IDR 28,000 per kg, the revenue and income analysis is as shown in (3) to (7).

   - Number of receipts $= Harvest\ x\ selling\ price$ (3)
     $= 600\ Kg \times Rp\ 28.000$
     $= Rp\ 16.800.000$
   - Total Income $= \text{Number of receipts} - \ planting\ needs$ (4)
     $= Rp\ 16.800.000 - Rp\ 8.825.000$
     $= Rp\ 7.975.000$
   - AVC $= \frac{Total\ Variable\ Cost}{Total\ Production}$ (5)
     $= \frac{Rp\ 7.825.000}{600\ Kg}$
     $= 13.042$
   - BEP Unit $= \frac{TFC}{P - AVC}$ (6)
     $= \frac{1.000.000}{28.000 - 13.042}$
     $= 66.85\ Kg$
   - BEP Rupiah $= P \times BEP\ Unit$ (7)
     $= Rp\ 28.000\ \times 67.99\ Kg$
     $= Rp\ 1.871.800$

2. After Using the Tool

By planting 125 kg of seeds, farmers now get a harvest of 800 kg. With the selling price of shallots remaining at IDR 28,000 per kg, the revenue and income analysis is as shown in (8) to (12).

- Number of receipts

$$= Harvest\ x\ selling\ price \quad (8)$$
$$= 950\ Kg \times Rp\ 28.000$$
$$= Rp\ 26.600.000$$

- Total Income

$$= \text{Number of receipts} - \ planting\ needs \quad (9)$$
$$= Rp\ 26.600.000 - Rp\ 9.856.488$$
$$= Rp\ 16.743.512$$

- AVC

$$= \frac{Total\ Variable\ Cost}{Total\ Production} \quad (10)$$
$$= \frac{Rp\ 5.375.000}{930\ Kg}$$
$$= 5.658$$

- BEP Unit

$$= \frac{TFC}{P - AVC} \quad (11)$$
$$= \frac{4.481.488}{28.000 - 6.719}$$
$$= 200{,}58\ Kg$$

- BEP Rupiah

$$= P \times BEP\ Unit \quad (12)$$
$$= Rp\ 28.000\ \times 200{,}58\ Kg$$
$$= Rp\ 5.616.240$$

Based on the calculation results, it is clear that the use of the tool increases profits significantly. The profit after using the tool amounts to Rp 16,743,512, compared to Rp 7,975,000 without the tool. This represents a profit increase of Rp 8,768,512, a substantial improvement. This increase is also achieved due to reduced expenses on pesticides and spray equipment.

4. CONCLUSION

The implementation of solar-powered pest control tools in shallot farming has proven to be highly effective in reducing pest populations, improving crop quality, and significantly increasing farmer profits. Before the introduction of the tool, shallot farmers struggled with low yields and high production costs due to continuous pesticide use and manual pest removal. The developed pest control system, which utilizes solar energy, UV lamps, high-voltage wires, and a raindrop sensor, provides an efficient, eco-friendly solution that can be used for multiple harvests. By applying this technology, farmers have been able to increase their yield from 600 kg to 800 kg, with profits rising by IDR 8,768,512 compared to traditional methods. The use of the tool not only reduces the dependency on chemical pesticides but also minimizes labor costs and enhances the economic value of shallot farming by producing larger, higher-quality crops. Overall, this innovation presents a sustainable and economically viable alternative for pest control in agriculture, contributing to both environmental and financial benefits for farmers.

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