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Using a smart watering system for controlling thrips inside mangosteen canopy in Nakhon Si Thammarat province, Southern Thailand

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Abstract

Mangosteen (*Garcinia mangostana*) production is important in Thailand for domestic consumption and export in other countries. High-quality mangosteen is considered when there is no scar on the surface. Thrips infestation is a common cause of scars which reduces the market value of mangosteen. Thrips density is highly affected by humidity; higher humidity decreases thrips numbers. In this study, a smart watering system was designed, developed, and used to increase the humidity and reduce thrips numbers inside mangosteen canopy in Southern Thailand. The system successfully reduced the thrips numbers. This study also shows a negative correlation between humidity and thrips numbers.

Keywords

Mangosteen, Humidity, Thrips, Smart watering system, Southern Thailand.

Introduction

Thrips (Thripidae: Thysanoptera) are little hemimetabolous insects with recognizable cigar-shaped bodies. Thrips are small insects, with an adult body size ranging from about 0.5 to 15 mm (Goldarazena, 2011). Thrips cause several problems for various fruits and vegetables. They impact the young leaves, flowers, and young fruits of the strawberry (Allen and Gaede, 1963), mangosteen (Thongjua and Thongjua, 2013), and aubergine (Kawai, 1990). Additionally, they have an impact on a variety of vegetables, including cucumbers, tomatoes, and sweet peppers (Rosenheim et al., 1990; Welter et al., 1990; Shipp et al., 1998; Hao et al., 2002). Thrips affect the leaves and flowers of fruits and vegetables and reduce their production (Devi and Roy, 2017). Moreover, they lower the market value of fruits and vegetables by damaging their appearance (Heinz et al., 1992). In this way, thrips consequently lower the quality of fruits and vegetables and result in lost revenue. Thrips affect the mangosteen (*Garcinia mangostana*) too. Thrips infestation is the reason why mangosteen develops scars on their surfaces. The typical symptoms of thrips infestation are silvering or pale yellow or brown discoloration of the fruit skin, and elongated and uneven scars that may cover the entire fruit surface. The severely damage skin and inhibits fruit development, resulting in smaller-sized fruits than normal size (Affandi et al., 2008). Thrips also cause problems with flowers, young fruits, and young leaves, and reduce fruit quality. Thrips create problems in mangosteen production in several countries such as Indonesia (Affandi et al., 2008), Spain (Planes et al., 2004) and Brazil (Sacramento et al., 2007). A similar problem happens in Thailand too. Due to its flavor and nutritional benefits, mangosteen is known as the 'queen' of all fruits in Thailand. They are economically vital for both exports and domestic consumption. Though many

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countries produce mangosteen, Thailand is the world's top producer. Though mangosteen is a widely grown crop in Thailand, they mostly grow in the south and east (Thongjua and Thongjua, 2015). From 2006 to 2007, mangosteen was cultured on 316,413 rai (6 rai = 1 ha) in Southern and Eastern Thailand (Pankeaw et al., 2011). Among southern provinces, Nakhon Si Thammarat produces the majority of the mangosteens. From 2019 to 2021, the total mangosteen production in Thailand, Southern Thailand, and Nakhon Si Thammarat province were 1,145,695 kg, 568,702 kg, and 203,425 kg, respectively, and the revenues were 3,081,017 USD, 1,552,750 USD, and 571,400 USD, respectively (Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, 2022). In Nakhon Si Thammarat province, mangosteen cultivation is significant since it generates a significant revenue (Musik, 2020). The market demand of mangosteen solely depends on the fruit's quality. Fruit's qualities depend on many factors such as fruit size (>70 g/fruit), fruit's surface without any scar, and fruit's flesh without any translucent or gamboge (Pankeaw et al., 2011). The rough scarring on the fruit's surface reduce it's market value in domestic and foreign markets. Less than 60% of the overall mangosteen production is of high-quality (Thongjua and Thongjua, 2015). Therefore, it is crucial to reduce the thrips density in mangosteen orchards in Thailand.

Several studies show that different methods are utilized for thrips control in different countries; for example, in Japan, South Florida, UK, and Brazil people use chemical methods to control the thrips (Raetano et al., 2003; Smit et al., 2005; Cannon et al., 2007). In Japan and UK, people use biological methods for thrips control (Rodriguez et al., 2003; Smit et al., 2005). Physical method and integrated pest management (IPM) methods (e.g., mass trapping by using sticky traps) are used by the people in Venezuela and Japan (Salas, 2004; Yano, 2018). However, several studies suggest that these methods utilized in different countries have negative effects on the environment and human health (Cannon et al., 2007; Zhang et al., 2008). Therefore, an environment-friendly method needs to be developed to control the thrips. It is well known that various environmental factors affect the thrips density and distribution such as humidity, rainfall, temperature, and wind (Thongjua and Thongjua, 2015), but humidity is the one that affect the most (Waiganjo et al., 2008). There is a negative relationship between humidity and thrips numbers (Akram et al., 2013; Thongjua and Thongjua, 2015); it means that high humidity can reduce the numbers of thrips inside mangosteen canopy. Therefore in this study, we would like to develop and use a smart watering system to control thrips numbers through controlling humidity inside the mangosteen canopy.

Farmers may increase their mangosteen productivity and receive more benefit by using this smart watering method inside mangosteen canopy. Previously, smart watering systems has been used by people in several countries for various purposes.

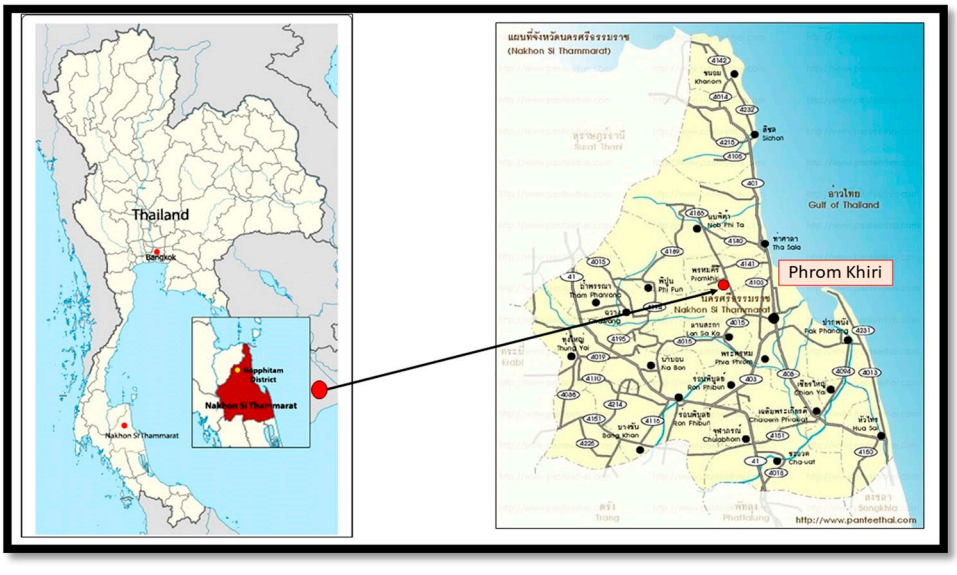


Figure 1: The red dot inside Thailand map indicates Nakhon Si Thammarat province (left hand side) and another red dot inside Nakhon Si Thammarat map indicates Phrom Khiri (right hand side) which is our study site.

For example, smart watering systems were utilized in mango orchards in Spain to control the irrigation process and in China to control the soil moisture content, respectively (Wei et al., 2017; Zuazo et al., 2021). In Thailand and India, several fruit and vegetable orchards have better irrigation process due to the use of smart watering systems (Sikka et al., 2016; Musik, 2020). In Thailand, smart watering system is used to control the humidity in mangosteen orchard (Malee et al., 2022). Smart sensing systems were created in New Zealand and Australia for monitoring nitrate levels in ground and surfacewater used in agricultural purposes (Alahi et al., 2017a, 2017b, 2018a, 2018b, 2018c, 2022). In these countries, smart watering systems were developed for monitoring the water quality in aquaculture and agriculture (Akhter et al., 2021a, 2021b).

Materials and methods

Study site

Thong Hong mangosteen garden in Phrom Khiri district (latitude: 8° 12´ N and longitude: 99° 28´ E), Nakhon Si Thammarat province, Thailand was selected to conduct this study. The size of this garden is 13.837 acres, and there are 700 trees. The trees are approximately 8 to 9 m long, and the distances between the trees are 7 to 8 m. The study area is shown in Figure 1.

Developing and using a smart watering system to control thrips inside the mangosteen canopy

In this study, we have developed and used a smart watering system to control humidity as well as thrips inside mangosteen canopy. Figure 2 demonstrates that the system consisted of open-close water pumps, a control room with magnetic contactor and switches for switching between manual and automatic systems, smart phone (android), a microcontroller board, Bluetooth, Wi-Fi, sensors (Modbus TRU RS485 SHT20), and a Thingcontrol application. In this system, the magnetic contactor in the control room was connected to the smartphone (Android) and with a microcontroller board by Thingcontrol application and Wi-Fi. A magnetic contactor controlled the open-close pumps, and the magnetic contactor was automatically controlled by a smartphone (Android). Figure 3 illustrates a mangosteen garden's automatic water management system controlled by a microcontroller board. The system was designed and developed from March 2021 to March 2022.

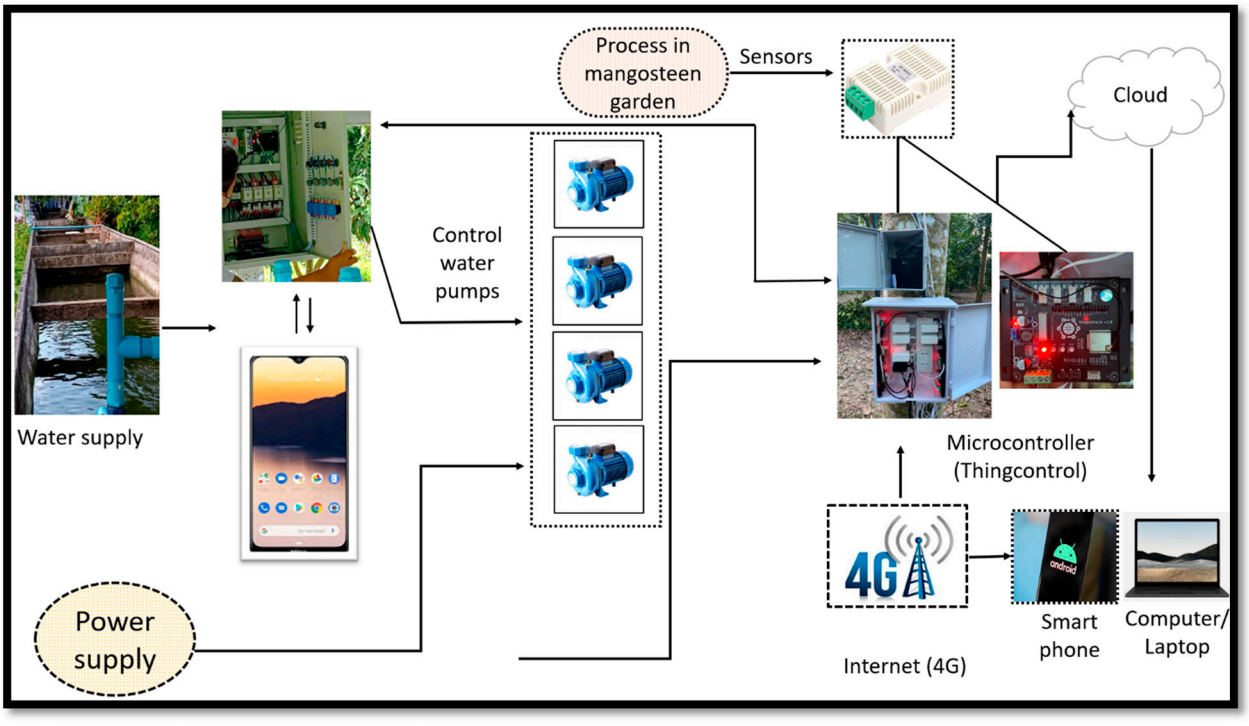


Figure 2: The development stage of smart watering system in orchard.

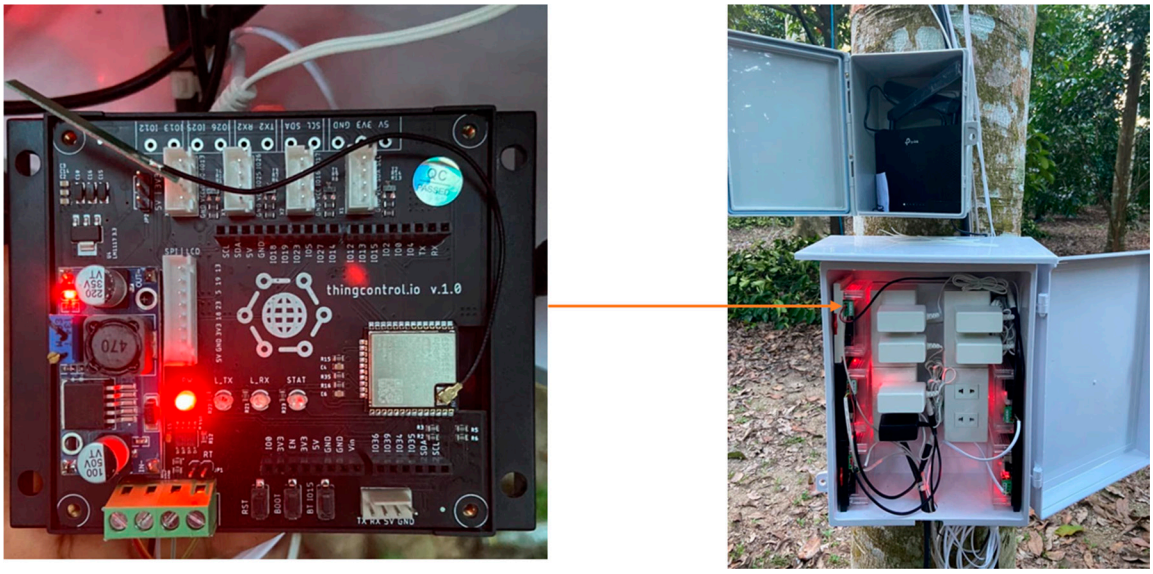


Figure 3: The microcontroller board used in the smart watering system in orchard.

Experimental design

We had two treatments in this study: (i) a control system and (ii) an automatic water management system. The conventional watering system was used in the control system, where the farmers provided water at the bottom of the trees for only half an hour (11.00 am-11.30 am) every day. Here, two trees were randomly selected, and one sensing system was installed in each tree (Fig. 4). In control, there was no smart watering system. Similarly, two trees were randomly selected in the automatic water management system. One sensing system was installed in each tree and a smart watering system was used (Figs. 4 and 5). In this area, humidity (%) falls below 80% from 9.00 am to 5.00 pm (Malee et al., 2022), and low humidity increases the number of thrips inside the mangosteen canopy (Akram et al., 2013). That is why we controlled the smart watering system to provide water inside the mangosteen canopy every hour (from 9.00 am to 5.00 pm) for 15 min. Figure 6 demonstrates the watering inside the mangosteen canopy.

In each tree of both treatments, one yellow sticky trap sheet (dual-sided 25 × 20 cm) was hung for 24 hr to collect thrips which is shown in Figure 7. Collecting thrips using yellow sticky trap sheet is common in many countries (Heinz et al., 1992; Boonham et al., 2002; Affandi et al., 2008; Aliakbarpour and Rawi, 2011; Devi and Roy, 2017). In Thailand also, the



Figure 4: Installation of sensing system on the mangosteen tree.

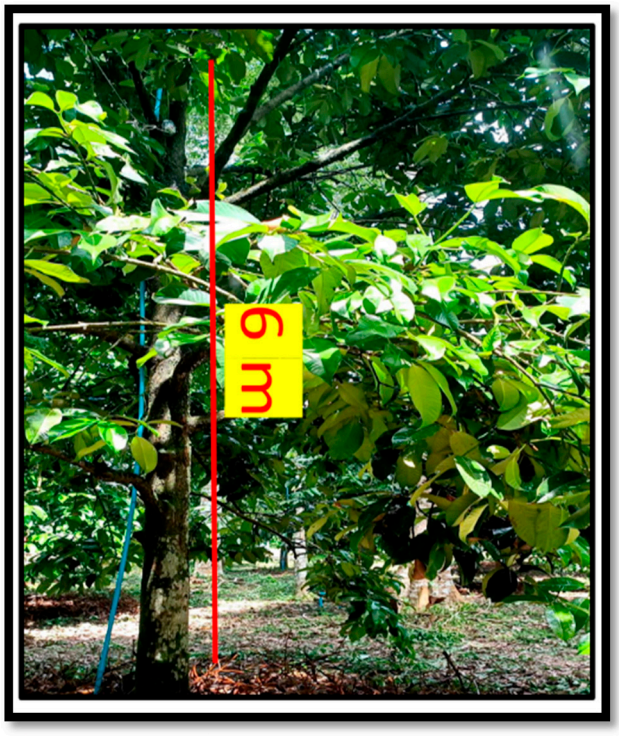


Figure 5: The installation of automatic watering system and water pipe (6 m long) inside the mangosteen canopy.

farmers use these traps to catch and reduce thrips numbers inside mangosteen canopy. We hung the sheet between 9 and 10 am, and counted thrips numbers the next day at the same time. The thrips get attached easily at both sides of the yellow sheet and cannot fly away (Boonham et al., 2002; Aliakbarpour et al., 2011). After removing each sheet from each tree, the thrips were identified by eye observation and circled with a permanent marker which is shown in Figure 8. Afterwards, the thrips numbers were counted from both sides of the sheet and data were recorded. The size (length) of randomly selected five thrips was measured and their size range was 1.2–3.9 mm, as shown in Figure 9. This experiment was conducted from 24th June to 3rd July, 2022.

Humidity data collection through sensors

In this study, humidity (%) data were also collected simultaneously when thrips data were collected. Thingcontrol company's (https://thingcontrol.io/) sensors were used to collect humidity (%) data. Everyday's humidity data (i.e., average humidity) inside the mangosteen canopy were collected by sensors. The data loggers inside the Thingcontrol console collected the data from sensors using AIS 4G Wi-Fi. These data are stored in the public cloud by file service Protocol (MQTP). Using the Thingcontrol application, the data were transferred from the cloud to the computer. The computer had a 1 GB data storage capacity, which allowed it to store data for a very long time. Furthermore, the information was collected on an Android phone using the Thingcontrol Application. The process is shown in Figure 10.

Data analysis

We assessed the normality of the data before starting the analysis. Parametric statistics were used when normality or other assumptions of parametric tests were met. Independent sample *t*-tests were conducted to test the differences in humidity (%) as well as thrips numbers per yellow sticky trap between control and automatic water management systems. Spearman correlation was used to test the correlation between humidity (%) and thrips numbers. The data were reported as mean ± SE, and all tests were considered statistically significant at $p < 0.05$.

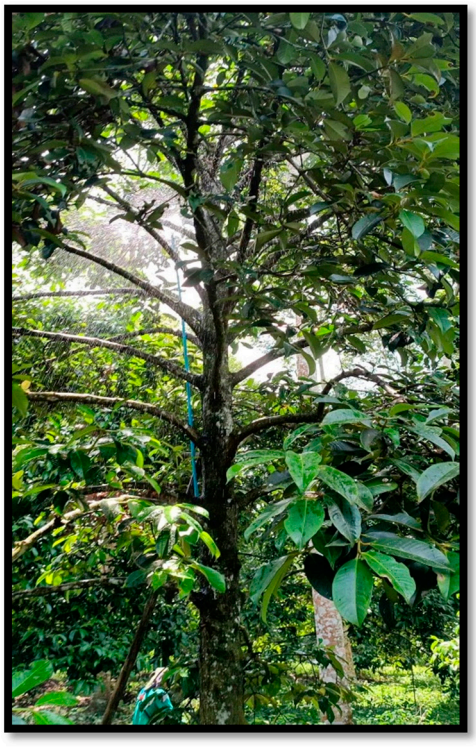


Figure 6: The demonstration of the watering inside the mangosteen canopy.



Figure 7: Yellow sticky trap for collecting thrips inside the mangosteen canopy.

Results

Differences in humidity (%) between 'control system' and 'automatic water management system'

It was observed that mean (± SE) humidity (%) was different between control and automatic water management systems (Fig. 11). In control system, humidity (%) was significantly lower than in automatic water management system ($t = -4.04$, df = 38, $p < 0.001$) (Fig. 11).

Differences in thrips numbers between 'control system' and 'automatic water management system'

It was observed that thrips numbers per yellow sticky trap (dual-sided 25 × 20 cm) were significantly higher in the control system than in the automatic water management system ($t = 3.51$, df = 38, $p < 0.005$) (Fig. 12).

The correlation between humidity (%) and thrips numbers

There was a negative relationship between humidity (%) and thrips numbers (Spearman's correlation coefficient (r_s) = –0.767, $N = 40$, $p < 0.001$) (Fig. 13). It indicates that when humidity is high, thrips numbers are less.

Discussion

In this study, a smart watering system was developed and used for controlling humidity and thrips inside the mangosteen canopy. Previously, smart watering systems were created and employed in several fruit orchards (i.e., chestnut tree gardens, durian gardens, and mangosteen gardens) for controlling irrigation processes and various climatic factors (Mota et al., 2018; Musik, 2020; Malee et al., 2022). It was observed that our system increased humidity as well as reduced thrips numbers effectively inside mangosteen canopy. In a previous study (Malee et al., 2022), it was observed that a smart watering system was able to control humidity inside fruit orchards. However, it was not tested whether the system could control thrips numbers or not. It has been assumed that smart watering system can control thrips density



Figure 8: The thrips (inside the circles) on the yellow sticky trap.

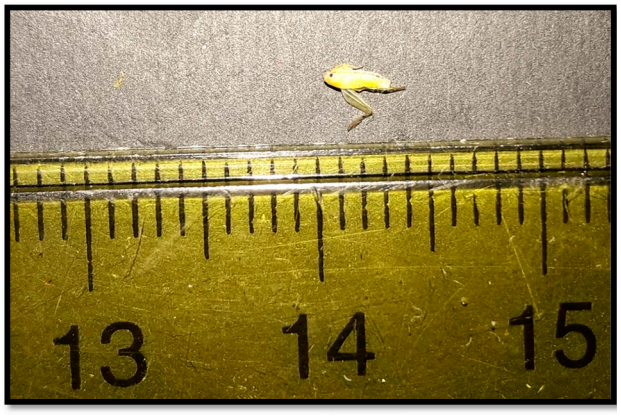


Figure 9: The size (mm) of a randomly selected thrips from the mangosteen canopy.

through increasing humidity inside fruit orchards since there is a negative relationship between humidity and thrips numbers (Akram et al., 2003; Thongjua and Thongjua, 2015; and this study).

Thrips are more prevalent and more capable of destroying orchard fruits when there is low humidity. They impact the young leaves, flowers, and young fruits of the strawberry (Allen and Gaede, 1963), mangosteen (Thongjua and Thongjua, 2015), and aubergine (Kawai, 1990). Additionally, they impact a variety of vegetables, including cucumbers, tomatoes, and sweet peppers (Rosenheim et al., 1990; Welter et al., 1990; Shipp et al., 1998; Hao et al., 2002). Cucumbers can be infected by thrips in two different ways: they can have scars, or their shape can be changed, which reduces their production (Rosenheim et al., 1990). Another study found that thrips infections in cucumbers reduced the quantity of tendrils and leaves which increased plant fatality (Welter et al., 1990). In tomatoes and sweet peppers, thrips can produce silvery and bronzy colors which damage the appearance of vegetables and lower their market value (Shipp et al., 1998). Thrips directly damage the vegetables through eating their leaves and blooms. It changes the carbon allocation in these plants (Rosenheim et al., 1990; Shipp et al., 1998). Thrips consequently lower the quality and quantity of the fruits and vegetables, resulting in lost revenue. In Thailand, mangosteen are exported to many countries like China, Hong Kong, Canada, Taiwan, and Japan (Ongkunaruk et al., 2011; Pankeaw et al., 2011) due to the increasing demand for this fruit on worldwide markets. The value or market demand of mangosteen depends on the quality of the fruits. If thrips outbreak develops in mangosteen orchards when the fruits are young, they produce scars on the fruit's surface

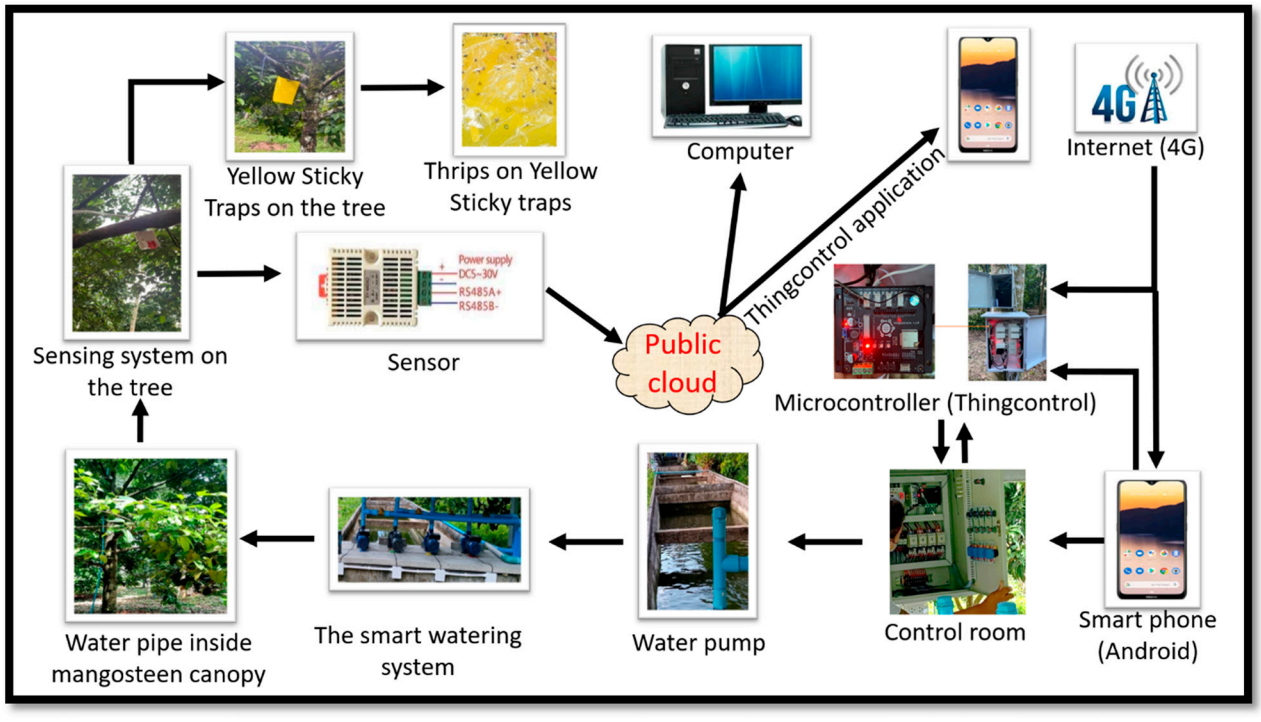


Figure 10: The complete process of smart watering system for controlling humidity and thrips inside mangosteen canopy.

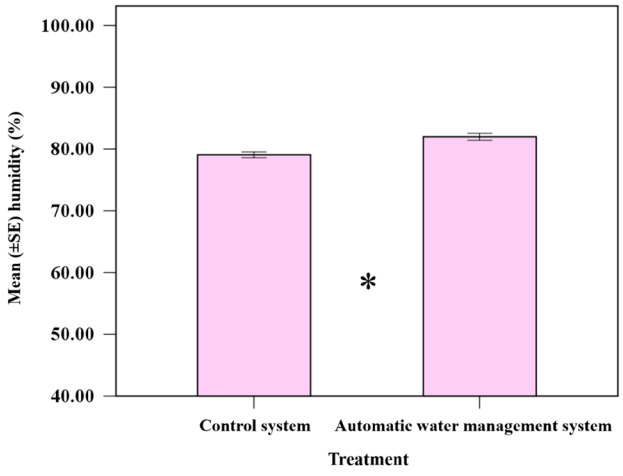


Figure 11: The mean (± SE) humidity (%) in 'control' and 'automatic water management system'. '*' indicates the significant difference ($p < 0.001$).

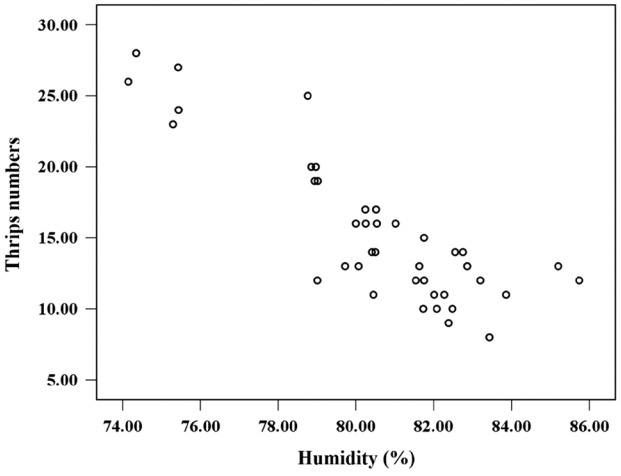


Figure 13: The correlation between humidity (%) and thrips numbers per yellow sticky trap (dual-sided 25 × 20 cm).

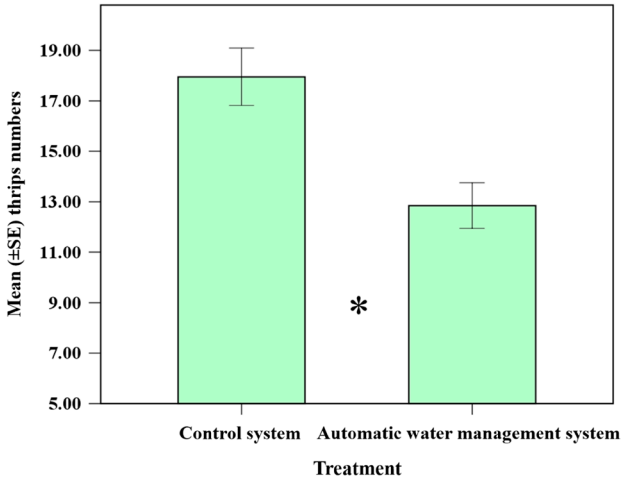


Figure 12: The mean (± SE) thrips numbers per yellow sticky trap (dual-sided 25 × 20 cm) in 'control' and 'automatic water management system'. '*' indicates the significant difference ($p < 0.005$).

(Thongjua and Thongjua, 2015). Sometimes severely damaged skin can inhibit fruit development, resulting in smaller-sized fruits than normal. Thrips also causes translucent flesh disorder, and fruit gamboge. All of these problems reduce their market value inside and outside of Thailand. However, high humidity inside the mangosteen canopy creates an unsuitable environment for thrips populations and can reduce them by eliminating both adult and larval populations (Thongjua and Thongjua, 2015). That is why it was important for us to develop a smart watering system for increasing the humidity in mangosteen orchards and control thrips numbers.

Conclusion

The present study developed and used a smart watering system to control thrips effectively through increasing humidity inside mangosteen canopy. This system can be used by the farmers effectively to control the thrips population inside other fruit and vegetable orchards. For this reason, this system needs to be familiar and socialized with the farmers who culture mangosteen and other fruits in Thailand and other countries thus they can realize the importance of the system for controlling humidity and thrips numbers. Through using this system, they will be able to increase the quality and quantity of the fruits and earn more money.

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