# The Influence of Ambient Temperature on Soil Temperature in Concrete Containers with Lime Trees

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## ABSTRACT

Soil temperature is an important factor for plant growth and varies according to ambient conditions. In this paper, we study the soil temperature changes in concrete containers 80 cm in diameter and 40 cm in height due to ambient temperature. Temperature measurements were carried out at 0, 10, 20, 30 and 40 cm soil depth in containers with lime trees aged 1, 2 and 5 years. Both ambient temperature and soil temperature data were collected from a lime orchard in Chonburi, Thailand. The results indicated that the temperature changes of soil at each depth were different and fluctuated widely in shallow soil in all containers. The average soil temperature of the 1-year-old lime tree was higher than that for 2 and 5-year-old trees at daytime but was nearly constant, and a similar trend in temperature variation was found during the nighttime in all depths of three trees. Straight-Line Regression Analysis with the Coefficient of determination, $R^2$ showed that the ambient temperature and soil temperature had a strong correlation to surface soil at daytime ($R^2 \approx 0.76 – 0.78$) and at nighttime in all depths ($R^2 \approx 0.87 – 0.96$). This experiment provides primary data for determining soil temperatures from ambient temperature for lime tree planting or the cultivation of other crops in concrete containers

*Keywords: soil temperature, ambient temperature, concrete container, lime tree*.

## INTRODUCTION

Sudden and severe changes in climate today not only impact plant growth and crop yields but also cause damage to agricultural products as well. In addition, daily weather fluctuations are also responsible for changes in soil temperature, which is significant to a number of processes relating to biochemistry and physics and essential for plant growth (Kunkel, Wells and Hancock, 2016; Díaz-Pérez, 2009). Soil temperature changes have many factors which consist of heat exchanges taking place primarily on the soil surface, soil thermal properties, geographical location, vegetative cover and human management (Tyagi and Satyanarayana, 2010). The changes of soil temperature have also been shown to be varied with the depth of soil (Florides *et al*., 2011; Ozgener, Ozgener and Tester, 2013; Popiel, Wojtkowiak and Biernacka, 2001). Each crop species prefers its own range of soil temperature for maximum growth (Tenge *et al*., 1998), for of the Citrus family, the optimum soil temperature for root growth is 12 – 35 °C and maximum growth is at 25 – 30 °C (Yara, 2015).

Planting in containers such as boxes, old tires, bowls, pots, and water tanks have long been practiced (Spomer, 1976), but it was done for domestic consumption to cut household expenses only (Agricultural Knowledge Office of Agri Research and Extension Maejo University Chiang Mai, 2015). Not many years ago, concrete containers (septic tanks) were first adapted for use as plant containers, particularly off-season planting of lime trees or sour citrus (*Citrus aurantifolia* Swingle) (Sriboon, Tuntiwaranuruk and Sanoamuang, 2017), which is one of the economically significant plants and is in demand all year round of Thailand (Kaewsuksaeng *et al*., 2015; Nonthanum and Tansakul, 2008). In Thailand this practice has become popular due to the fact that planting in this way has helped relieve produce shortage in summer and enabled growers to demand higher prices for their produce, which can be ten times as high as the price in other seasons (Jittanit, Suriyapornchaikul and Nithisopha, 2013; Sethpakdee, 1997). Planting lime trees in concrete containers have a number of advantages. It is easy to do, takes almost no time or space, and can be practiced in all areas. It requires minimal care, weed control, and the monitoring of fruit blossoming and fruit yields are likewise easy (Poolperm, 2008). In addition, concrete containers are available in various sizes ranging from 60 cm to 100 cm diameters and 30 cm to 40 cm heights, while 80 cm diameter and 40 cm height are the most popular for planting and important because it is within the root zone (Fares and Alva, 2000). On the other hand, planting lime trees in concrete containers has some limitations including environment for plant growth and root expansion, limited capacity for water and nutrient supply, as well as more restrictions in water drainage and soil aeration, when compared to planting in soil in its natural state (Meyer and Cunliffe, 2004; Fonteno, 1993; Spomer, 1976). MacDonald (1991) and Arnold and MacDonald (1999), referring to a number of past studies, found that root-zone soil temperatures closer to the sun-exposed walls of the concrete containers are higher than those of the soil in its natural state, which affects the plant growth.

Many studies have confirmed that the soil temperature is variable with respect to the amount of solar radiation and the ambient temperature (Florides and Kalogirou, 2004, 2005; Nofziger, 2003; Van Manen and Wallin, 2012). But the instruments used to measure solar radiation are very expensive and more difficult to use than air temperature instruments. In addition, the past many years, numerous studies have been conducted on soil temperature changes, but most of these have focused on temperature changes of soil in its natural state. In contrast, studies examining temperature changes of soil in planting containers have been relatively limited. The present field experiment research, therefore, aims to investigate the hourly change of soil temperature in concrete containers with lime trees 1, 2 and 5 years of age as the result of daily ambient temperature. Hourly measurements were taken in both horizontal and vertical radii at various depths in order to help the farmers understand the soil temperature variation and control the soil temperature to be suitable for planting within the cement containers. In addition, this experiment provides primary data for determining best times of the day to water or to mulch, and in order to monitor soil temperature for optimum plant growth from ambient temperature in the future.

## MATERIALS AND METHODS

The study investigated Pan lime trees (*Citrus aurantifolia* Swingle cv. Pan) aged 1, 2, and 5 years in concrete containers with a diameter of 80 cm, and height of 40 cm. The experiment was conducted in the Phu Manow lime orchard, Chonburi, Thailand. The same mixture of soil was used in the three containers, and one-day unwatering is the same, and the experiment was based on local environment, and the plants were subject to the usual care of the grower as shown in Figure 1.

To monitor the soil temperature variations in the concrete containers with 1, 2, and 5 years old lime trees, sensor probes were installed in 20 different points at depths of 0 (surface soil), 10, 20, 30 and 40 centimeters (in Figure 2). Thermocouple type K, interfaced with data logger model BTM-4208 SD, was used to measure soil temperature, and ambient environment information such as ambient temperature was collected from a compact meteorological instrument (Professional Wireless Weather Station MISOL model WA-1091). Data on soil temperatures and ambient temperature was recorded hourly from 10 - 12 August 2016.

(a) (b) (c)

Figure 1 Lime trees for experiment aged 1 year (a), 2 years (b) and 5 years (c)

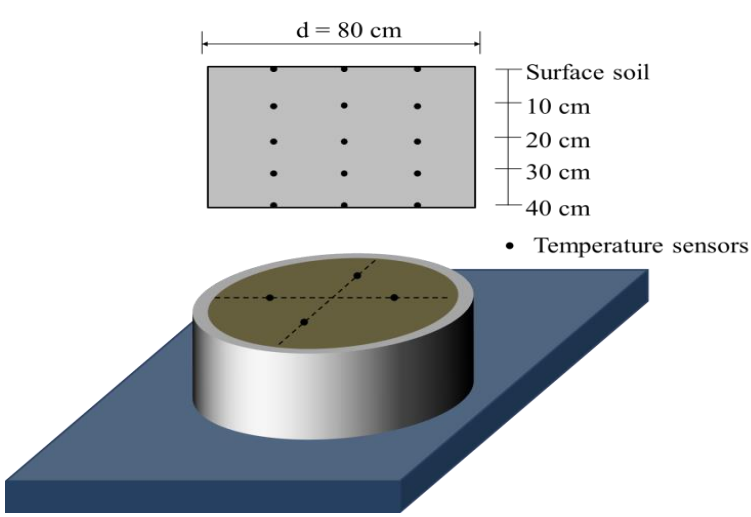



Figure 2 Thermocouple installation for monitoring soil temperature

## RESULTS AND DISCUSSION

Due to the fact that sensor probes were installed in four directions and at all different depths studied, an average value of temperatures measured in each soil layer was used for analysis and explanation of patterns of soil temperature changes during the day in order to find the best time to water lime trees for their optimum growth.

### Soil temperature variation

The study on the relation between daily temperature in the natural environment and changes of soil temperatures in concrete containers in each layer revealed that the average temperature of the surface soil in concrete containers with 1, 2 and 5 year old lime trees soil varied with the increase of ambient temperature at daytime (Fig. 3). From Figure 4, It was observed that natural weather conditions during the experiment period widely fluctuated throughout the day, which is typical in the rainy season, and the average ambient temperature was 27 – 33 $^{o}$C. From 06:00 – 07:00 am, the average ambient temperature was measured between 27 - 28 $^{o}$C, and during this time, the ambient temperature and that of surface soil were found to be lower than that of soil in deeper layers. The collected data also revealed that ambient temperature affected very little change in soil temperature at the depth of 20 - 40 cm, while the surface soil temperature noticeably varied with the ambient temperature. From 8:00 am -13:00, the ambient temperature was continually rising until climbed to its highest of the day which was about 33.37 $^{o}$C. The soil temperature in all layers of lime trees aged 1, 2 and 5 years increased with the air temperature. In particular, the surface areas were increased than the soil at a deeper level. During 14:00 – 18:00, the air temperature was decreased, but the soil temperatures had risen to the highest within a day. The highest soil temperature during the day at each depth level of the age of 1, 2 and 5 years was dissimilar. The maximum of soil temperature was shifted when the soil was deeper. At surface soil and 10 cm, the time of highest soil temperature was about at 15:00 and 17:00, respectively, while at 20 – 40 cm had been the same time at 18.00. The data also revealed temperatures of surface soil noticeably different from that of the natural environment with the highest variation found in the soil with the 1-year-old lime tree, and less variation in the soil in the containers with 2 and 5 year-old lime trees. The reduced variation can be explained by the bigger canopy sizes of the 2- and 5 - year-old lime trees, resulting in lower temperature of surface soil than that of the environment. The shade was also responsible for the higher heat transfer above the surface soil in the containers with 1 - year – old lime tree. The soil's efficient heat capacity and absorption also accelerate heat storage in the soil, thus increasing soil temperature. The temperature of the soil in deeper layers also slightly differed from that of the natural environment.

After 18:00 until 05:00 on the next day, the period with continually decreasing temperatures, the data revealed the greater variety of surface soil temperatures in all three concrete containers as a result of changes in ambient temperature than temperatures at deeper layers. The data also revealed a continual decreasing of surface soil temperature, which is different from daytime when temperature tends to continually increase. The soil temperature variation during this period was obviously caused by heat transfer from the soil surface to the area above (Hillel, 2003; Gan, 2015). At the same time, the soil's low thermal conductivity made it hard for the heat at deeper

layers to transfer to the surface, resulting in lower temperature of surface soil than that in deeper layers.

When the average soil temperature in concrete containers with 1, 2, and 5 year-old lime trees at the depths of 0, 10, 20, 30 and 40 cm was studied, it revealed tht that at 10 - 40 cm of depth, the average soil temperature measured in each container and at each soil layer was slightly different during the day, whereas the most variation occurs in the surface soil. The average temperature of at 10 -40 cm of the depth of the 1-year-old tree was 0.01 – 1.25 $^{o}$C higher than the average for lime trees aged 2 and 5 years at daytime, while the average temperature at each soil layer for the 2 and 5 year- old trees was shown to be only slightly different at night time. At soil surface, the temperature of the 1-year-old tree was found to be 0.04 – 2.93 $^{o}$C higher than the average of lime tree aged 2 and 0.15 - 3.11 $^{o}$C for the lime tree aged 5 at daytime and slightly different at night time.

However, when the comparison was made with the optimal temperature for Citrus family of Yara (2015), the temperature at all soil layers was found to be higher than the optimum temperature range at different times. The surface soil temperature , in particular, was found to be higher than the optimum temperature than the temperature at other soil layers. The soil temperature at the containers with 1, 2, and 5 year old lime trees lime trees was found to be higher than the optimum temperature between 9.30 am - 5.30 pm, 11.30 am - 6.30 pm and 12.00 - 7.00 pm, respectively. Therefore, watering roughly before the time mentioned would result in the optimum range for growth. Moreover, mulching or ground covers will also reduce the soil temperature, particularly, of younger lime trees.

**Correlation between ambient temperature and soil temperature**

Figure 5 shows the correlation between ambient temperature and soil temperature in the concrete containers at all soil layers during daytime (Figure 5 a), and during nighttime (Figure 5 b). The correlation was determined using Straight-Line Regression Analysis with the Coefficient of determination, $R^2$, which analyses the relationship between a dependent variable and one independent variable and formulates the linear relation equation between dependent and independent variable (Uyanik and Guler, 2013). In other words, it describes how well the model fits the data. An $R^2$ close to 1 implies an almost perfect relationship between the model and the data, whereas an $R^2$ close to 0 implies that just fitting the mean is equivalent to the model fitted (Saunders, Russell and Crabb, 2012). Analysis revealed that the value of $R^2$ was found to be between -0.10 – 0.51 during the daytime, which is rather low in deeper layers. While at surface soil was found to between 0.76 – 0.78, which indicated that ambient temperature and soil temperature had a relation to this layer. During nighttime, the value of $R^2$ was found to be between 0.87 – 0.96 in all layers, which is higher than that of daytime. The data shows that Straight-Line Regression can explain the correlation between ambient temperatures on diurnal soil temperature during daytime better than on nocturnal temperature because of more solar radiation reaching the soil, which results in greater soil temperature variation. This supports the findings of Klompong (2009) which states that ambient temperature has an influence during nighttime, but solar radiation has an influence on soil temperature during daytime.

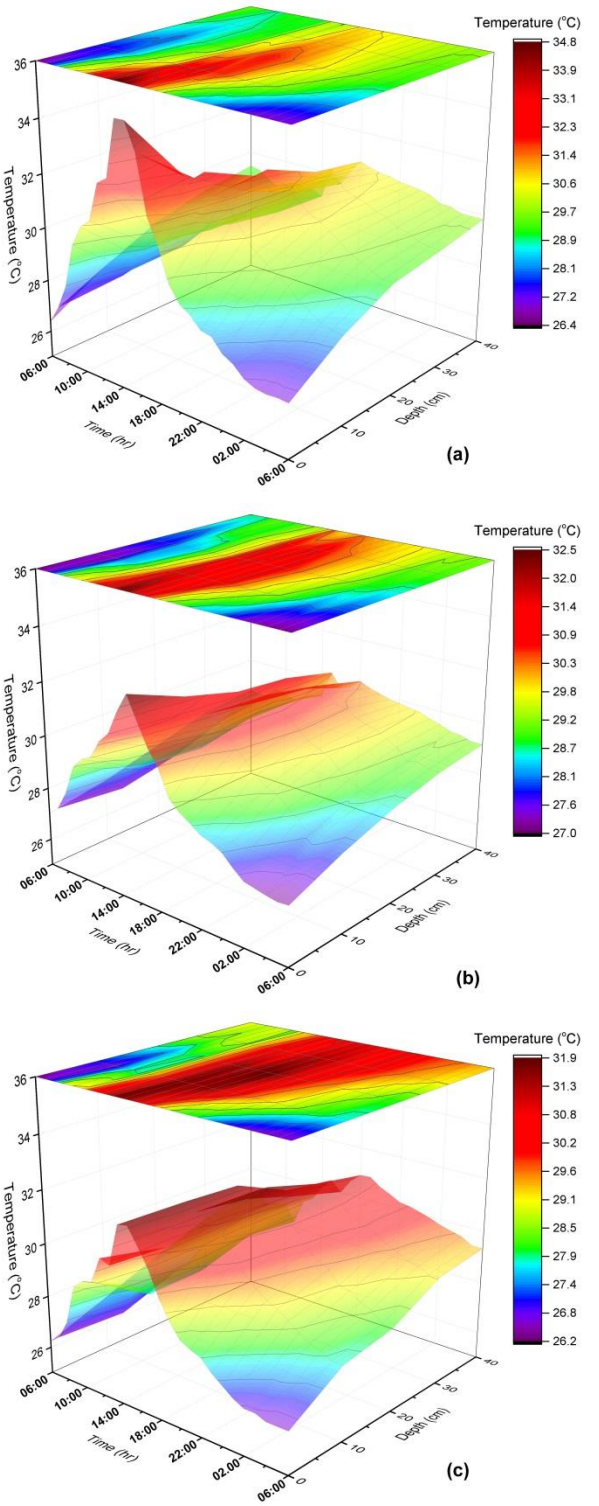



Figure 3 Diurnal variation of soil temperature at various depths
(a) lime tree aged 1 year (b) lime tree aged 2 years and (c) lime tree aged 5 years

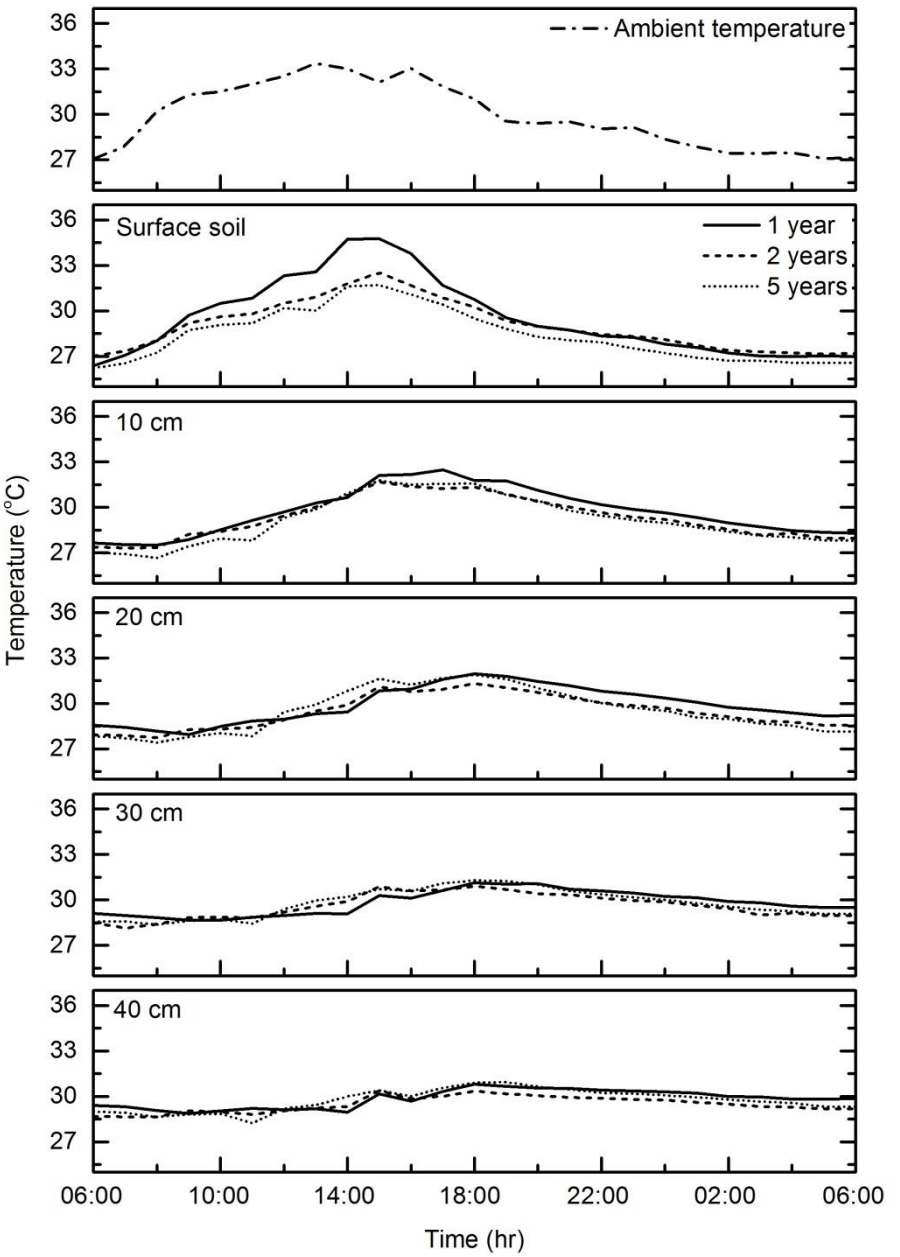
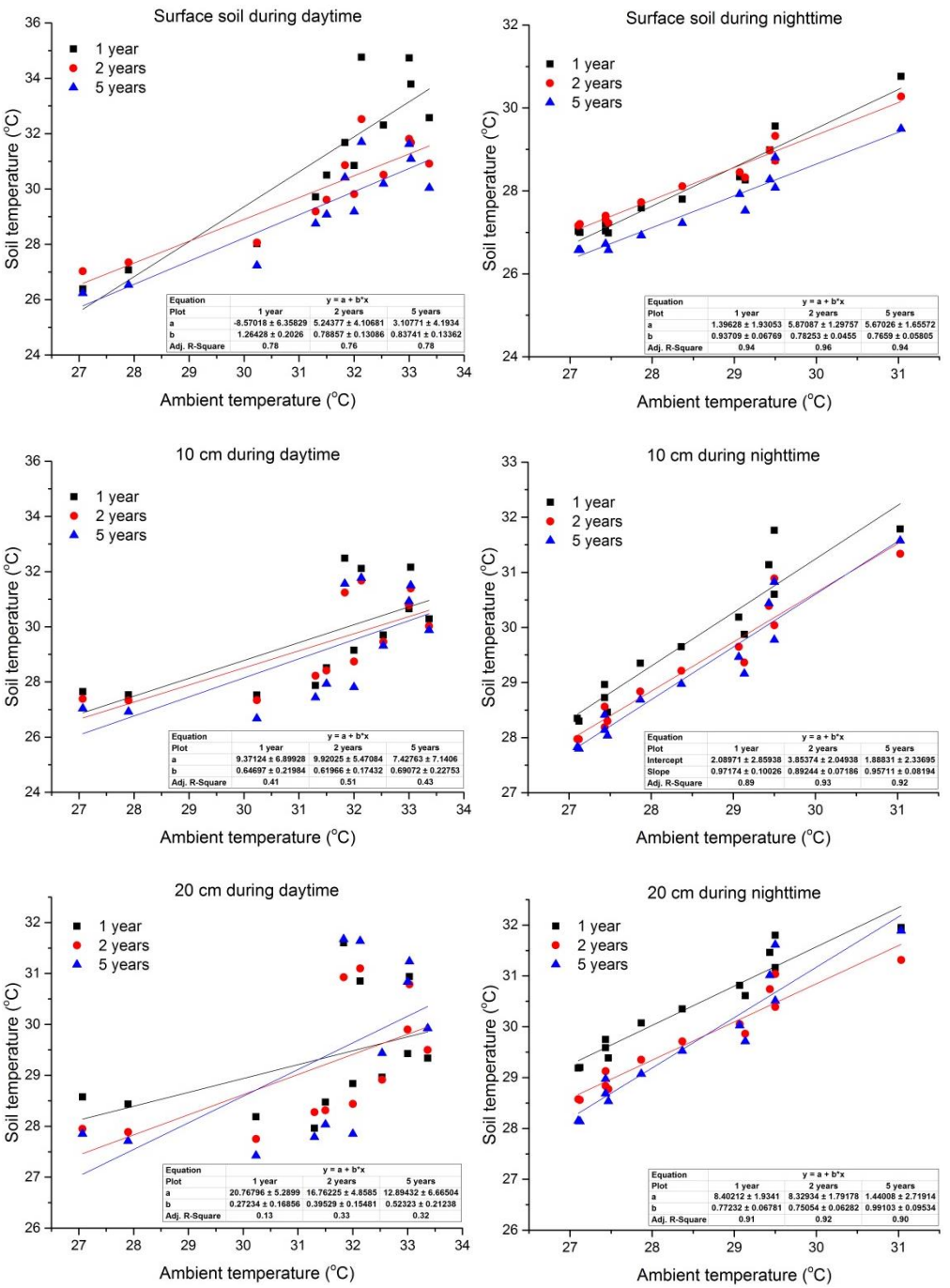
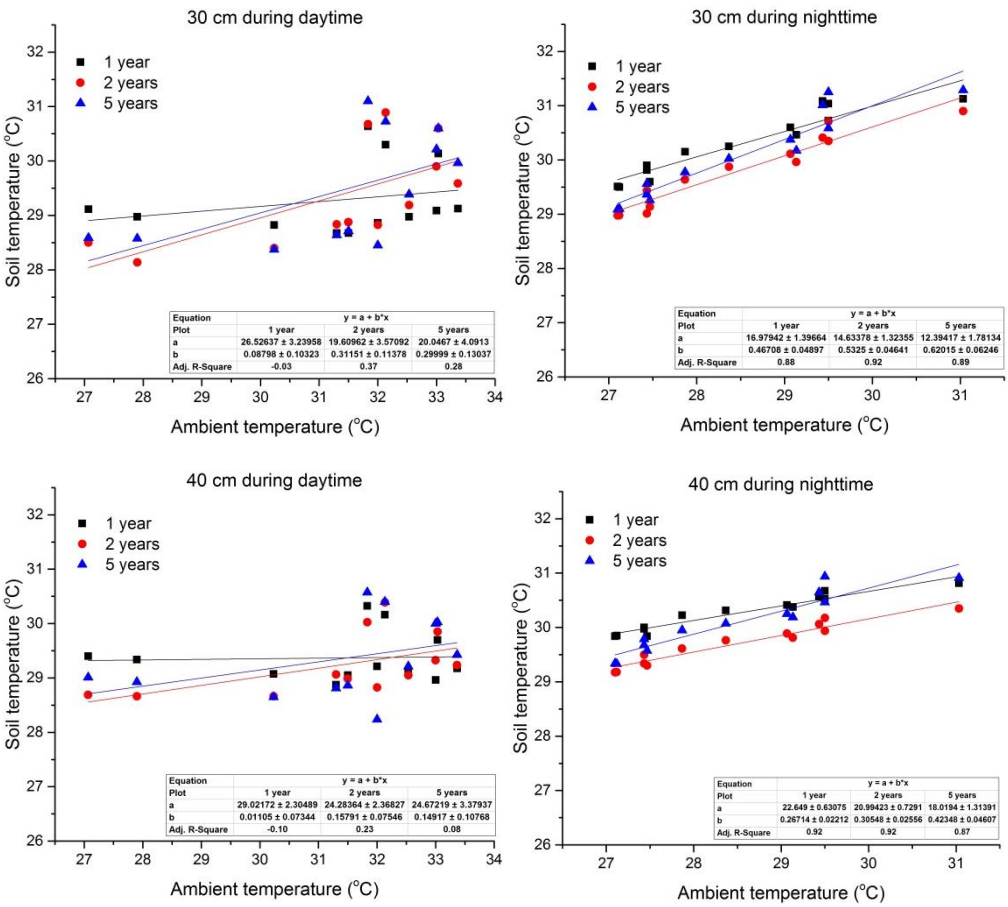



Figure 4 Variation of soil temperature in each layer of lime trees aged 1, 2 and 5 years




(a) (b)

Figure 5 Correlation of ambient temperature on diurnal (a) and nocturnal and (b) soil temperatures




(a) (b)

Figure 5 Continue

## CONCLUSION

The field experiment on the influence of ambient temperature on soil temperature at depths of 0 - 40 cm in concrete containers with lime trees aged 1, 2 and 5 years reveals more temperature variation at soil surface than at deeper layers. The average soil temperature of containers with 1-year-old lime tree was found to be higher than those in the containers with 2 and 5-year-old lime trees at surface soil approximate between 0.04 – 2.93 $^{o}$C and 0.15 - 3.11 $^{o}$C respectively, and 0.01 – 1.25 $^{o}$C at 10 – 40 cm of depth during daytime, due to the different canopy size of the trees. While at nighttime, the average soil temperatures were not different. .

In addition, the watering should be done at about 9.30 am, 11.30 am and 12.00 pm for 1, 2 and 5 year-old lime trees, respectively. Mulching or groundcovers will also help to keep the temperature suitable for growing, for younger trees.

When analysis was conducted on the correlation between ambient temperature and soil temperature in the concrete containers at all soil layers during the day by Straight-Line Regression Analysis with the Coefficient of determination, $R^2$.reveals a value of $R^2$ (0.87 – 0.96) closer to 1 during nighttime at almost all deeper layers but at daytime a value of $R^2$ (0.76 – 0.78) close to 1 at surface soil only, thus the influence of ambient temperature on soil temperature is strong correlation with at surface soil on diurnal time and all depths on nocturnal time.

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