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Development of a smart watering system for controlling humidity inside mangosteen canopy in Nakhon Si Thammarat province, Southern Thailand

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Abstract

In Thailand, mangosteen (*Garcinia mangostana*) production is essential for domestic consumption and export. Mangosteen without scars on their surface is considered high-quality fruit. Scars reduce their market demand. The common cause of scars is thrips infestation. Humidity is an important climatic factor that affects the thrips populations. Lower humidity inside the mangosteen canopy increases the thrips numbers. Thus, increasing humidity can control the thrips population. This study developed a smart watering system to increase the humidity inside the mangosteen canopy in Nakhon Si Thammarat province, southern Thailand. This system provided water automatically and increased humidity inside the mangosteen canopy.

Keywords

Mangosteen, Humidity, Thrips, Smart watering system.

Introduction

Mangosteen (*Garcinia mangostana*) is considered the “queen” of the fruit in Thailand due to its taste and nutritional value. Mangosteen is a popular agricultural crop in Thailand, especially in southern and eastern Thailand. They are economically important both for domestic consumption and export. The major production comes from Thailand, Malaysia, Indonesia, and the Philippines. Thailand is the largest producer globally, and most of the production comes from southern and eastern provinces (Thongjua and Thongjua, 2015). The planting area of the mangosteen was 316,413 rai (6 rai = 1 ha) in 2006-2007, which was planted in southern and eastern Thailand (Pankeaw et al., 2011). Among southern provinces, most of the mangosteen production comes from Nakhon Si Thammarat province. From 2018 to 2021, the total production of mangosteen in Thailand, southern Thailand, and Nakhon Si Thammarat province was 1,146,295 kg, 567,601 kg, and 202,423 kg, and their values were 112,336,996 Thai Baht (THB), 55,624,898 THB, and 19,837,454 THB, respectively (Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, 2022). Because of the high demand for mangosteen in international markets, Thailand exports mangosteen to different countries like Canada, Japan, Hong Kong, China and Taiwan (Ongkunaruk and Piyakarn, 2011; Pankeaw et al., 2011).

In Nakhon Si Thammarat province, mangosteen culture is important because they produce a huge revenue for this Province (Musik, 2020). The value or market demand of mangosteen depends on the quality of the fruits. High-quality mangosteen is defined as a good fruit size (>70 g/fruit), no scar on the fruit surface, no translucent flesh disorder, and no fruit gamboge (Pankeaw et al., 2011). The common cause of scars on fruits’ surfaces is thrips (Thripidae: Thysanoptera) infestation. Typical symptoms of the mangosteen fruit affected by thrips are silvering of the skin, pale yellow to brown discolouration, and elongated and patchy scars that may cover the entire fruit surface. Heavily scarred skin can sometimes prevent fruit development which causes smaller-sized fruits than standard size (Affandi et al., 2008).

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

Thrips also damage flowers, young fruits and young leaves and decrease the quality of the fruits, causing economic loss. Both local and International markets dislike the rough scarring on the fruit surface, and the price of mangosteen at the farmers' level is determined based on the quality of the mangosteen. The production of high-quality mangosteen is less than 60% of the total output (Thongjua and Thongjua, 2015). In 100% mangosteen gardens, there is thrip damage (Pankeaw et al., 2011).

Thrips create scars not only on mangosteen but also on other fruits such as apples (Childs, 1927; Jacobs, 1995), grapes (Mcnally et al., 1985), and avocados (Dennill and Erasmus, 1992; Hoddle and Morse, 1997). Several climatic factors affect thrips population and distribution, such as humidity, temperature, rainfall, and wind (Gahukar, 2003; Waiganjo et al., 2008; Akram et al., 2013; Thongjua and Thongjua, 2015). Dry weather with moderately high temperatures increases thrips numbers. On the other hand, a wet season with relatively high humidity decreases thrips numbers (Waiganjo et al., 2008). Among many climatic factors, humidity is the one that affects the thrips distribution most (Waiganjo et al., 2008). A negative relationship was observed between humidity and thrips populations (Akram et al., 2013; Thongjua and Thongjua, 2015). It indicates that high humidity can decrease the thrips populations and their distribution in the orchards.

This study aims to increase the humidity inside mangosteen canopy in Nakhon Si Thammarat province by developing a smart watering system. Thus, it can control the thrips populations and their distribution inside the mangosteen canopy. The development of smart watering system for controlling humidity as well as thrips inside mangosteen canopy can help the farmers to increase their mangosteen production and earn more money. Several previous studies developed and used smart watering systems for various purposes;

for example, a smart watering system was used to control the irrigation process in a mango orchard in Spain (Zuazo et al., 2021). Another study in China used a smart water management system to control the soil moisture content in a mango orchard (Wei et al., 2017). A smart watering system was utilized to improve the irrigation process in mangosteen and durian orchards in Thailand (Cheychom et al., 2019; Musik, 2020). In India, a smart water management system was used to control the soil moisture content, temperature, drought of water, and to improve the irrigation process in several orchards such as: cauliflower, rice, long gourd, cotton, chilli, wheat, onion, and brinjal (Alok et al., 2016). In New Zealand and Australia, a smart sensing system was developed for nitrate monitoring in surface and groundwater in the agricultural industry (Alahi et al., 2017a, 2017b, 2018a, 2018b, 2018c, 2022). Moreover, smart watering systems were also developed for monitoring water quality in small fisheries farming and other agricultures (Akhter et al., 2021a, 2021b). The development of the smart watering system is explained in the second section.

Materials and methods

Study site

This research was conducted in Thong Hong mangosteen garden in Phrom Khiri district (latitude: 8° 12′ N and longitude: 99° 28′ E), Nakhon Si Thammarat province, Thailand. This mangosteen garden is 35 years old. The size of this garden is 56,000 m^2, and there are 700 trees. The height of the trees is approximately 8–9 m, and there are 7–8 m distances between the trees. The study area is shown in Figure 1.

Developing a smart watering system

An automatic watering system was developed to control the humidity in the mangosteen canopy. It consists of Wi-Fi, a microcontroller board, a Thingcontrol application, Bluetooth, sensors (Modbus TRU RS485 SHT20), water pumps, and solenoid and ball valves. The development stage of the smart watering system is shown in Figure 2. The smartphone (Android) was connected with the microcontroller board, open-close pumps, and solenoid valves by Wi-Fi and Thingcontrol application. Figure 3 illustrates the process of open-close pumps and solenoid valves of the automatic water management system in the mangosteen garden. The valves can be controlled directly by the smartphone (Android). Figures 4 and 5 show the water pipe system and a set of 6-valves in the automatic water management systems inside the mangosteen garden. The diagram of the microcontroller board for controlling the automatic watering system in the mangosteen garden is shown in Figure 6. The smart watering system was designed and developed from March, 2021 to March, 2022.

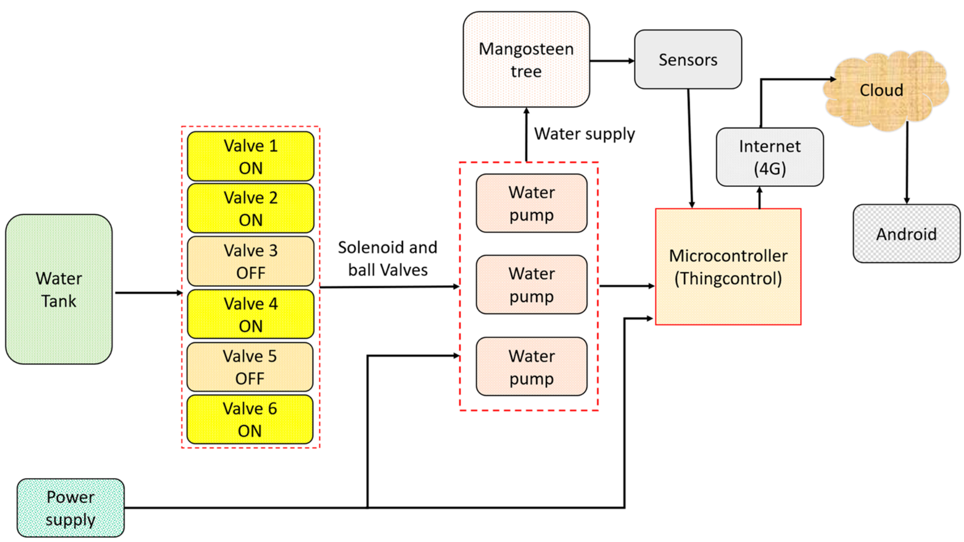

Figure 2: The development stage of smart watering system.

Experimental design

In this study, we had two treatments: (1) a control system and (2) an automatic water management system. We used the conventional watering system that the farmers use in the control system. The farmers usually provide water only for half an hour (11.00 am–11.30 am) every day. They give water at the

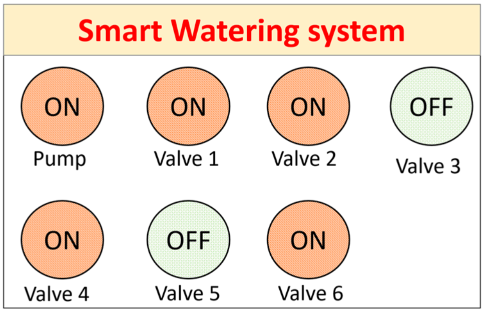

Figure 3: A set of 6-valves in the smart watering system.

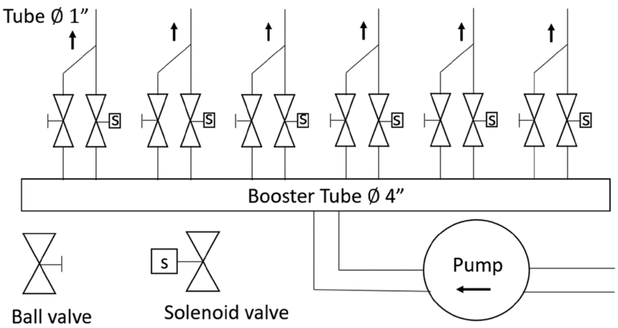

Figure 4: The water pipe system (6-valves in the smart watering system).

Figure 5: The 6-valves in the automatic water management system inside the mangosteen garden.

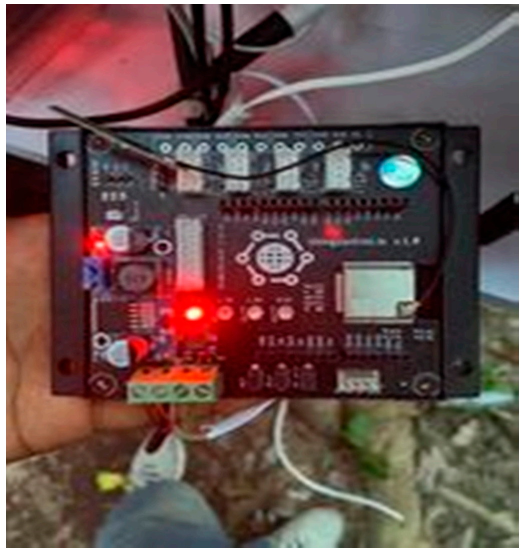

Figure 6: The microcontroller board used in the smart watering system.

Figure 7: Sensing system on the mangosteen tree.

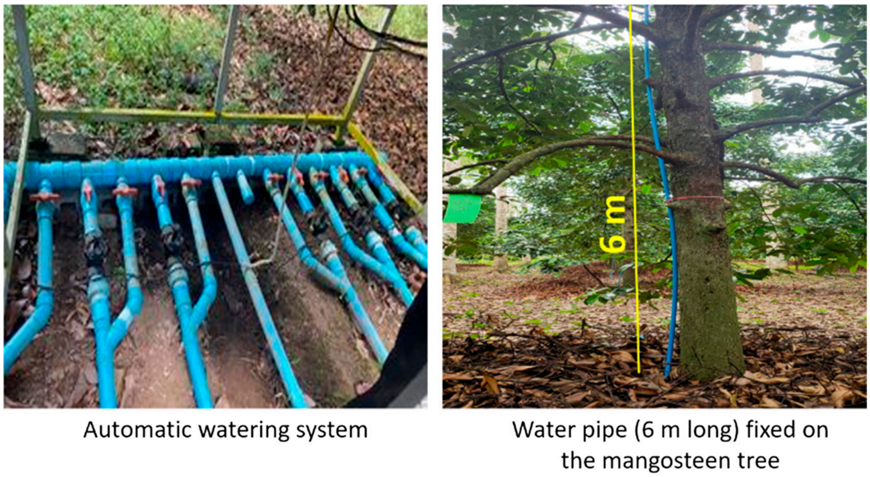

Figure 8: The demonstration of the installation automatic watering system and water pipe in the mangosteen tree.

bottom of each tree. In this treatment, 2 trees were randomly selected, and one sensing system was installed in each tree, as shown in Figure 7. No smart watering system was used in this treatment. In the automatic water management system, 2 trees were randomly selected and a smart watering system was used, as shown in Figure 8. One sensing system was installed in each tree. Previously it was observed that humidity (%) falls below 80% from 9.00 am to 5.00 pm, and that is why the smart watering system was controlled to provide water inside the mangosteen canopy every hour (from 9.00 am to 5.00 pm) for 15 minutes. How the system provided water inside the mangosteen canopy is shown in Figure 9.

Data collection through sensors

In this study, we used the sensors from Thingcontrol company (https://thingcontrol.io/) to collect humidity data. The real-time monitoring of humidity inside the mangosteen canopy was done by the sensors that stored data in every 1 hr a day. The data were collected from 7 to 9 April, 2022. The sensors sent the data to the data loggers (Thingcontrol) inside the Thingcontrol console using AIS 4G WiFi. These data were sent to the public cloud storage system through file service Protocol (MQTP). The data were collected from the cloud to the computer by using the Thingcontrol application. The data storage capacity of this computer was 1 GB which was able to store data for a long time. Moreover, the data were also collected on an Android phone using the Thingcontrol Application. The whole system 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. A scatter plot was made between the time in a day (o'clock) and humidity (%). An Independent sample *t*-test was conducted to test the differences in humidity (%) between control and

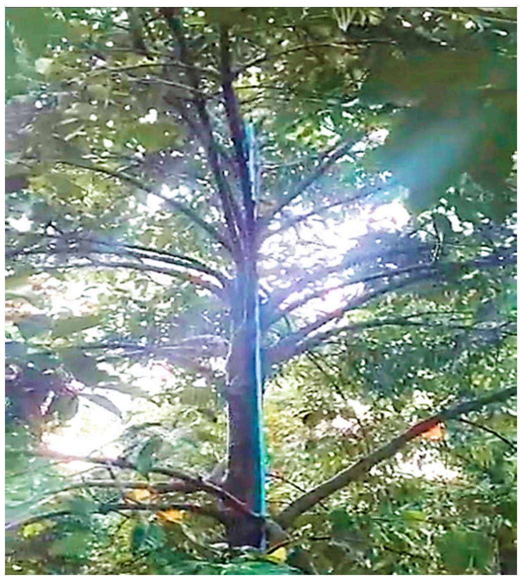

Figure 9: The demonstration of the watering inside the mangosteen canopy.

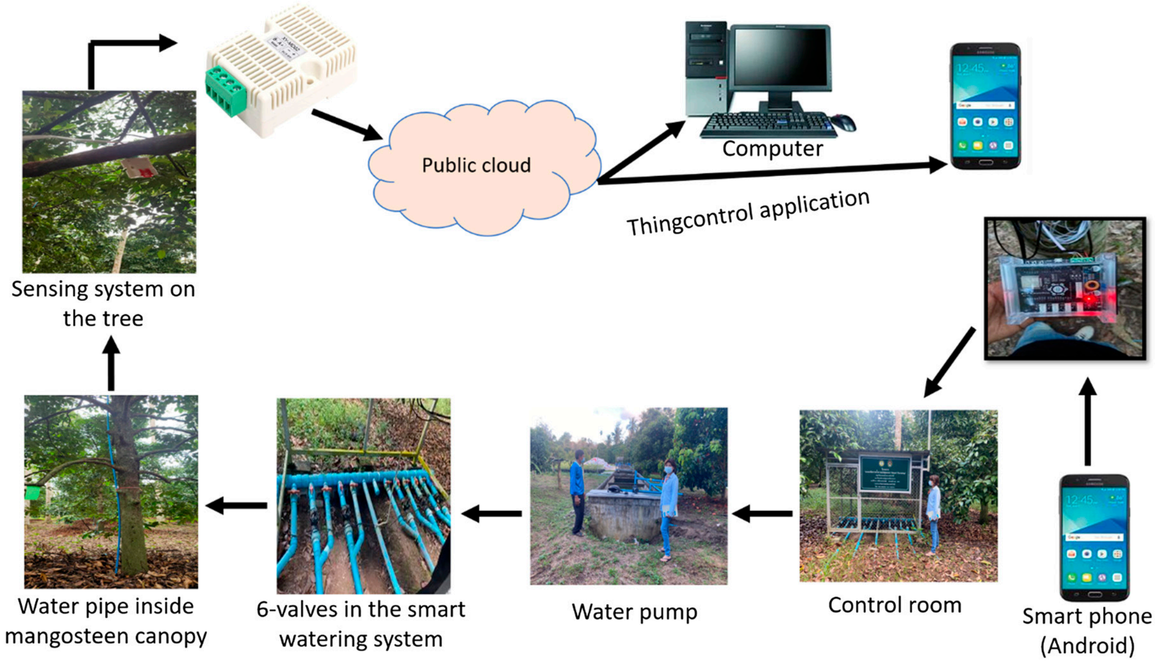

Figure 10: The complete process of smart watering system for controlling humidity inside mangosteen canopy.

automatic water management systems. The data were reported as mean ± standard error (SE), and all tests were considered statistically significant at $P < 0.05$.

Results

Humidity (%) at different times (o'clock) in a day

It was observed that in control system, humidity (%) started to decrease at 7 o'clock in the morning and it increased again at 18 o'clock in the evening, and it was lower than 80% from 9 o'clock in the morning to 17 o'clock in the late afternoon (Figure 11). However, during this time, the humidity in the automatic water management system was slightly higher than in the control system (Figure 11).

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

Out result shows that automatic water management system increased humidity (%) significantly than control system ($t = -2.25$, df = 286, $P = 0.025$) (Fig. 12). It indicates that our automatic water management system is efficient in increasing humidity (%) in the mangosteen canopy.

Discussion

In this study, we successfully developed a smart watering system for controlling humidity in the mangosteen garden. Previously, smart watering systems were developed and used in several orchards such as chestnut tree gardens, durian gardens, and mangosteen gardens for controlling the irrigation processes and several weather factors (Mota et al., 2018; Cheychom et al., 2019; Musik, 2020).

In the control system in our mangosteen garden, the humidity falls below 80% from 9 o'clock in the morning to 17 o'clock in the late afternoon, which can create a suitable environment for thrips and other pests. Previously it has been observed that low humidity is ideal for thrips populations, and it can create an outbreak of thrips (Mukawa et al., 2011). A negative relationship was also found between humidity and thrips populations (Thongjua and Thongjua, 2015). It means that the thrips are higher in numbers during low humidity and can destroy the fruits in orchards. They affect the young leaves, flowers and young fruits of mangosteen (Thongjua and Thongjua, 2015), chestnut (Mota et al., 2018), and

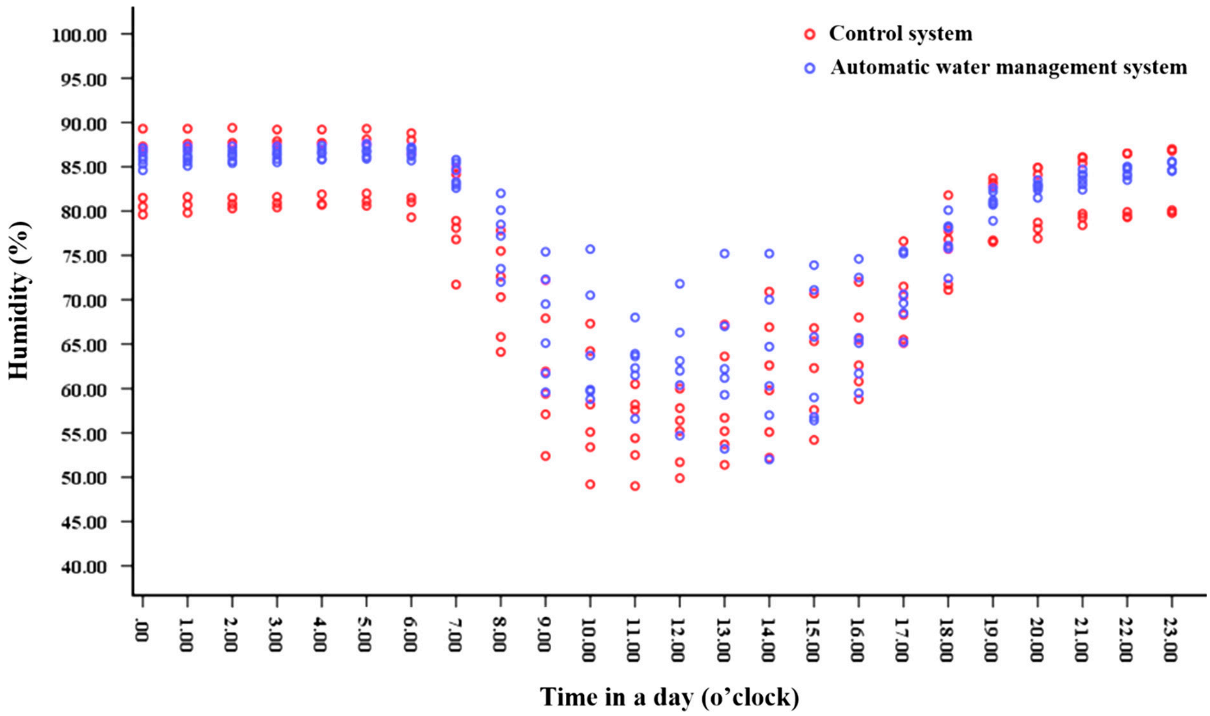

Figure 11: Humidity (%) observed in 'control' and 'automatic water management system' at different times in a day.

strawberry (Allen and Gaede, 1963). They also affect several types of vegetables such as cucumbers, tomatoes, and sweet peppers (Rosenheim et al., 1990; Welter et al., 1990; Shipp et al., 1998; Hao et al., 2002). Thrips can damage cucumbers in two different ways; they leave scars on the cucumbers and change their shapes, affecting their production (Rosenheim et al., 1990). Another research showed that infestations of Thrips in cucumbers could decrease the tendrils number, leave numbers, and increase the plant mortality (Welter et al., 1990). In the case of tomatoes and sweet peppers, thrips can cause silvery and bronzy colours that affect their appearance and decrease their market value (Shipp et al., 1998). Thrips can also damage these vegetables by feeding their leaves and flowers. Their feeding modifies the carbon allocation in these plants (Shipp et al., 1998; Hao et al., 2002). Therefore, thrips decrease the quality of fruits and vegetables and cause economic loss. In the case of mangosteen orchards, if thrip outbreak occurs when the fruits are young, it creates scars on the fruit surface and reduces their value to the customers (Thongjua and Thongjua, 2015). However, high humidity is not suitable for thrips populations and it can suppress their populations by killing larvae, and adult populations (Thongjua and Thongjua, 2015). That is why it is important to control the humidity in fruit gardens for controlling thrips. We observed that our smart watering system is able to increase the humidity successfully compared to the control system which could control the thrip populations inside mangosteen canopy.

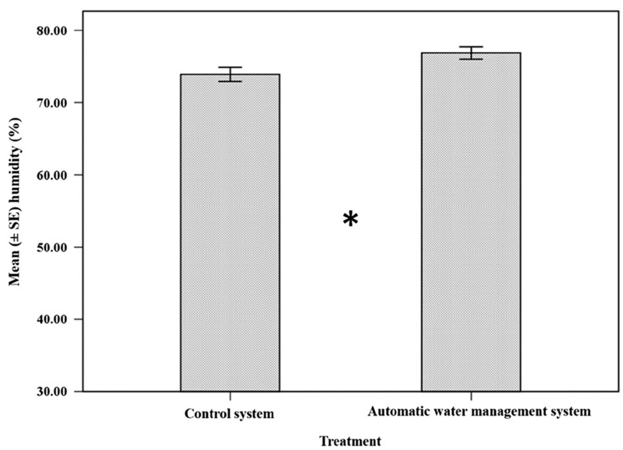

Figure 12: The mean (±SE) humidity (%) in 'control' and 'automatic water management system'. "*" indicates the significant difference (*P* <0.05).

Conclusions

The present study implies the importance of using our smart watering system to increase the humidity inside the mangosteen canopy when needed. This system might be helpful for other orchards where high humidity is required. Since this system successfully increases the humidity, it presumably controls the thrips populations, but further research is needed to test that. This smart watering system needs to be socialized and familiar with the mangosteen farmers in Thailand thus, they can understand the importance of the system to control humidity in their mangosteen orchards.

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