The Development of Soil Moisture Control System based on Wireless Communication Technology for Off-Season Durian Production in Nopphitam District, Nakhon Si Thammarat Province, Thailand

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Abstract

This study is a part of the research granted by the National Research Council of Thailand (NRCT). In this first stage, the study aimed to design and develop wireless communication system collecting data concerning soil moisture, light, temperature and humidity in the experimental off-season durian plantation. According to the experimental off-season durian plantation investigation, durian planting was divided into four phases. The site preparation phase started from January to April. From May to June was the controlling phase. Later, the pruning phase started from July to November and, finally, the harvesting phase was from December to January. Soil moisture analysis in those four periods found an average soil moisture content of 65 %. However, in April, soil water decreased by an average of 20 %. Therefore, irrigation was required to promote normal growth of durian. During the irrigation, temperature dropped and humidity increased by an average of 5%. All of these results will be used to develop soil moisture control system in the next stage.

Keywords: Off-Season Durian, Soil Moisture, Wireless Communication, Measurement and Control System

Introduction

Durian (Durio zibethinus Murr.) belongs to the genus Durio and the family Bombacaceae, which is best known for showy flowers and woody or thin-shelled pods filled with small seeds and silky or cottonlike fiber (Botanical-online, 2015). Widely known and revered in Southeast Asia as the "king of fruits", the durian is distinctive for its large size, unique odor, and formidable thorn-covered husk. It is also more expensive when compared to other fruits in Thailand, especially off-season durian that is twice more expensive.Because of the high economic value of durian, durian growers tend to grow off-season durians more than on-season ones (Office of Agricultural Economics (OAE), 2014; Na Nakorn & Chulumpak, 2015; Radchanui & Keawvongsri, 2017; Tantrakonnsab &Tantrakonnsab, 2018). However, off-season production and approaches for flowering induction of durian are in demand and attract much research (Hau & Hieu, 2018). For instance, management for flower induction, water management, and fertilizer application are involved in the process. According to Nopphitam farmer report in 2015, many rubber farmers have turned to grow on and off-season durians. One of the major factors affecting off-season production of durian is irrigation system. Water and soil moisture are very crucial especially during flowering and fruit development stages to achieve good and quality yields. This has caused problem as soil moisture cannot be measured by durian growers. Thus, monitoring soil moisture on an ongoing basis at several positions within the root zone and systematically using this information to make irrigation decisions requires measurement devices, computers and networked communication equipment. Precise control over the root zone environment, in terms of both water and nutrient content, leads to healthier crops and higher yields (Evant, Cassel, & Sneed, 1996; Dursun & Ozden, 2011). In recent years, technology has played a big role in developing the agricultural industry. It enables farmers to both increase land yield and improve the quality of their produce. Moreover, agriculture technology is providing a much-needed lifeline contributing significantly to the improvement of working conditions such as irrigation (Na & Junfeng, 2010; Bhosale & Dixit, 2012; Getu & Attia, 2015; Suba, Jagadeesh, Karthik, & Sampath, 2015; Morillo, Martin, Camacho, Rodriguez, & Montesinos, 2015). Accordingly, this study aimed to investigate off-season durian production in Nopphitam District, Nakhon Si Thammarat Province, Thailand and to develop soil moisture control system based on wireless communication technology for off-season durian production. In addition, this research has received grants from the National Research Council of Thailand (NRCT) for three consecutive years. In this first stage, the study aimed to design and develop wireless communication system collecting data concerning soil moisture, light, temperature and humidity in the experimental off-season durian plantation. The second stage, the study will be aimed to develop soil moisture control system linking with the data collected from the first stage. In the final stage, system monitoring and evaluation will be implemented.

Materials and Methods

Plant materials

The experiment was conducted in a durian orchard of Mr. Sombat Sintun and Ms. Sirilak Boonnoy located in Nopphitam District, Nakhon Si Thammarat Province, Thailand.

Methods

The wireless communication technology design included irrigation system design, control cabinet installation, and sensor installation.

1. Irrigation system design

Irrigation system was designed to collect soil moisture data in the experimental orchard. Durian trees were planted in 11 rows spaced about 8 meters apart. Each row was 120 meters long. Figure 1 showed irrigation system design of the durian orchard. Multi-stage centrifugal pump, MT-105, 3 HP, was installed to extract water to each zone. 2-and 1.5-inch PVC pipes were used as the main pipe and service pipelines respectively. 1.5- inch PVC ball valve was put into service as a gate valve in order to control water flow in each row. Service pipelines were attached to ¼-inch sprinklers. 1-inch PVC pipes were lined up under the canopy. Owing to the slope planting, the irrigation system was divided into 3 zones in order to apply water efficiently and effectively.

The system was developed to control both manually and automatically. Typically, the grower turned on the gate valve (1.5- inch PVC ball valve) in each zone manually before turning on the pump. The pump cannot be turned on before the gate valve as the high pressure will damage the service pipelines.In this study, automated irrigation system using a wireless communication technology was employed. Three of 2-inch solenoid valves (S) with 24 VAC were installed. The 1.5- inch PVC ball valve was always turned off. It can be turned on when using the grower's typical mode. This was presented in Figure 1. Irrigation system in the three zones was labeled as S1, S2, and S3, respectively. Moreover, flow sensor (DIGITEN G2", FL-1608), attached next to the pump, measured water consumption in each zone.

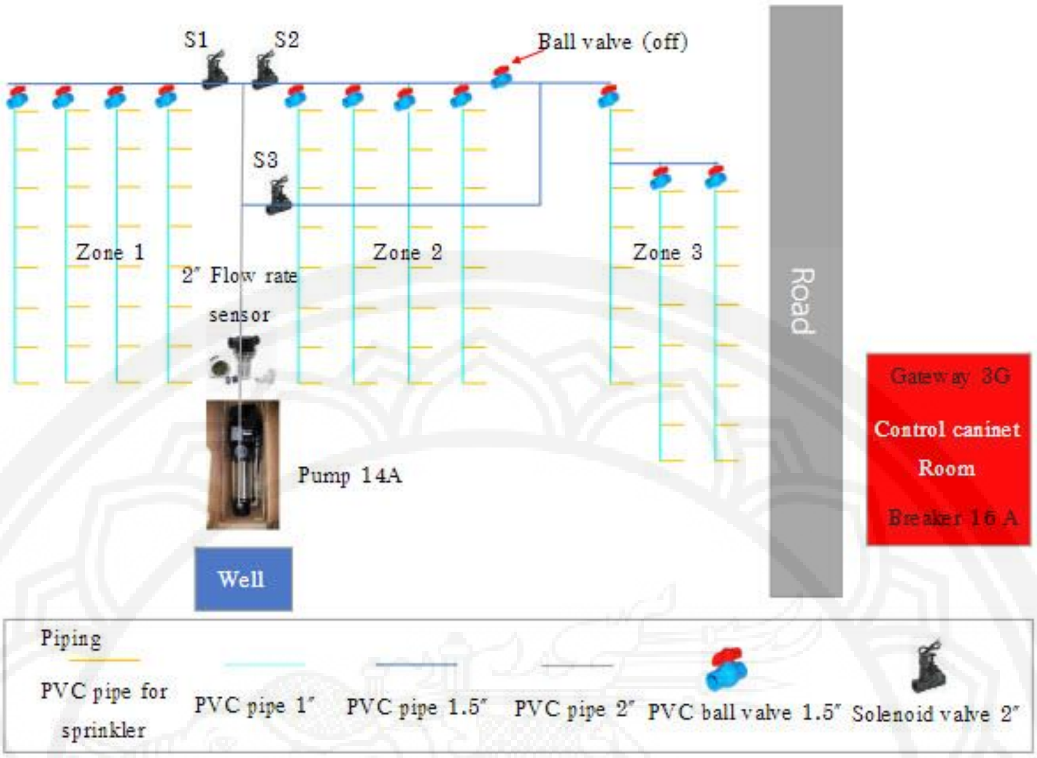

Figure 1 Irrigation system design

2. Control cabinet design and installation

The control cabinet was designed into two modes—manually and automatically. The irrigation system can be controlled manually at the control cabinet and it can be controlled via wireless communication as well.

The control cabinet contained diverse components including an aMG Plant Buddy, Chrome DIN Rail Power Supply 12V, Delta, a circuit breaker (ABB S201-C32) with 16A fuse, a digital phase protector, W-OP2, and magnetic (15A). Eight built-in slave relays were installed in the aMG Plant Buddy. The first relay controlled magnetic for pump. The second to fourth relays controlled three solenoid valves respectively.

The control cabinet was supplied with a VCT wire (60 m. 3x2.5 mm^2.) controlling pump. A CAT 5E, PE outdoor was used to control solenoid valve with 24 VAC. And an aMG repeater with 12 VDC was installed as well. Surface wiring was used as shown in Figure 2.

Communication devices sending and receiving sensor signals to controlling system consisted of 2 sets of aMG repeater, aMG Fio glide 2, flow sensor, and aMG PWS 3 (3/5VDC) (power supply regulator) as shown in Figure 3.

Figure 4 showed the control panel of the control box equipped with 5 selector switches. The switch had three selectable positions—Manual, Off, and Auto. ‘Manual’ means turning-on the controlled devices and, they will be turn off if the switch is at ‘Off’ position. ‘Auto’ is when controlled devices working under the designed condition that will be operated in the next project. Apart from that, there are 7 LED status lights, one for power status, one for overload, one for pump status, and the other four for valves.

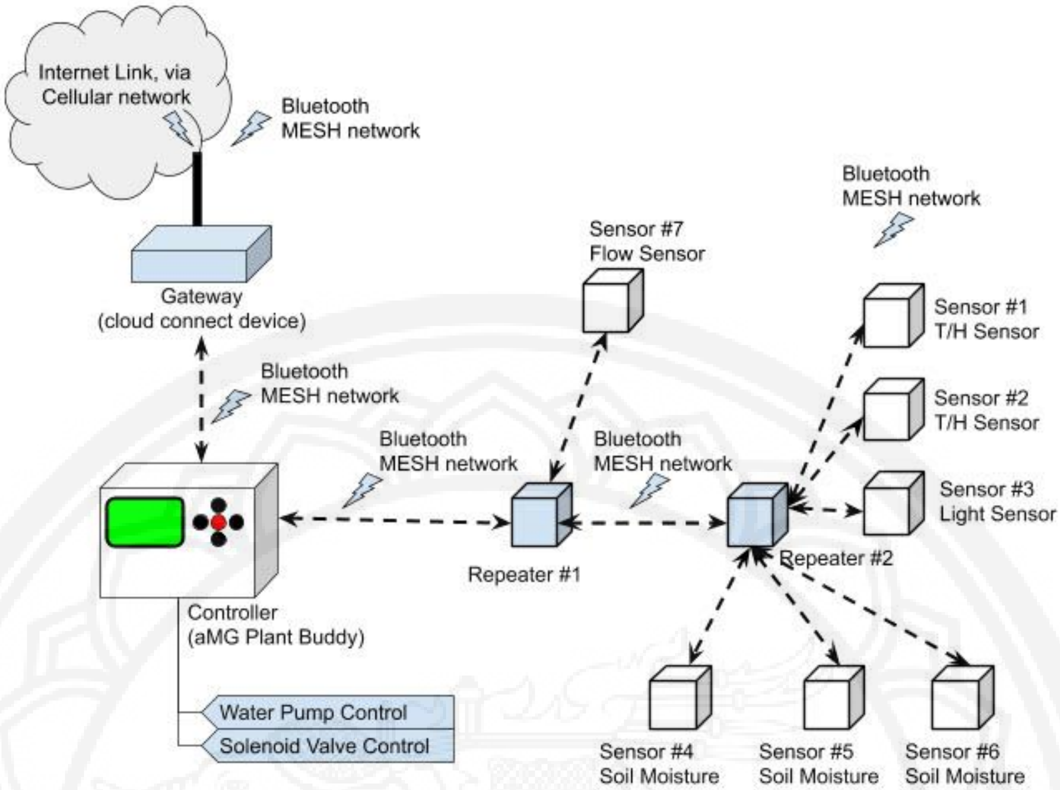

Figure 2 Control cabinet design and installation

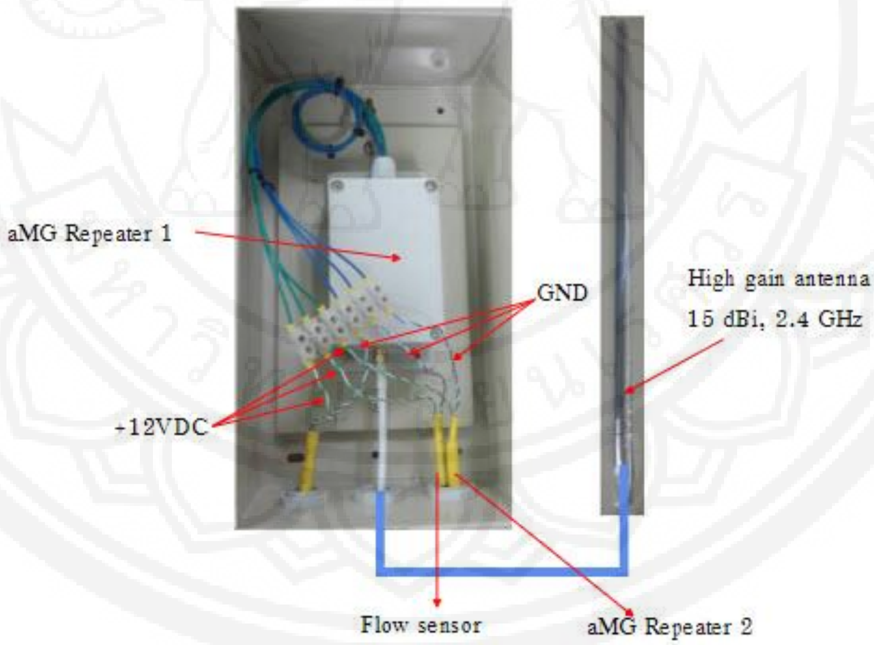

Figure 3 Repeater

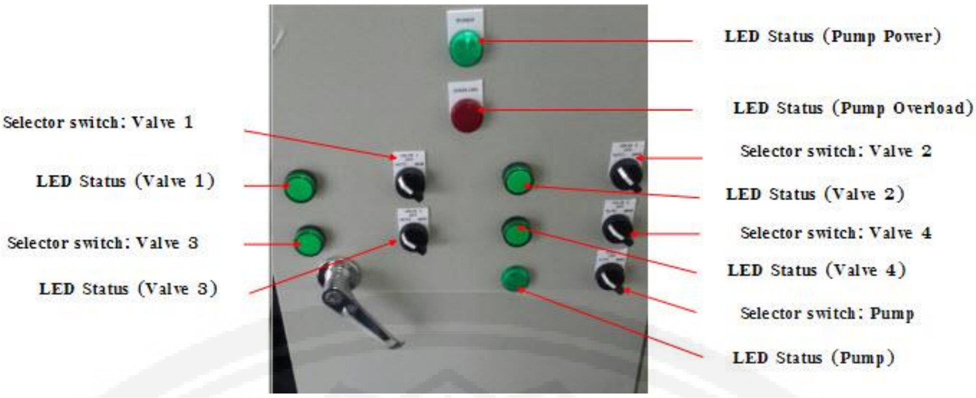

Figure 4 Control panel of the control box

3. Sensor installation

Data collected in this study included temperature ($^\circ$ C), humidity (%RH), solar intensity (lux), soil moisture (%), and flow rate (m^3/s). Therefore, sensors operated as ultra-low power in order to relocate and install in the experimental field conveniently. The temp/RH (HIH6100 Series, Honeywell HumidIcon™ Digital) and the light sensor (MAX44009, Maxim Integrated) were installed between the 6^{th} and 7^{th} row. Soil moisture sensors (GS1, Decagon Devices, Inc.) were installed at the 6^{th} and the 10^{th} durian tree in the middle of the 2^{nd} zone. Flow rate sensor was installed at the outlet of the pump. The sensor installation was presented in Figure 5.

Sensors signal was transmitted with Bluetooth supporting on the frequency band of 2.4 GHz. Data were directly sent to the second aMG Repeater (ID: aMG_Repeater_82) on the red line, excepted flow rate sensor sending data to the first aMG Repeater (ID: aMG_Repeater_81). Then, data collected from the second repeater were sent to the first repeater. Next, the first repeater forwarded the data to the aMG Plant Buddy and the aMG Plant Buddy Gateway 3G. Finally, the data received from the Gateway were created on the Internet every 2 minutes as shown in Figure 6. All of the data were stored on the server.

4. System testing for collecting data through wireless communication

The aMG Plant Buddy Gateway 3G was used to collect the data. Stored data on the server were retrieved via web application—Google Sheet. Figure 6 showed the example of data collected from all sensors installed at the experimental orchard. "View Live Data (sheet)" and "Home" menus presented the data. Moreover, raw data can be analyzed off-line by clicking "file" menu and select "download as".

Sensor installation and the designed system were presented in Figure 7.

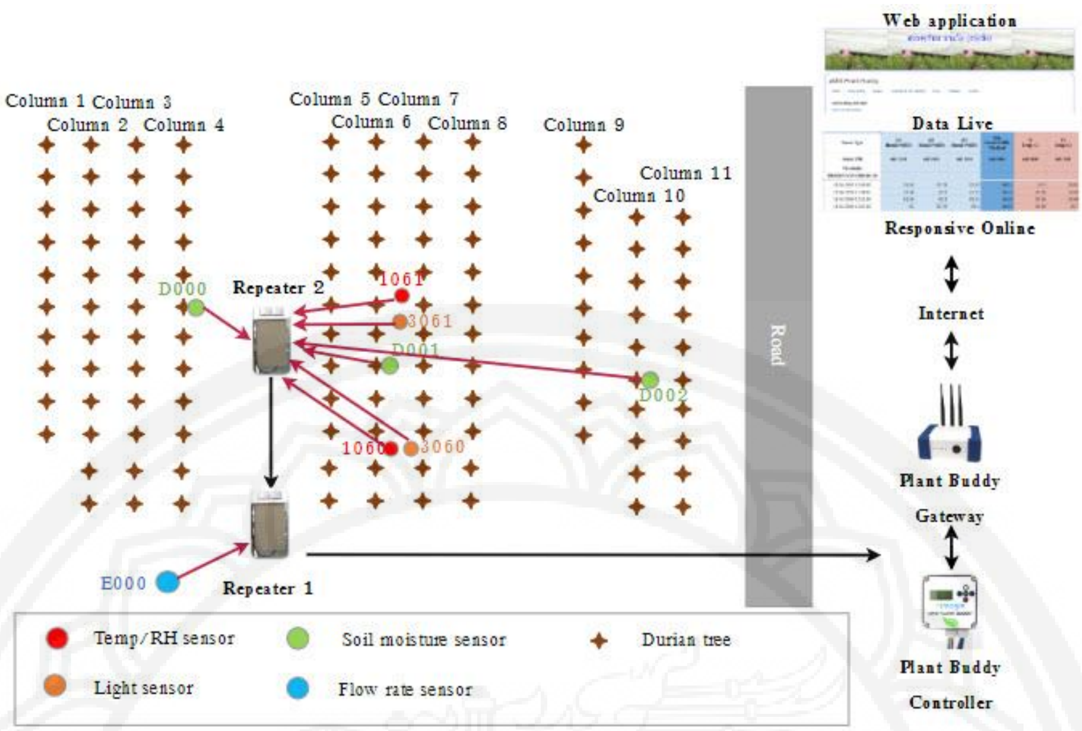

Figure 5 Sensor installation

Live Data (chano)

	Date/Time	Humidity		Temperature		Light		Soil Moisture			Water Flow
		uid: 1060 Humid (%RH)	uid: 1061 Humid (%RH)	uid: 1060 Temp (C)	uid: 1061 Temp (C)	uid: 3060 Light (lux)	uid: 3061 Light (lux)	uid: D000 Moist (%)	uid: D001 Moist (%)	uid: D002 Moist (%)	uid: E000 Flow (p/m)
		Humid1	Humid2	Temp1	Temp2	Light1	Light2	SoilMost1	SoilMost2	SoilMost3	
3844	28/09/2018 12:08:16	82.61	82.84	29.25	28.91	13632	13180	62	64	69	0
3845	28/09/2018 12:03:58	75.49	68.63	30.37	30.6	13439	12531	63	65	68	0
3846	28/09/2018 12:01:58	69.98	68.63	30.75	30.6	13309	12984	61	64	69	0
3847	28/09/2018 11:59:57	66.3	66.49	31.49	31.21	14278	14343	61	64	68	0
3848	28/09/2018 11:57:57	63.9	63.51	32.64	31.74	16284	14343	62	65	68	0
3849	28/09/2018 11:55:57	65.36	66.56	33.23	32.32	18098	17191	62	64	69	0
3850	28/09/2018 11:53:08	66.61	65.28	33.44	32.89	22367	19002	62	64	69	0
3851	28/09/2018 11:51:07	64.03	58.89	33.39	33.01	22367	20426	62	64	69	0
3852	28/09/2018 11:49:07	64.03	60.93	33.39	33.13	25602	22754	62	65	69	0
3853	28/09/2018 11:46:53	63.19	57.42	33.61	33.62	27155	24827	61	64	69	0
3854	28/09/2018 11:43:59	59.31	56.17	33.89	34.48	30520	26122	61	65	69	0
3855	28/09/2018 11:41:54	61.12	56.17	34.17	34.48	32073	25602	61	65	68	0
3856	28/09/2018 11:38:58	59.98	55.65	35.04	34.8	58476	42428	61	65	69	0
3857	28/09/2018 11:36:58	53.2	54.44	35.98	35.48	46309	42945	62	65	68	0
3858	28/09/2018 11:34:20	53.2	50.6	35.98	35.75	113087	49415	63	65	68	0
3859	28/09/2018 11:32:20	54.13	50.6	36.19	35.75	110500	90310	61	65	69	0
3860	28/09/2018 11:30:19	54.13	49.66	36.19	35.61	107911	88240	61	65	68	0
3861	28/09/2018 11:28:19	53.15	51.11	35.95	35.19	107911	88240	62	65	69	0
3862	28/09/2018 11:26:12	54.88	51.11	35.2	35.19	107394	86687	63	65	68	0
3863	28/09/2018 11:24:05	54.61	52.53	36.16	35.17	111017	90830	61	65	68	0

Figure 6 System testing for collecting data through wireless communication

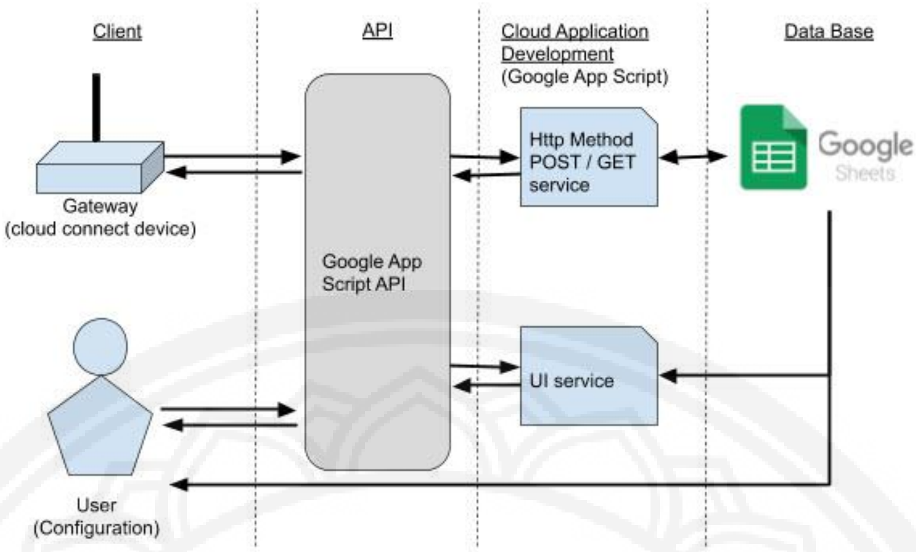

Figure 7 Sensor installation and the designed system

Results

Temperature, humidity, solar intensity, and soil moisture were collected in this study. The data were collected in every phases of off-season durian production starting from the fourth week of September 2018 to the second week of April 2019 as shown in Figure 8-11.

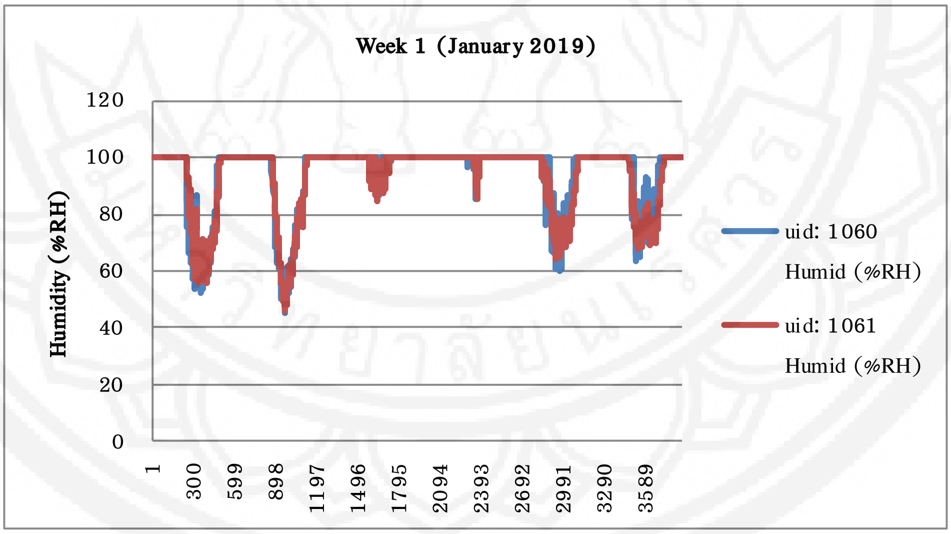

Figure 8 Humidity (Week 1 (January 2019))

Figure 8 showed humidity (0-100%) data sent every 2 minutes. The relative humidity was usually 100 percent at night. During the day the humidity dropped rapidly; for example, during 778-1037 minutes the humidity was 45 percent. However, during 1555-1814 minutes, day time, the humidity increased at 90-100 percent because of rainfall.

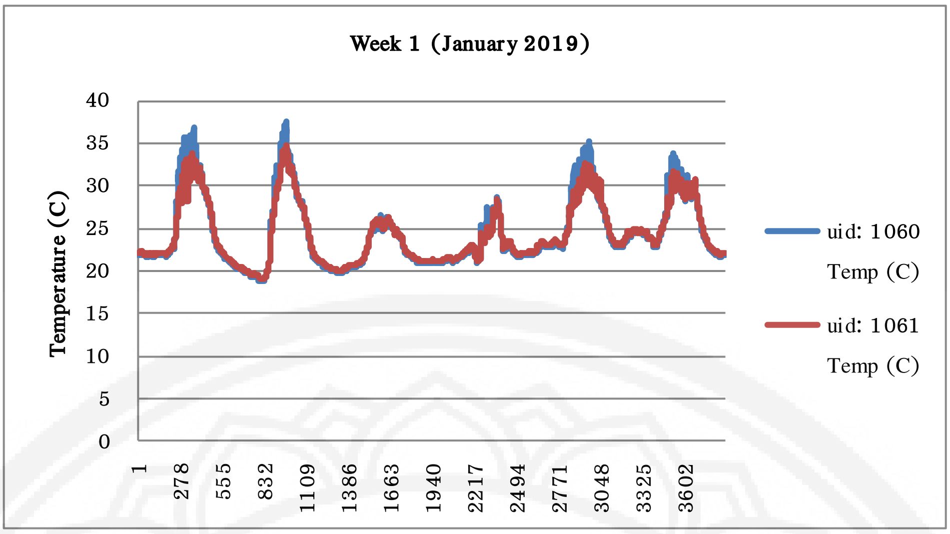

Figure 9 Temperature (Week 1 (January 2019))

Figure 9 presented temperature. The temperature was 22° C at night as can be seen during 1-230 minutes; however, it reached a high of 38° C during the daytime. Likewise, in the daytime, the temperature was at 20-25 ° C during 1604-1833 minutes because of rainfall.

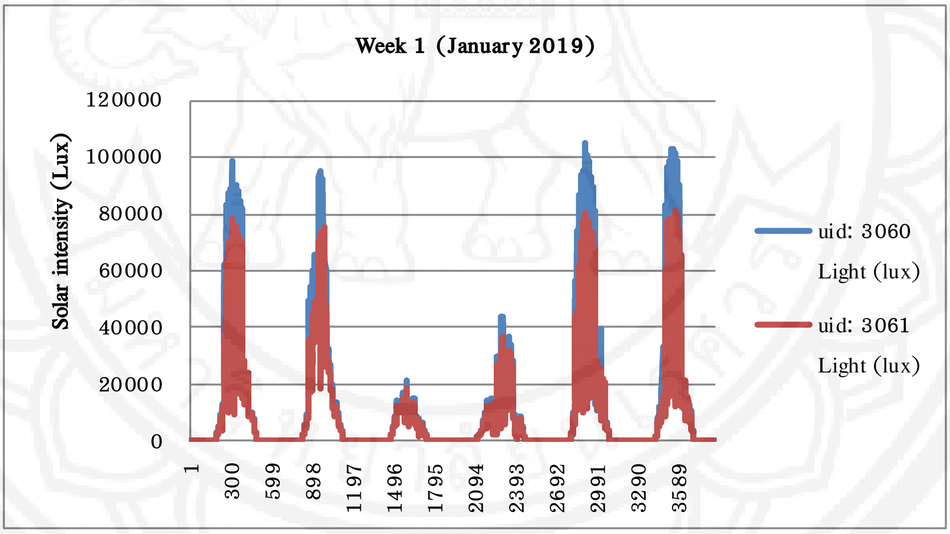

Figure 10 Solar intensity (Week 1 (January 2019))

Figure 10 indicated that solar intensity at night was at 0 lux. In contrast, in the daytime, solar intensity rose up to 80,000-110,000 lux. If it rained during the daytime, the solar intensity was low as can be seen from 1555 minutes.

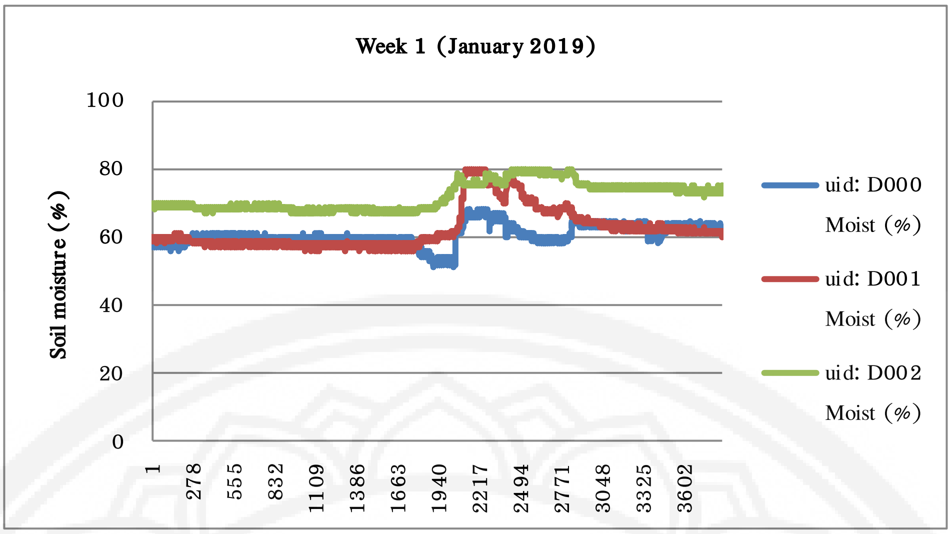

Figure 11 Soil moisture (Week 1 (January 2019))

Three soil moisture sensors were installed at 5 cm. depth. Due to the slope planting, each of soil moisture sensors reported soil humidity differently. In Figure 11, soil moisture increased from 2062 to 2291 minutes indicated that it was raining at that time. To conclude, according to Figures 8-11, data obtained from the sensors were consistent with the weather data at the orchard.

Conclusion and Discussion

According to the field observation of off-season durian production, there are 4 periods as presented in Figure 12. The site preparation starts from January to April. In this period, fertilizer application and irrigation are needed. In May-June, flower induction process takes place. Drought conditions have to be created, in combination with irrigation ditch drainage, and subsequent foliar application of fertilizer. The time for flower induction is when leaves turn from light to dark green, about 2-3 months after emergence. Flowering period is in July-November. Irrigation is required to promote growth during this initial stage of floral development. At about 5 weeks after flower emergence, if the density of flowers is more than 6 inflorescences per 1 meter of branch length or if various stages of flower development are observed on the same branch, flower thinning is required. During December to January, mature fruit can be harvested. Immediately after the harvest, the durian trees must be pruned and fertilized with equal proportions of NPK fertilizers to prepare the trees for healthy growth.

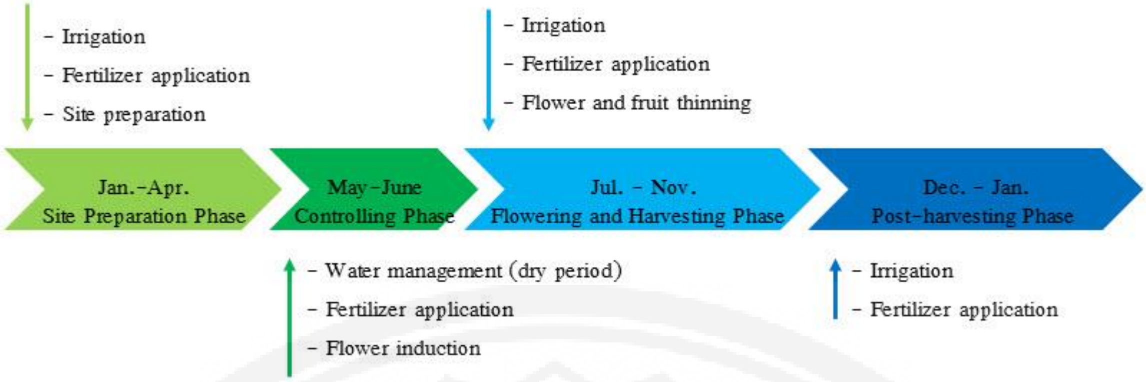

Figure 12 The 4 periods of off-season durian production

Soil moisture analysis in those 4 period indicated that the sensors D000 and D001 showed less averaged soil moisture levels than that of sensor D002 due to hillslope. Soil moisture content of the sensors D000 and D001 were 60 percent, and the sensor D002 was 70 percent. In April, soil moisture of all sensors dropped about 20%. Thus, irrigation was required to promote normal growth. In the control period or flowering and harvesting period, irrigation can be cut as it is the wet season. The soil moisture in this period went up to 60-70%. All of this soil moisture data were collected to design the soil moisture control system in the next phrase.

Acknowledgement

The authors wish to express their appreciation to Mr. Sombat Sintun and Ms. Sirilak Boonnoy, the holder of durian orchard for their contribution to this study. We gratefully acknowledge Songkhal Rajabhat University, Faculty of Industrial Technology and Institute of Research and Development. We are also immensely grateful to the Nation Research Council of Thailand for the financial support.

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