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A STUDY OF DIURNAL SOIL TEMPERATURE AND MOISTURE CONTENT CHANGES IN CONCRETE PIPE CONTAINERS WITH LIME TREE PLANTING AFTER WATERING: A FIELD EXPERIMENT

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ABSTRACT

This field experiment aimed to study soil temperature and moisture content changes at soil surface and at 5 different soil layers for lime trees with diurnal watering. The experiment was conducted in a certain lime orchard in Siracha district of Chonburi using lime trees aged 1and 2 years planted separately in concrete pipe containers 80 cm in diameter and 40 cm in height. The study revealed that the diurnal average soil temperature at the surface level of both containers varied according to solar radiation. The average soil temperature in the whole container with the 1-year-old tree was found to be 0.81 % and 1.18 % higher than that in the container with the 2 -year-old lime tree, with and without diurnal watering, respectively. The average soil moisture content in the whole container with the 1-year-old lime tree was found to be 2.64% and 2.26% higher than that in the container with the 2-year-old lime tree with and without diurnal watering, respectively. After watering, the moisture content at soil surface in both containers increased significantly while that in deeper layers increased slightly, and gradually decreased in all soil layers. The ambient environment was found to have no impact on soil moisture content variation. This showed that diurnal watering not only added water volume into the soil, but it also helped in monitoring suitable soil temperature for lime tree growing for longer periods than when there was no watering. The findings can be used as basic data for following soil temperature and moisture content variation with diurnal watering to monitor appropriate temperature range for optimum growth of lime trees in concrete pipe containers.

Keywords: soil temperature, soil moisture content, concrete pipe, lime tree, watering.

1. INTRODUCTION

Lime is a sour citrus fruit in the family Rutaceae [16], and is in demand all- year- round. It is grown extensively in tropical and subtropical regions in several countries [13, 14]. It is used as a cooking ingredient, in beverages, and for medicinal and industrial purposes [2, 21]. In Thailand, lime is grown in all areas, and yields fruit almost all-year-round [10]. However, the volume of produce each month is not always reliable. In the rainy season (July - September), limes are in abundance, which often causes oversupply, spoilage, and price drops. On the contrary, lime production is very limited in summer months (March-April) causing fruit shortages that push prices several times higher than in other seasons [17, 25].Over the last few years, concrete pipes (septic tanks) were adapted for use as planting containers, especially off-season planting of lime trees (Citrus *aurantifolia* Swingle) [18]. This practice has become popular for a number of reasons. It is easy to do, take almost no time or space, and can be practiced in all areas. It requires minimal care, and weed control, and the monitoring of fruit blossoming and fruit yields is likewise easy [8,11].

Soil temperature and moisture content, which vary with the depth of soil, are essential factors for plant growth [15]. Soil temperature is important for biological and chemical processes, seed germination, root expansion, water and nutrient absorption and transpiration, and for the presence of insects in the soil [15, 4, 23]. Soil moisture content also has an impact on plant growth since it is essential for chemical reactions within the plant, for plant conduction, and maintenance of plant temperature, and reduction of leaf and fruit swelling [15, 26]. Soil temperature and moisture content constitute a complex and inter-dependent mechanism [19]. A number of past studies have been conducted on soil temperature variation for optimum plant growth, but most of them were focused on changes of soil in its natural state, not in concrete containers adapted for planting. These studies include Rouse and Sherrod (1996) [12], who found that the soil temperature range for lime seed germination is 20.7-40.9 ^{o}C and the optimum temperature is 30 ^{o}C. Another study reported a range of 12-35 ^{o}C as suitable soil temperature for root growth in the Citrus family, and 25-30 ^{o}C as the optimum soil temperature range [22]. Reliable information from studies on soil moisture content suitable for optimum lime growth is still limited, and this lack of information prevents farmers from knowing when and how they should water their plants. In interviews, most farmers reported that they rely mostly on their personal experience. Most of them water their plants every other day or every third day till water spills from the concrete container rims, between 6.00-9.00 am or 2.00-4.00 pm. How long to water depends on the physical appearance of the lime trees or the physical appearance of the soil when touched by hand. Fares and Alva (2000) [1] reported that the blooming period and the beginning of the fruit yielding period of plants in the Citrus family are the most crucial time for monitoring soil moisture content. The moisture content should be maintained at a minimum of 33% of soil moisture usable by plants.

Therefore, this experimental study is aimed to collect data on soil temperature and moisture content

variation in concrete containers with and without watering at 5 different levels of soil depth and at 20 cm radial directions from the center of the containers. The lime trees planted in the containers are 1 and 2 years old and are likely to grow a strong healthy canopy of branches and leaves that will be able to produce well in the future [9]. The outcomes will be used to determine the appropriate time for watering and as basic information for planting lime trees in concrete containers.

2.2. MATERIALS AND METHODS

2.1 Experiment site

This experiment was conducted at Phu Manao lime orchard in Sri Racha District of Chonburi Province, where Pan lime is grown. The soil was a mixture of local soil (sandy soil), manure, and chopped coconut husk in a ratio of 3:1:1 in 200 concrete containers 80 cm in diameter and 40 cm in height with drains at the bottoms and the sides. The plant containers were laid on the ground without bottom covers and watering was done with 40-60 liter/hour mini-sprays at 2.00 pm for 15 minutes. The containers with the lime trees used for this experiment, with and without watering, were put beside each other (Figures 1a and 1b), and a comparative experiment was conducted in the natural state of the ambient environment, and with regular daily farming activities.

2.2 Instruments and installation

The data on soil temperature and moisture content within the concrete containers with 1 and 2 year-old lime trees, and data on ambient weather conditions were recorded hourly, between 2-13 August, 2016 at the soil surface (0 cm) and at depths of 10 cm, 20 cm, 30 cm, and 40 cm from the soil surface, and at radial directions 20 cm to the north, south, east and west, totaling 20 positions for each location (Figure-2). Soil temperatures were recorded using a thermocouple type K interlinked with data logger model BTM-4208SD, and soil moisture was recorded using a moisture meter type PR2/4 (Delta-T device) interlinked to moisture meter logger model HH2 (Delta-T device). For accurate recording of moisture content, access tubes 56 cm long specially designed for the task were buried in the soil, which had been drilled with an auger to make a hole for each tube. The tube was then hammered into the holes so that the soil was in direct contact with the tube wall and the tube was also in direct contact with the measuring sensors. Other weather data such as ambient temperature, relative humidity, wind speed and direction were recorded by Professional Wireless Weather Station-MISOL model WA-1091. Solar radiation was recorded by means of a pyranometer model CM3 interlinked with METEON Data Logger (Kipp & Zonen).

(a) (b)

Figure-1. The lime trees 1-year-old (a) and 2-years-old (b).

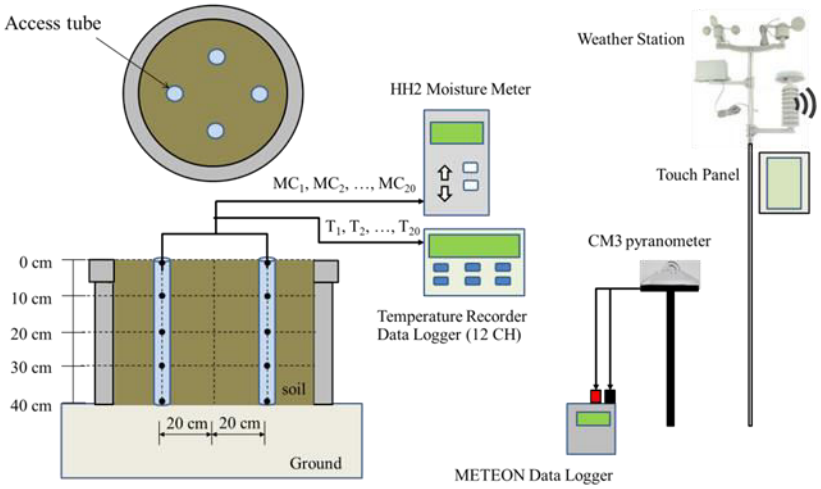

Figure-2. Schematic diagram for measuring soil temperature and moisture.

3. RESULTS AND DISCUSSIONS

In this experimental study on soil temperature and moisture content variation in different soil depths in concrete containers with and without watering, in which 1 and 2 year-old lime trees were planted, two analyses were conducted. One was on the experiment conducted on August 2, 2016, with 15 minutes of watering around 2.00 pm, and the other on August 13, 2016, when no watering was done. The choice of these two analyses was based on similar ambient weather conditions

When weather data were studied, the experiment revealed average solar radiation of 290 W/m2 and 204

W/m2from 6.00 am-6.00 pm, average diurnal temperatures of 30.64 °C and 30.10 °C, and average diurnal relative humidity of 63.88 %RH and 69 %RH, on the day with watering and the day without watering, respectively (Figures 3, and 4) Though rainy season conditions caused fluctuations of solar radiation on both days, analyses of soil temperatures and moisture content on both concrete containers were not affected. This is because the data were collected from radial directions at each soil depth (Figures 5-8).

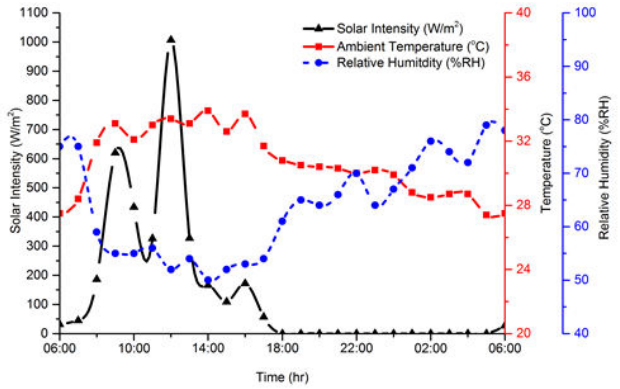

Figure-3. Ambient conditions during the experimental period: No watering.

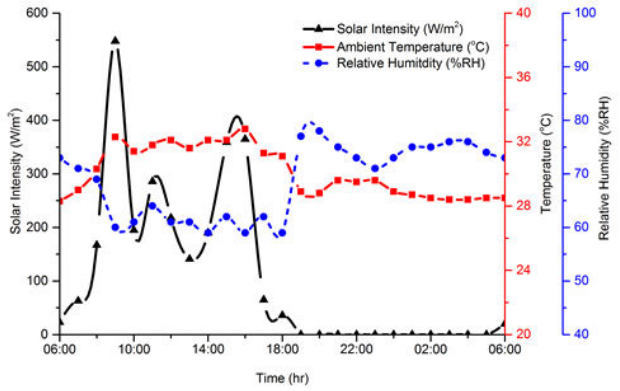

Figure-4. Ambient conditions during the experimental period: Watering.

3.1 Soil temperature changes in concrete pipes

The collected data on time and soil temperature changes in the concrete pipes with the 1-year-old lime tree and 2-year-old lime tree, and without watering (as displayed in Figure-5) revealed the lowest average temperature at the soil surface in both concrete pipes, with gradually increasing temperatures at deeper levels. Later on, as increased solar radiation caused the temperature at the soil surface to rise, slight increases in soil temperatures in accordance with soil depth were found. The average soil temperatures of the containers with the 1-year - old lime tree and the 2-year-old lime tree were found to be between 27.75 - 34.68 °C and 27.90 - 32.95 °C, respectively, with the highest average temperature between 2.00-3.00 pm, and the lowest between 05.00 - 06.00 am. The average diurnal soil temperature of the container with the 1-year-old lime tree at soil surface, and at 10, 20, 30 and40cm from soil surface was found to be 30.24, 30.13, 30.32, 30.12 and30.20 °C, respectively, while for the container with the 2-year-old lime tree, average temperatures were 29.65, 29.78, 29.93, 30.06 and 29.82 °C.

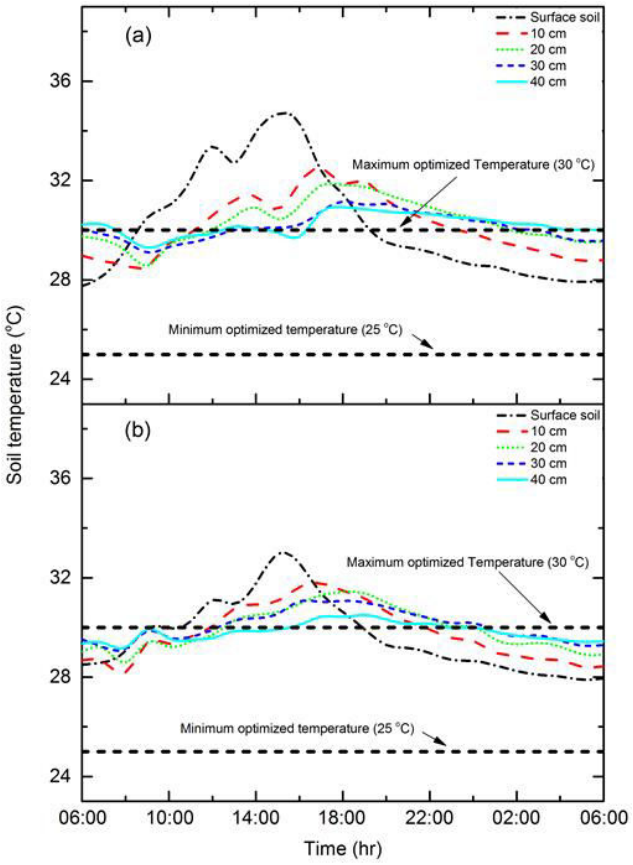

Figure-5. Soil temperature changes without watering within the concrete pipe (a) 1-year-old and (b) 2-years-old.

When soil temperatures in the containers with lime trees aged 1 year and 2 years were compared, the average soil temperature was found to be 1.18% higher in the container with the 1-year-old lime tree, due to the younger tree's smaller canopy, which allowed more solar heat onto the soil surface [5]. The average temperatures in both containers were found to conform to the ranges of plant growth earlier noted by Rouse and Sherrod (1996) [12], and in some time ranges, the soil temperature was found to be higher than the range of optimum growth (25 - 30 °C) earlier stated by Yara US (n.d.) [22], as shown by the dash lines in Figures 5(a), and 5(b).

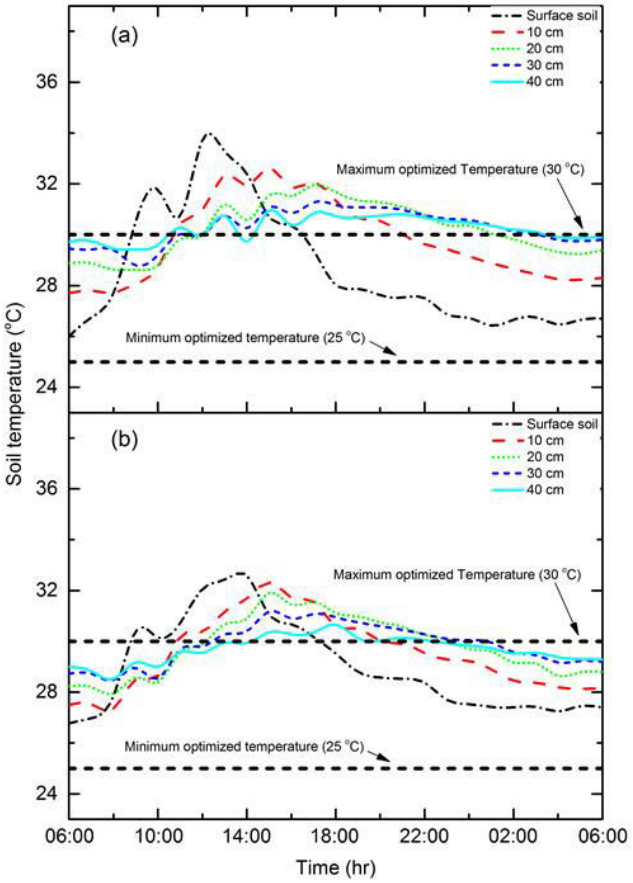

Figure-6. Soil temperature changes with watering within the concrete pipe(a) 1-year-old and (b) 2-year-old lime trees.

The collected data on time and soil temperature changes in the concrete pipes with 1 and 2-year-old lime trees, and with watering (as displayed in Figure-6) revealed increasing soil temperatures in accordance with increased solar radiation and ambient temperature. The average soil temperature at all soil layers in the container with the 1-year - old tree was between 26.00 and 33.73 °C, and 32.40, 31.95, 30.58, 30.25 and 29.73 °C at the soil surface and at depths of 10, 20, 30 and 40 cm, respectively. For the container with the 2-year-old lime tree, the average temperatures at all soil layers were 26.78 - 32.95 °C, and 32.58, 31.68, 30.90, 30.40 and 29.93 °C at the soil surface and at depths of 10, 20, 30 and 40 cm, respectively. After watering at 2.00 pm, the average soil temperatures at the soil surface in both containers were found to be 5.25 and 4.68% lower, respectively, with no significant impact on the average soil temperatures at depths of 10, 20, 30 and 40 cm. At these layers, the soil temperatures were found to be 2.03, 3.19, 2.73 and 4.12% higher in the concrete pipe with the 1-year-old lime tree, and 2.05, 3.24, 2.55 and1.42 % higher, respectively, in the container with the 2-year-old lime tree. In Figures 6a and 6b, data above the dashed line represent the time range where soil temperature was found to be higher than that of the suitable time range after watering in the container with the 1-year-old lime tree at the soil surface and at soil depths of 10, 20, 30 and 40cm. The data revealed that soil temperatures at a suitable range can be monitored to last longer with diurnal watering than without watering. Figure-1 displays soil temperatures in concrete pipes without diurnal watering and with diurnal watering.

Table-1 presents average diurnal temperatures of containers with lime trees aged 1 and 2 years at soil depths between 0- 40 cm, the area where the roots of Citrus plants are densest [1, 6, 20]. The standard deviation (S.D.) from the outcomes of the experiment on both containers revealed a higher distribution of soil temperatures at the soil surface than at deeper soil layers. This indicates that the soil temperatures in both containers obviously varied with diurnal ambient weather conditions at the soil surface while little change was found in deeper layers. This finding also conformed to past studies on temperature variation of soil in its natural state conducted by Liu *et al.* (2005) [3], Klompong *et al*. (2009) [7], to name a few.

Table-1. Comparative soil temperature average with and without watering in the concrete pipe.

Sample (years)	**Depth** (cm)	**Temperature** (°C)							
		Unwatering				**Watering**			
		T_{min}	T_{max}	X	S.D.	T_{min}	T_{max}	X	S.D.
1	0	27.75	34.68	30.24	2.25	26.00	33.73	28.60	2.37
	10	28.55	32.48	30.13	1.22	27.70	32.60	29.75	1.61
	20	28.58	31.83	30.32	0.88	28.63	31.95	30.19	1.06
	30	29.10	31.15	30.12	0.56	28.80	31.28	30.27	0.70
	40	29.30	30.93	30.20	0.42	29.43	30.95	30.23	0.48
2	0	27.90	32.95	29.65	1.47	26.78	32.58	29.08	1.82
	10	28.20	31.78	29.78	1.12	27.35	32.33	29.57	1.46
	20	28.60	31.43	29.93	0.86	27.95	31.90	29.83	1.18
	30	29.15	31.08	30.06	0.63	28.48	31.18	29.89	0.83
	40	29.20	30.50	29.82	0.37	28.53	30.65	29.70	0.53

Table-2. Comparative soil moisture content average with and without watering in the concrete pipe.

Sample (years)	Depth (cm)	Moisture content (%Vol)							
		Unwatering				Watering			
		MC_{min}	MC_{max}	X	S.D.	MC_{min}	MC_{max}	X	S.D.
1	0	6.00	8.28	6.84	0.67	9.40	16.00	12.36	1.43
	10	11.20	12.98	11.85	0.49	12.53	17.53	14.47	1.19
	20	16.38	17.53	16.89	0.34	16.38	18.20	17.48	0.65
	30	18.80	19.95	19.30	0.37	20.30	22.38	21.51	0.81
	40	24.45	25.83	24.85	0.45	25.80	29.08	27.85	1.25
2	0	6.13	7.68	6.70	0.56	6.63	10.88	8.91	0.90
	10	10.95	12.65	11.49	0.51	12.23	15.80	14.10	1.11
	20	17.33	19.00	17.92	0.55	18.08	20.58	19.40	0.80
	30	19.10	20.75	19.79	0.53	19.98	23.88	22.24	0.10
	40	21.28	23.63	22.07	0.72	24.23	28.25	26.60	1.39

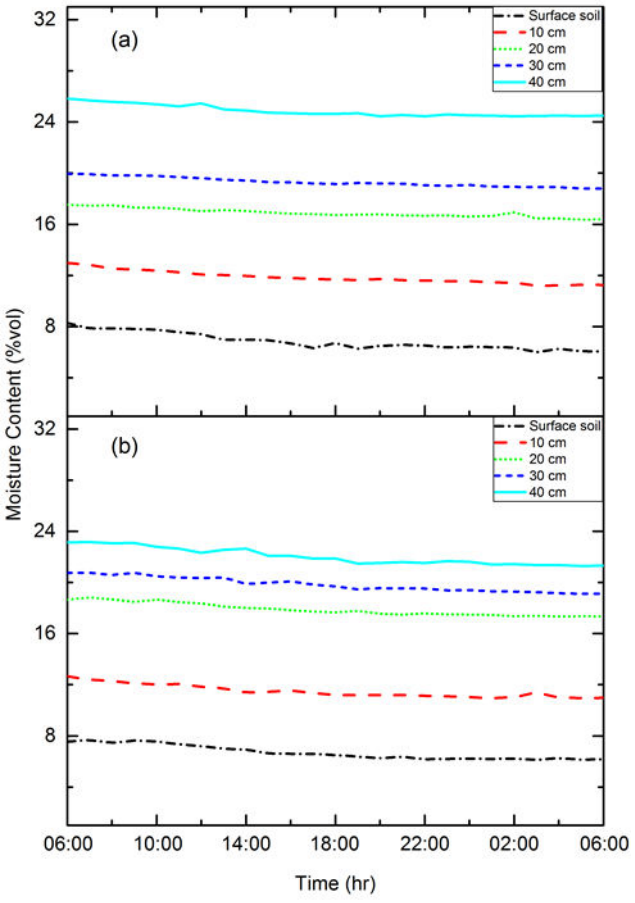

Figure-7. Soil moisture content changes without watering in the concrete pipe(a) 1-year-old and (b) 2-years-old.

3.2 Moisture content variation in concrete pipes

The data on average soil moisture in the containers with 1-year-old and 2-year old trees at all depths, together with the data on times derived from the experiment with and without watering indicated moisture variation from level to level (Figures 7 and 8). The moisture content was found to be lower at soil surface and increasingly higher in accordance with soil depths, and very little variation was found during daytime due to the low standard deviation at all depths, which was very similar during the none-watering period (Figure-7). The moisture content at soil surface and at depths of 10, 30 and 40 cm in the container with the 1-year- lime tree was found to be approximately 2.31, 2.97, 3.19 and11% higher respectively than that of the 2-year-old tree, possibly as a result of the effect of high relative humidity during nighttime on the soil surface in the container with the 1-year - old lime tree. On the contrary, moisture content at the depth of 20 cm in the container with the 2-year-old lime tree was found to be 6.55% higher than in the one with the 1-year –old tree. The average moisture content throughout the container with the 1-year-old tree was found to be 2.26 % higher than that of the one with the 2-year-old tree. When the diurnal rate of decrease in moisture content was studied (Figure-9), the container with the one-year-old lime tree had a higher rate of decrease in moisture content at soil surface, and both containers had an equal rate of decrease at the depths of 30 and 40 cm. At the depths of 20 and 30 cm, a similar rate of decrease was found in both concrete containers. This may be a result of the bigger canopy of the 2-year-old lime tree, which blocked solar radiation and in turn resulted in lower evaporation of water at soil surface.

Figure-8 displays the high decrease in moisture content at soil surface and at the depth of 10 cm when compared to other soil depths before watering, where the moisture content in the container with the 1-year-old tree was found to be at 9.40 and 12.53% by volume respectively, and the moisture content at depths of 20,30, and 40 cm was found to be 16.38, 20.30 and 25.80% by volume, respectively. The soil moisture content in the container with the 2-year-old tree at soil surface, and at depths of 10,20, 30 and 40 cm was found to be approximately 6.63, 12.23, 18.08, 20.68 and 24.53% by volume, respectively. Soil moisture content, after

watering, was found to increase, which conforms to the research by Antonopoulos (2006) [24], who studied water and heat movement in the soil and found that soil moisture content varied highly with rain quantity, and the soil moisture content at each soil depth increased rapidly at the beginning until reaching its peak. The greatest increase was found at the soil surface, and then gradually lowered at deeper soil layers. This experiment revealed a rapid increase in average soil moisture before watering at all soil depths to 70.21, 39.92, 10.23, 7.39 and 10.47% at the depths of 0, 10, 20, 30 and 40 cm in the container with the 1-year –old tree, and to 64.15, 29.24, 11.83, 15.48 and 14.58% at 0, 10, 20, 30 และ40 cm in the container with the 2-year-old tree. One hour later, the moisture content at soil surface and at the depth of 10 cm was found to be visibly decreasing until it became stable, while the moisture content at the depths of 20, 30 and 40 cm decreased slightly. In addition, the average moisture content thought the container with the 1-year-old tree was found to be 2.64% higher than in the container with the 2-year-old lime tree. The data on average moisture content with and without watering in both containers are displayed in Table-2.

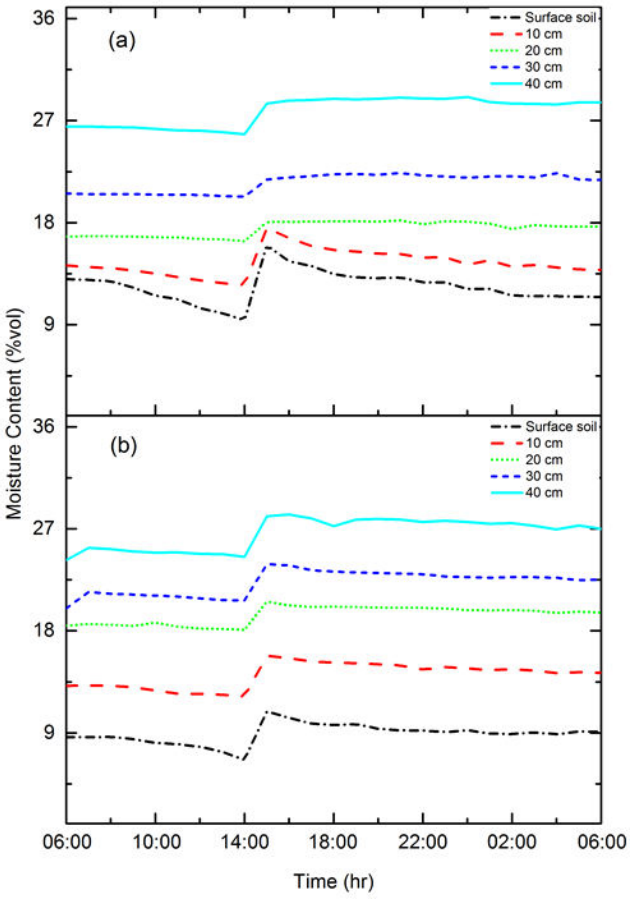

Figure-8. Soil moisture content changes with watering in the concrete pipe(a) 1-year-old and (b) 2-years-old.

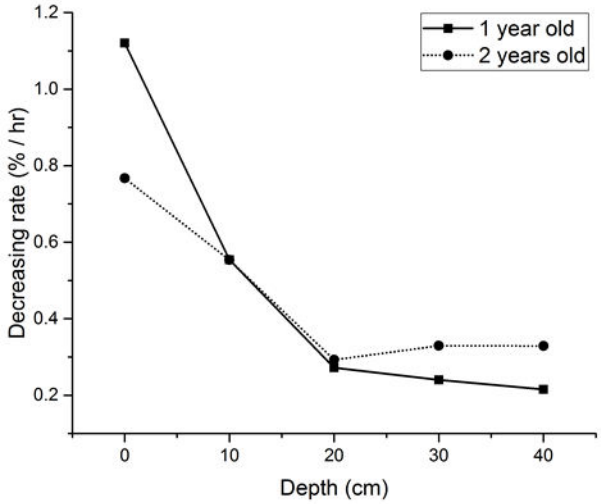

Figure-9. Decreasing rate of soil moisture content without watering during a day.

4. CONCLUSIONS

The outcomes of the field experiment on soil temperature and moisture content variation with watering at 2.00 pm and without diurnal watering for lime trees planted in concrete pipes can be summarized as follows:

a) The average soil temperature at the soil surface in the containers with 1 year-old and 2-year-old lime trees varied more with solar radiation than at deeper soil layers. With watering, the average soil temperatures in both containers were 26.00 - 33.73 ^{o}C, and 26.78 –32.95 ^{o}C respectively, and 27.75 - 34.68 ^{o}C, and 27.90 –32.95 ^{o}C respectively. The average soil temperature throughout the container with the one-year-old lime tree was 0.81% higher with watering than without watering respectively, and the suitable soil temperature for planting lime trees at their initial fruit yielding period, which is also the temperature for optimal growth, was 26.00 - 34.68 ^{o}C.

b) The soil moisture content of the containers with the one-year-old and 2-year-old lime trees at all soil depths did not vary with solar radiation and ambient environment, but with diurnal watering. The soil moisture content suitable for planting lime trees in concrete pipes was 6.00 - 25.83 % by volume, and 6.13 - 23.63 % with and without watering, respectively. The average moisture content throughout the container with the 1-year-old tree was 2.65 and 2.26 % higher than the container with the 2-year-old lime tree with and without diurnal watering, respectively.

c) The likeliness for soil temperature and moisture content to change at all soil depths both with and without diurnal watering was similar. However, diurnal watering helped reduce soil temperatures in the containers with 1 and 2-year old trees by 5.25% and 4.68%, respectively. This allowed for average soil temperatures for optimum growth at all depths to be controlled for longer periods.

The data on soil temperature and moisture content with and without watering for lime trees planted in concrete pipes can be used as basic information for

determining the right time for watering and for the control of the soil temperature for optimum plant growth.

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