DESIGN OF INSECT TRAP AUTOMATIC CONTROL SYSTEM FOR CACAO PLANTS

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DESIGN OF INSECT TRAP AUTOMATIC CONTROL SYSTEM FOR CACAO PLANTS*

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Abstract

Insect pests attacks on Cacao (*Theobroma cacao* L) plantations are generally controlled using chemical (non-organic) pesticides. Pesticides that are applied continuously can cause pest resistance, pest resurgence, and environmental pollution. Environmental pollution can disrupt the ecosystem due to increased toxic residues in plant tissue or the soil. Therefore, it is necessary to design a pest trap with charm and an automatic actuator based on a microcontroller on the Arduino board. This automatic insect trap is called the Teptrap v1. Five units of the infrared sensor type E18-D50NK are used to detect insect pests. The attractants used were TL lamps, yellow lights and attractants attached to the trap system. Teptrap v1 shows excellent performance during 33 days of research. As evidenced by the fan actuator system that works stably with a catching accuracy of 82.74%, insect drop time is 6 minutes 33 seconds, and the actuator response speed turns on the light, yellow LED and pumps <1 second (± 10 mS). This insect pest control trap can reduce the use of spray pesticides by 20-50%, thereby saving the cost of purchasing pesticides up to IDR 74,468 per hectare of Cacao.

Keywords: cacao plants, insect trap, microcontroller, pest control

1. Introduction

Cacao is one of the agricultural commodities that have the potential to provide great benefits in Indonesia. However, the pest infestation is the major challenge that faced by the Cacao farmers because it can reduced the production by more than 80% (Basri AB, 2010). According to (Habibullah, 2018), Cacao production decreased to 658.400 tons in 2016 which caused by the land reduction of Cacao plantation area due to the farmer's inability to reduce the insect pests attack. Insect pest attacks on Cacao significantly affect the decline in Cacao

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production (Billah et al., 2014). Insect control on Cacao plants generally uses insecticides. The intensity and dose of insecticides that are applied continuously cause pest resistance to insecticides, pest resurgence, and environmental pollution. One of the causes of damage to Cacao is the attack of insect that suck Cacao pods. The affected fruit shows puncture marks in the form of black spots on the surface of the fruit. In severe attacks, the entire surface of the fruit is covered with black and dry puncture marks; the skin is harden and cracked. This fruit-sucking insect attack is classified as difficult to eradicate because it tends to be resistant to insecticides (Arif, 2015).

Some simple technologies to attract insect include the use of lamps, yellow binders, and attractants. The community tends to use lights to catch flying pests in agricultural areas (Pertiwi et al., 2013). Flying pests are attracted to gathering at light sources. The use of yellow light (waterproof paper material or yellow LED) is also considered as a solution to attracting insects into the trap. The insects have a high interest to yellow color, which provides a stimulus related to changes in plant color during flowering and fruit ripening (Hakim et al., 2017). Another method to trap the insects use as attractants. The odor caused by fruit or synthetic attractants made of methyl eugenol causes fruit flies, Ceratitis sp. and Bactrocera sp. attracted closer to the material. The aroma of the attractant from the hanging methyl eugenol diffuses in the air so that it can be detected by fruit flies (Hasyim et al., 2010). The results of previous research can be used as a reference for a better pest trap design strategy.

A unique strategy need to be developed to deal with Cacao plant pests on an ongoing basis through the application of technology with low operating costs to increase the profit ratio of farmers through designing pest traps with microcontroller based automatic attractants and actuators. The decoys used are TL-lamps, yellow lights, and attractants attached to the trap system. This design tool is called Teptrap v1. The use of this tool works to effectively reduce the effect of pest attacks in preventing insect attacks on cacao plantations.

2. Materials and methods

This research was conducted at the Laboratory of Energy and Agricultural Engineering, University of Lampung, Indonesia. The application of insect traps and data collection was carried out in farmers' Cacao farms in Sukoharjo 1 Village, Pringsewu Regency, Lampung.

2.1. Design Criteria

The insect trap automation system is designed to control fan actuators, automatic feeds, infrared sensors, and pumps that are in the insect trap, to lure insects to approach the tool and drop them into an insect reservoir filled with water. The pest trap automation system uses the ATMega microcontroller on the Arduino board because it is easy to assemble, tough, and stable for the use of measurement data acquisition and control system design in agriculture (Telaumbanua et al., 2019; Triyono et al., 2019). The Microcontroller module design is equipped with an LCD, RTC, and MicroSD Module. The power used to turn on the microcontroller and actuator in the pest trap comes from Solar Cell. The electricity generated by the Solar Cell is in the form of DC voltage so that for actuators that require AC voltage electricity is taken from the Solar Cell which has been through the inverter.

The E18-D50NK infrared sensor has a reading accuracy of 1 mm with a detection distance of 50 cm. This infrared sensor can detect changes in infrared energy. This sensor is used to detect insects lured into the pest trap and insects that enter the pest trap. The design of the types of decoys used in the traps is TL-lamps, yellow multi LEDs, and attractants. The design of actuators used in pest traps is to use a fan, a decoy (TL-lamp, yellow light, attractant) and a water pump with a voltage of 220V and a power of 35 watts. The fan blows the wind to knock down insects when insects detected by infrared sensors are inside the pest trap catching room. The use of a water pump functions to circulate water in the insect collection tub at 06.15-06.30 AM to prevent trapped insects from escape and to make it easier for researchers to count insects (for analysis) manually. The seductive TL-lamp are turned on at 6.00 PM - 06.00 AM, while the yellow and attractant lights are always on (Fig. 1).

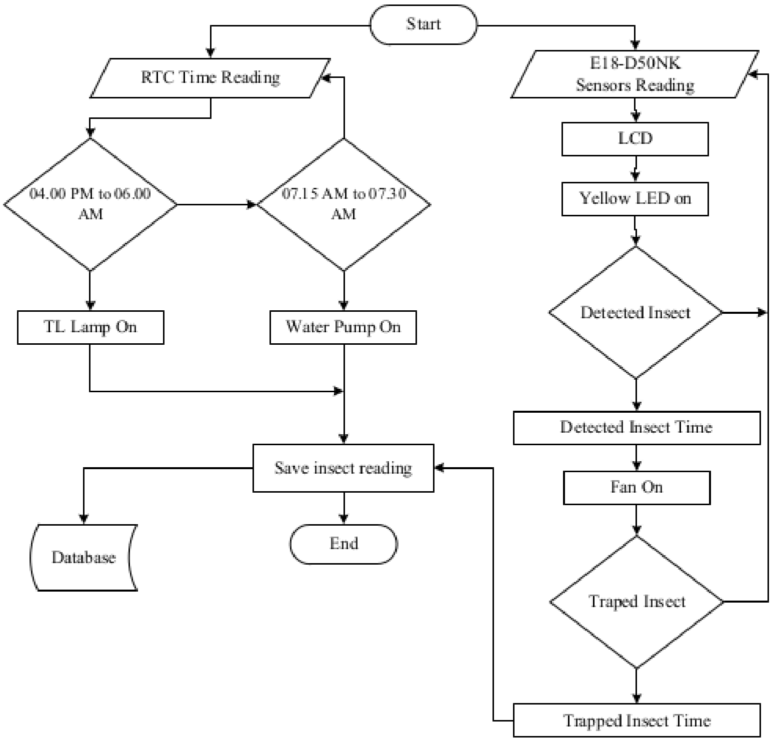

Fig.1. Flow diagram of insect trap Teptrap v1

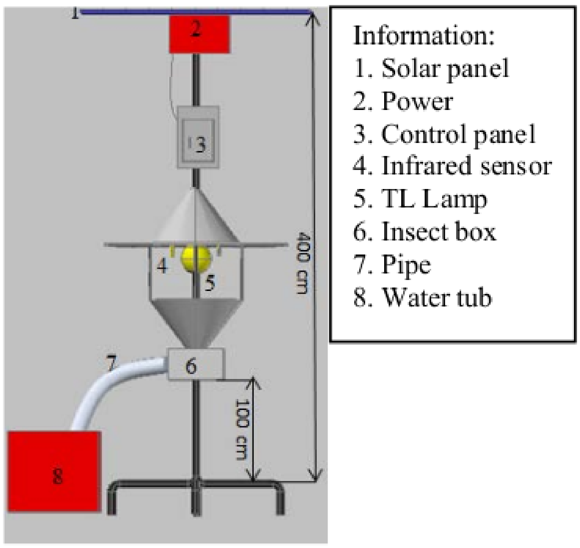

Fig.2. Prototype of cacao insect trap

The pest trapping framework was designed regarding research on the design of a rice plant pest-trap device using Arduino mega2560 (Cahyono and Nurmahaludin, 2015). Pest traps are installed at the height of 1 meter above the ground. The height of the solar panels from the ground is 4 meters so that the solar panels get maximum sunlight, not shaded by trees pest trap design, as shown in Fig. 2.

2.2. Field Test

The research begins with designing and assembling insect traps using hardware and software. Before using the infrared sensor, calibrate the reading distance by adjusting the reading distance by turning the infrared sensor potentiometer. The next step is to know the speed of reading on each infrared sensor used. The aim is to adjust the turn on the fan actuator to drop insects. Then, the insect comes and is detected by the sensor. The sensor sends a signal to Arduino then Arduino processes and sends a command to turn on the fan actuator (on) so that the insects are pushed into the insect collection tub. No insects approaching the tool makes the infrared sensor not send a signal to Arduino, so Arduino does not turn on the fan (off).

The observation variable carried out in this research is the number of insects caught in automatic Cacao pest traps compared to the number of insects trapped by yellow traps and attractant traps commonly used by farmers. Observation aims to determine the effect of using an automatic control system on pest traps. Observational data were measured once a day for 44 days. Data when insects arrive and insects that fall into the insect container will be stored in the MicroSD card Module.

The Teptrap v1 sensor design uses five detection sensors. Four units of sensors are used to detect insects and the fan actuator activator (Fig. 3). One sensor unit is placed in the insect shelter funnel, which can count incoming insects. The performance of actuators and types of decoys in the insect trap control system (Teptrap v1) measured includes the accuracy of sensor readings of various insect sizes, response speed, stability, system accuracy, and the average time of insect dropping.

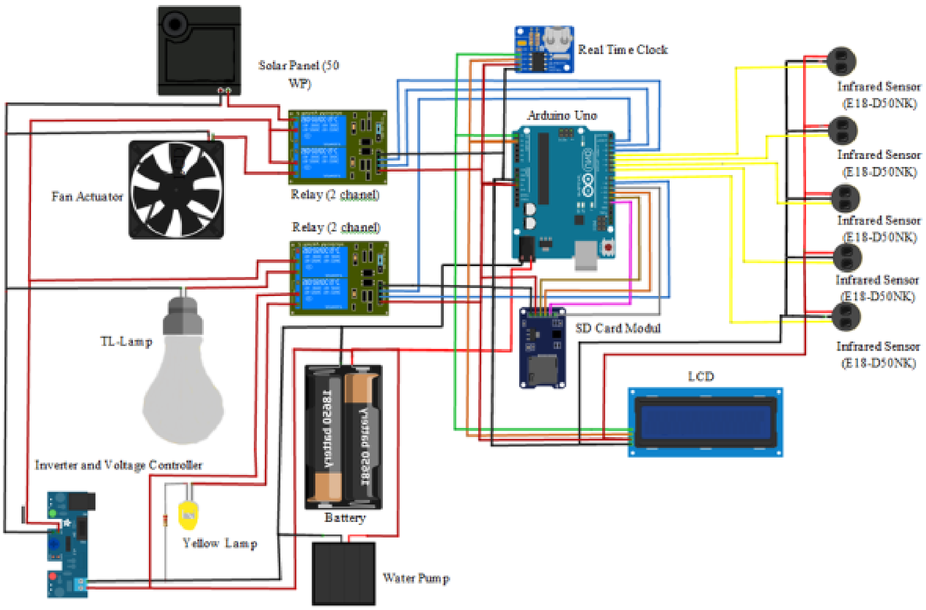

Fig.3. Schematic of sensor and actuator

3. Results and discussions

3.1. Design of Automatic Insect Trap for Cacao Plants

The automatic pest trap called Teptrap v1 has been successfully designed and tested to attract and catch Cacao insect pests. This trap is expected to be able to reduce population numbers and insect attacks on Cacao plantations. Also, the use of automatic insect traps is expected to reduce the use of chemical pesticides in pest management to reduce environmental pollution. The insect traps are designed in the form of a cylindrical frame with a height of 4 meters, a height of 40 cm in fishing space, and a diameter of 40 cm. The top and bottom of the trap space are cone-shaped with a height of 40 cm and a diameter of 60 cm, equipped with a temporary insect storage box measuring 40 cm x 30 cm x 20 cm (Fig. 4). The part of the support pole in the middle of the tool is slightly tilted to increase the strength of the support pole. This trap room features an insect drive fan actuator, TL lamp, attractant, yellow LED and an E18-D50NK sensor. In this automatic insect trap, the ATmega328 microcontroller on Arduino Uno functions as a data processor. It is integrated with various actuators for supporting components such as LCD, RTC, MMC. 2 channel Relay Module, and so on.

The energy of this insect trap comes from solar panels that convert sunlight into electricity. The power supply component consists of 2 solar cells with a capacity of 50 WP, a 45Ah battery, solar control charge, and a 300-watt inverter. The solar cell used has a capacity of 100 WP which means that the solar cell can produce 100 watts of power when the sun is hot (not obstructed by clouds).

3.2. Mathematical Model of Trap Sensor and Detection Sensor

The relationship between detected insect sensor readings (x) and trapped insect sensor readings (y) is described by the following formula:

$$y = 1.879 \cdot x^{0.82} - 3.1 \quad (1)$$

Fig. 4. The automatic insect trap in cacao plantation

The data from the detected insects and trapped insects showed a strong relationship with a correlation coefficient value of 0.812 (Fig. 5). The results of the observation data on insects coming and insects entering resulted in an RRMSE value of 31.9% (Haryanto et al., 2020). The RRMSE value between the detection sensor and the trapped sensor has a high average error value because not all insects that come and are detected are trapped into the instrument. The reading of the number of insects on the trapped sensor is more than the detection sensor because the insects come in groups, so the detection sensor reads one in each group.

The formula for correlation between trapped insects (x) and dead insects (y) is following:

$$y = 2.438 \cdot x^{0.786} - 3.65 \quad (2)$$

The data on this graph shows that there is only a slight difference between the sensor readings for trapped insects and those that are dead (calculated manually). Data from observations of trapped insects with dead insects show a strong correlation coefficient with a value of 0.974 (Fig. 6).

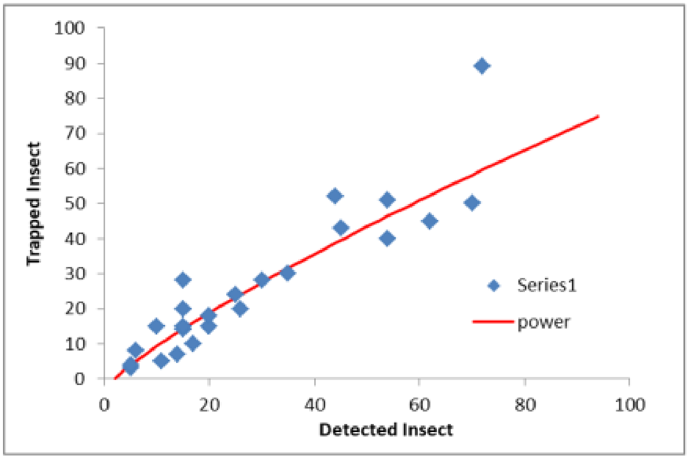

Fig. 5. Correlation of incoming insect vs incoming insect sensor readings

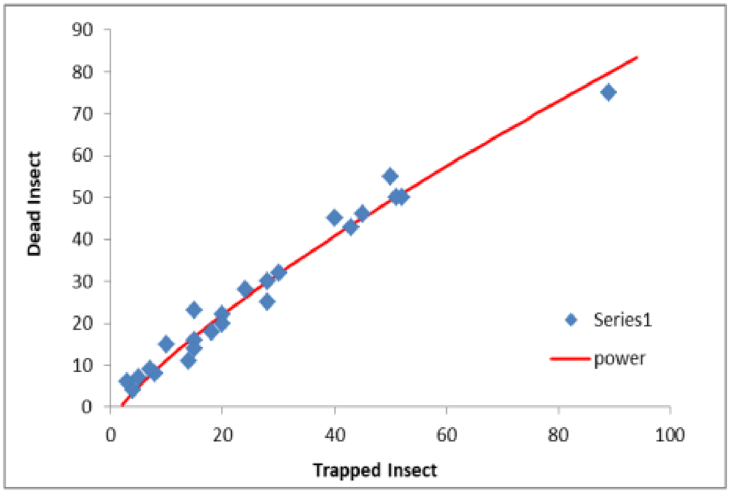

Fig. 6. Correlation of sensor readings for incoming insects vs dead insects (manual count)

The results from the data on incoming insects and dead insects resulted in an RRMSE value of 15.1%. This RRMSE value shows that the number of insects read by the trapped insect sensor and the number of dead insects has a small average error value. The cause of the number of insects killed is more than the insects read by the incoming sensor is because the size of the insects is below 1 mm, so the sensor cannot detect these insects.

3.3. Control system performance

3.3.1. Efficiency

The efficiency of catching insects is carried out by observing the number of insects counted by the detection sensor and the insect counter sensor trapped in the insect storage tank (Fig. 7). Detected insects are defined as insect pests detected by four detection sensor units. Trapped insects are insects that are counted by one trapped counter sensor unit, and dead insects are defined as the number of insects that are counted manually to determine the catch performance by the design of the pest trapping tool. Manual calculations are carried out on the filter in place after water storage (trap box). Pests that enter the filter have died from being submerged in water so that they can be counted manually.

The catch efficiency is defined as the accuracy of the fan actuator in pushing insect pests into the trap (water reservoir) based on the detected insects. This value can also be called the system accuracy in catching insects with the following formula:

$$E_p = \frac{\sum_{i=1}^{n}\left(\frac{S_0}{S_i}\times 100\right)}{n} \quad (3)$$

where:
E_p–catch efficiency (%)
S_0 –dead insects
S_i –detected insects
n –number of observation days

From the calculation results, the total efficiency in catching insects for 33 days is 82.74%.

Information:
1. Brown Beetle
2. Flies
3. Grasshopper
4. Butterfly

Fig. 7. Trapped Insects

3.3.2. Insects drop control speed

The insect drop control speed is defined as the average time it takes the actuator to drop the insect when an insect passes the sensor.

The formula for calculating the controlling speed of a fan actuator is:

$$R_{WP} = \frac{\sum_{i=1}^{n} Aon_i + D}{n} \tag{4}$$

Where :

R_{wp}–average time of falling insects

Aon_i–actuator turn on to-i (minutes)

D–time until the detection sensor doesn't read the insects (minutes)

n–data amount

From the observations, the speed of falling insects for 24 hours of observation is 6 minutes 33 seconds and the automatic insect trapping system works stable.

3.3.3. The response speed to turns on the actuator

The response speed to the tool design setting point in turning on the TL lamp actuator, the yellow multi-LED actuator and the water pump actuator takes <1 second (± 10 mS). This is because the speed of the microcontroller to execute commands takes 10 mS for each order.

3.3.4. Stability

Capture stability is defined as the ability of the tool (trap) to work precisely in detecting and making arrests over a long period. Good system stability is a system that can detect, measure, execute instructions, and activate actuators equally well, without experiencing significant deterioration in performance.

The performance of the Teptrap v1 tool in catching insects, as shown in Fig. 8, can be said to be stable because the insect sensor values detected by the dead insects did not differ significantly. The fluctuation of insect fishing is caused by environmental factors such as wind speed, air temperature and rainfall intensity. Some research report that the use of insect traps can reduce the use of chemical pesticides by 20-50%.

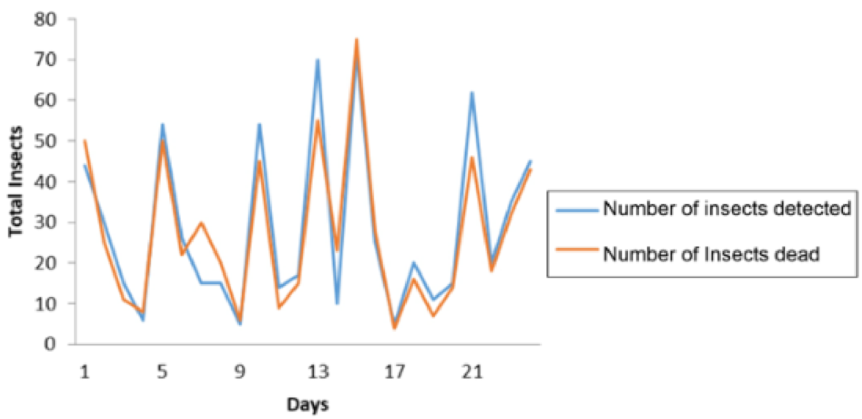

Fig.8. Stability of Insect trap

The Teptrap v1 has the advantage compared to the common insect trap which only have one manual trap, so it is expected that Teptrap v1 can be more effective to reduce the use of pesticide. This is certainly able to save the maintenance costs of plantation crops of IDR 74,468 per hectare of cacao crop in the cost of purchasing pesticides (Bunga, 2016).

4. Conclusion

Based on the research results, the design of the cacao insect trap actuator for 33 days has shown excellent performance. This is evidenced by the fan actuator system that works with an efficiency value (accuracy of capture) of 82.74%, the time it takes for the fan to drop the insects is 6 minutes 33 seconds. The actuator response speed turns on the lamp, the yellow LED and the pump takes <1 second and the system works stably. Automatic pest traps Traptep v1 was able to catch insects very well, as evidenced by the correlation coefficient of detected insect readings and trapped insects were 0.812, while the correlation between trapped insects and dead insects was 0.974. The use of this trap can reduce the impact of insect attacks because it slows down the rate of reproduction of insect pests. This is undoubtedly able to minimize the use of non-organic pesticides in pest control.

References

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