The Observation on Soil Temperature from Kiwi Fruit Garden and Parent Material Xiashu Loess, Liuhe Nanjing, China

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Abstract. Soil temperature is one of the most important soil physical characters. The soil samples from different parent materials, Xiashu Loess from Nanjing Lvhang Kiwi fruit garden and alluvium of Yangtze River from Yangzhou Chahe, was tested on the temperature change with time and others in this study. Preliminary conclusions have been drawn: The firstly, soil temperatures change are consistent with air temperatures. Secondly, soil temperature change greatly in 10cm depth at 24:00 and 15cm depth at 14:00 in April, so soil temperatures management should be strengthened for Kiwi fruit garden in this month. Thirdly, soil temperatures from Kiwi fruit garden drop from 30˚C or so in September to 15˚C in October. Fourthly, applying the regression equations forecast the soil temperatures (y) by air temperatures (x).

For 10cm depth in Kiwi fruit garden:

\[ y = 0.8306x - 0.2539 \]  

(1)

For 15cm depth in Kiwi fruit garden:

\[ y = 1.2857x - 7.8571 \]  

(2)

For 5cm depth in Chahe soil samples:

\[ y = 0.6316x + 9.378 \]  

(3)

Fifthly, in this study, the cylindrical soil bed are simulation method for soil temperatures, but this results need to make further experiments in field site.

N.C. Brady believes that soil temperature can play a significant role in humans [1]. Soil temperature is one of the important physical properties of soil. It not only affects other physical, chemical, and biological properties of the soil, but it also greatly affects the growth and development of the plants on it. [2-5] Soil temperature is a comprehensive reflection of solar radiation, soil thermal balance, and soil thermal properties. It is assumed that without considering the former two, there are differences in soil thermal characteristics such as soil heat capacity, soil thermal conductivity, and soil thermal conductivity of different parent materials, which cause differences in soil temperature, thereby affecting the plants grown thereon.

This article is one of a series of studies, and the main research object is Nanjing Lvhang Ecological Kiwi Orchard soil. At present, the kiwifruit (Actinidia Chinensis Planch.) Cultivated by
Lvhang is a succulent root system, which requires higher soil drainage, and the root system is concentrated below 25-30cm below Table 1 (Chief Engineer Zhang Bangfu, 2014.1.9); Unlike the Loess Plateau, the root system of kiwifruit in Shaanxi is vertically distributed in the 0-60cm soil layer. New Zealand kiwi grows on volcanic ash loose soil, with good drainage and developed root system. The parent material for soil development of Liuhe kiwi fruit orchard is different from that of the Loess Plateau. The parent material of Xiashu Loess and its developed soils are compact, bulky, and water is not easy to infiltrate. It affects the rooting and root system growth of kiwifruit, which in turn affects the growth and development of fruit trees, and affects the resistance of fruit trees to changes in air temperature and soil heat and cold. In view of the large amount of early investment of planted kiwi, etc., in terms of two-way choice of improving varieties and improving the soil environment, priority is given to improving the soil environment here. In order to improve the soil and understand the soil temperature characteristics, this study uses simulation experiments and compares it with the soil of the Yangtze River alluvium parent material developed in Chahe Town, Yangzhou. This provides a basis for decision-making on kiwi orchard soil improvement and optimization of kiwi orchard soil management.

**Materials and Methods**

The soil samples for soil temperature observation were from Nanjing Liuhe Luhang Kiwi Orchard. The sampling locations were N32˚31΄32.8˝ and E119˚00΄31.5˝. The comparison samples are from the Yangzijin Campus of Yangzhou University, Chahe Town, Yangzhou City, and the sampling locations are N 32˚20΄32.01˝, E 119˚24΄3.56˝. The former is the parent material of Xiashu loess, and the latter is the alluvial material of the Yangtze River. The newly collected soil moisture content was measured by microwave oven method. The water content (wet basis) of the fresh soil sample (n = 5) of the former is 21.23% - 22.61%, and the latter is 24.44% - 26.32%.

The air-dried, pulverized, and sieved soil samples were spread on filter paper, and the area and thickness of the steel yuan were the same. The soil color parameters were obtained by using the Munsell soil color chart. The soil color of Liuhe kiwi garden is 10YR5/8, and the color of Luohe soil is 5Y7/1. According to test [10], The organic matter content of 30-60cm soil samples of Lvhang Kiwi Orchard was 9.37g/kg, pH 5.75. In this study, the organic content of 0-30cm soil samples in kiwi garden was 12.00 g/kg; the organic content of 0-30cm soil samples in Chahe, Yangzhou was 11.0 g/kg, pH 7.31.

According to Stokes' law, a specific gravity meter method was used to analyze the soil samples of kiwi orchards developed in Xiashu Loess. According to the analysis of the soil particle classification made in the United States, in the 0-20cm soil layer sample, sand accounts for 46%, silt 38%, and clay 16%. Soil-like sand grains in the rhizosphere (25-30cm) of the kiwi orchard were 54%, silty sands were 28%, and clay particles were 18%. The kiwi orchard soil sample has a bulk density of 1.53-1.59 g/cm³, while the Chahe soil sample has a bulk density of 1.35-1.47 g/cm³; the Luohe 0-20cm soil layer has 55% of sand particles, 31% of silt and 14% of clay.

**Soil Temperature Research Methods**

The liquid thermometer, which is now commonly used and uses the principle of liquid expansion, was made in the middle of the seventeenth century. In the eighteenth century, Table 1 was made in Celsius and Fahrenheit, and soil temperature observation and temperature observation were performed at the same time. [11]

The United States and the former Soviet Union first used remote sensing to observe soil temperature. The United States earlier applied the aerial remote sensing method to soil temperature research, using a transmitter to transmit heat to a special radiometer installed on the aircraft and calculate the zero point of the reading. Metrological correction was performed and 25 levels of images were monitored indoors to compile regional heat maps. [12] The former Soviet Union used
satellites to study soil temperature. The light tones on the infrared image corresponded to the low temperature area of the soil Table 1, while the dark tones were high temperature areas. At present, inversion of the actual temperature of Table 1 using satellite remote sensing has become one of the ways to observe soil temperature. However, both theoretical models and accuracy guarantees are far from practical.

At present, small-scale, large-scale orchard soil temperature research is mostly performed using existing meteorological observation station data and test methods. Orchard and woodland soil temperature research has also yielded more results, including He Zhaoquan’s (2014) on vineyards, Cao Bing’s (2009) research on the Chinese wolfberry garden, Wang Lianrong’s (2005) study on soil of Taolu, Nan Juan (2011) and Niu Tao’s (2008) research on jujube garden, Dongguo Zhou (2011) and Li Jinxue’s (2010) research on Lemon Garden, Meng Chun’s (2009) research on planted forest land, Gao Yonggang’s (2008) study on newly seeded fields of Korean Pine, Wang Xiaozheng’s (2005) research on peach garden, and K.B. Bevington et al.’s (1986) study on root growth and soil temperature of young citrus trees.

In this paper, Fan Ai et al. (2002) used a cylindrical soil bed simulation method to study the soil temperature of Lvhang Kiwi Orchard. A cylindrical plastic bucket with a depth of 50 cm and a diameter of 30 cm was collected. The original soil of the kiwi garden was collected and placed on the terrace outside the laboratory window, and inserted into the soil with a special thermometer (10 cm and 15 cm). Observe the soil temperature data of Layer 1 and soil depth at regular intervals. The soil temperature of 0-5cm is measured by Hydra soil temperature, salinity, and moisture analyzer.

Results and Discussion

Daily Variation of Soil Temperature

April is the flowering stage of kiwi, which is divided into four stages: bud stage, first flowering stage, full flowering stage, and last flowering stage, and then enters the fruit setting stage. The soil temperature at this time directly affects the nutritional supply of kiwi, as well as the quantity and quality of flower buds and fruits. The observation results of this study from April 1 to 30 are shown in Figures 1-4. From the data of the 10cm soil temperature measurement, the highest soil temperature measurement in April in the kiwifruit garden in April occurred at 21°C at 14:00 on April 30; The lowest temperature was 4°C, which occurred at 10 o’clock a total of 10 times, which were 5 times in early April, 2 times in the middle, and 2 times in the latter half, showing that the soil temperature was increasing with time and synchronized with the temperature. In contrast, the soil sample of Chahe Town, Yangzhou, as a reference sample, the highest measured temperature of all soils in April also occurred at 14:00 on April 30, 29°C, the lowest temperature was 9°C, and it happened once at 24:00 on the 3rd April.

From April 1 to 30, 2016, the data obtained from the observation of the soil samples has the following statistical characteristics (see Table 11, Table 2).

<table>
<thead>
<tr>
<th>Kiwi Orchard Soil Sample</th>
<th>Control Soil Sample (Chahe)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6:00</td>
</tr>
<tr>
<td>Arithmetric mean</td>
<td>11.23</td>
</tr>
<tr>
<td>Median</td>
<td>10.50</td>
</tr>
<tr>
<td>Mode</td>
<td>9.04</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.36</td>
</tr>
</tbody>
</table>

* Daily extreme value difference = maximum observed three times daily-minimum (Table 2, same as Figure 1-Figure 4)

From Table 11, the arithmetic mean of the 10cm temperature of the soil samples of the Lvhang Kiwi Orchard at 14:00 was 57% higher than 24:00 and 24% higher than 6:00. Some studies have
suggested that the Sun heated the Table 1 surface of the soil. The solar radiation reaching the soil surface at noon is the strongest, and the maximum temperature of soil at different depths appears at different times. [27] At 14:00, the soil sample had the highest temperature at 10cm depth. Combining the mean and standard deviation can better explain the distribution of a series. [28] The standard deviation of the April observation value of the 10cm soil sample of Lvhang Kiwi Orchard was the largest at 24:00, followed by 14:00 and the smallest at 6:00. Based on this, it can be seen that the temperature change of the soil sample in April is the largest at 24:00 at night, which puts forward certain requirements for the soil management of the kiwi garden. In comparison, the standard deviation at 10cm of the Chahe soil sample was the largest at 14:00, indicating that the temperature change affected by solar radiation was greater than the soil temperature of the kiwi garden. According to the comparison of daily extreme difference, the standard deviation of kiwi garden is much smaller than the control soil sample, which is more favorable for kiwi planting.

According to three observations, the analysis was performed. The temperature of the 10cm soil sample in Liuhe Kiwi Orchard was 6:00 and the highest temperature was 18˚C, which occurred on April 30. The lowest 7˚C occurred on April 3 and April 20. The highest temperature at 14:00 was also 10cm. The maximum value of all observations was 21˚C, which occurred on April 30, and the minimum value occurred on April 3. 8˚C; 24:00 The highest temperature was 16˚C, which occurred on April 30, and the lowest temperature was 4˚C, 5 times in early April, 2 times in mid-April, and 3 times in late April: In contrast, the Yangzhou Chahe soil sample had a maximum temperature of 21˚C at 6:00, which occurred on April 23, a minimum temperature of 12˚C, which occurred on April 4, and a maximum temperature of 29˚C, which was also 10cm, at 14:00. The highest value of the deep Chahe soil sample occurred on April 30, and the lowest temperature was 13 degrees, which occurred on April 3. At 24:00, the highest temperature was 17˚C, which occurred on April 30, and the lowest temperature was 9˚C, which occurred on April 3.

Judging from the statistical parameters of daily extreme difference, the temperature change of soil samples of kiwifruit orchard was smaller than that of Chahe soil, and its standard deviation was the smallest among 8 series of two types of soil samples, which was beneficial to kiwi growth. Daily extreme difference is one of the focuses of this study, and it has reference value for orchard soil management.

Table 2. Statistical table on values of soil sample temperature in 15cm depth by 3 times daily (n=30).

<table>
<thead>
<tr>
<th>Kiwi Orchard Soil Sample</th>
<th>Control Soil Sample (Chahe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>14:00</td>
</tr>
<tr>
<td>Arithmetic mean</td>
<td>16.73</td>
</tr>
<tr>
<td>Median</td>
<td>15.5</td>
</tr>
<tr>
<td>Mode</td>
<td>13.04</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.14</td>
</tr>
</tbody>
</table>

Table 2 shows that the arithmetic average temperature of the 15cm deep soil sample in Nanjing Liuhe Green Air Kiwi Orchard is the highest at 14:00 and is 27% higher than the arithmetic average of the measured values at 24:00; The standard deviation is the maximum at 14:00, which indicates that the temperature of the soil sample at this time is greater than that at 6:00 and 24:00. Compared with the control soil sample, the arithmetic mean temperature and standard deviation of the temperature were similar to those of the green kiwi orchard soil sample. Comparing the standard deviation of soil temperature at 10cm and 15cm in kiwi garden, the maximum standard deviation of 10cm occurred at 24:00, and the maximum standard deviation of 15cm occurred at 14:00. Some researchers suggest that [27] the impedance of soil heat conduction tends to reduce the temperature cycle at deeper depths. It is also noteworthy to take adjustment measures during the period when the soil temperature varies greatly.
Figure 1. The soil sample (Chahe Yangzhou) temperature in 10cm depth and observation in April 2016 by 3 times daily.

Figure 2. The soil sample (Liuhe Nanjing) temperature in 10cm depth and observation in April 2016 by 3 times daily.

Figure 3. The soil sample (Chahe Yangzhou) temperature in 15cm depth and observation in April 2016 by 3 times daily.
In short, from the daily variation of the temperature of the soil samples in the kiwi garden, the overall trend is in good agreement with the temperature. The maximum soil temperature at 10 cm in April occurred at 21°C at 14 o’clock on April 30; and the lowest temperature was 4°C, 5 times in early April, 2 times in mid-April, and 3 times in late April; The data was obtained three times a day at a depth of 15 cm, with a maximum of 29°C, which occurred at 14:00 on April 30; a minimum of 11°C, which occurred 3 times in early April.

Table 11 shows that the average soil temperature at a depth of 10 cm is 24 hours <6 hours <14 hours, standard deviation 24 o’clock > 14 o’clock > 6 o’clock. At 24:00 in April, the soil temperature had the lowest mean temperature and the largest standard deviation. Soil temperature management had a great relationship with kiwi growth. Table 2 shows that the average soil temperature at a depth of 15 cm is the same as that at 10 cm. At 24 o’clock <6 o’clock <14 o’clock, standard deviation 14 o’clock > 24 o’clock > 6 o’clock, which indicates that soil management at 15 cm deep at 14 o’clock needs to be strengthened. From the difference in daily extreme values in Table 11 and Table 2, only the standard deviation of 15 cm depth is greater than 10 cm depth, and the other three statistical parameters are opposite.

Compared with the control soil sample collected from Chahe River, the above characteristics of soil temperature of kiwifruit garden can be seen.

Variation of Soil Sample Temperature in Lvhang Kiwi Orchard in Autumn

The temperature of soil samples was selected from 9.15-10.15 in the autumn of 2016. At this time, the kiwi fruit was ripe, during which the soil temperature directly affected the yield and quality of the fruit. The general trend of soil sample temperature gradually decreased with time, from about 30°C to about 15°C (Figure 5). From Table 1 (Table 1 3) of soil temperature measurement, the arithmetic mean values of Liuhe soil samples are lower than the reference soil samples at 10 cm and 15 cm, and the median and mode are the same. The standard deviation of soil samples of Liuhe kiwifruit orchard was less than 15 cm at 10 cm depth, while the standard deviation of reference soil samples was opposite. According to related studies [27], the impedance of soil heat conduction tends to reduce the temperature cycle at deeper depths. The observation results of this study may be related to the fact that the temperature of 15 cm at the soil layer is higher than 10 cm at the observation period in autumn (September-October). Due to the rapid cooling due to the cold wave, the heat flow is directed to Table 1. The standard deviation of the reference soil sample (Chahe soil) in Table 13 is greater than 15 cm at 10 cm; the observation of soil temperature in autumn is
performed at 11:00-12:00 at noon. This is comparable to the observation time at 14:00 in April. With reference to the standard deviation of the observed values of the soil samples of the kiwifruit orchard in April, the standard deviation of the soil temperature data of the 15 cm soil sample is greater than 10 cm (see Table 11, Table 2). And at 14:00 in April, the standard deviation of the observed value of the Chahe soil sample at 10 cm is equal to 15 cm. This observation poses a challenge to the soil management of the kiwifruit orchard. In autumn, more attention should be paid to the effect of soil temperature on the yield and quality of fruit trees and fruits.

Table 3. Statistical table on values of soil sample temperature in 10 cm and 15 cm depth observation by 11:00-12:00 from 15th September to 15th October. (n=31).

<table>
<thead>
<tr>
<th>Statistical parameters</th>
<th>Soil samples of Lvhang Kiwi Orchard</th>
<th>Control soil sample (Chahe)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10cm</td>
<td>15cm</td>
</tr>
<tr>
<td>Arithmetic mean</td>
<td>21.60</td>
<td>25.66</td>
</tr>
<tr>
<td>Median</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Mode</td>
<td>20.68</td>
<td>23.68</td>
</tr>
<tr>
<td>Extreme difference</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.88</td>
<td>4.67</td>
</tr>
</tbody>
</table>

Figure 5. The soil sample (Chahe Yangzhou and Liuhe Nanjing) temperature in 10 cm and 15 cm depth and observation by 11:00-12:00 from 15th September to 15th October.

**Estimating Soil Temperature in Kiwi Orchard by Temperature**

Numerous studies have confirmed that soil temperature is closely related to air temperature. Hou Jianhua et al. [29] used the relationship between air temperature and soil temperature to establish a model to predict soil temperature, and it is concluded that the generally consistent change trend of soil temperature and air temperature. H. Langholz (1989) [30] proposed a simple model for forecasting the daily average soil temperature. Regressive prediction of soil temperature above 10 cm has high accuracy, and it can also be used for the prediction of 10-20 cm soil layer. Li Renjie et al. (2010) concluded [31] that the laws of ground temperature and temperature were basically the same, but there was a certain lag.

In order to improve the soil environment for kiwi growth, understand the change of soil temperature during kiwi growth, analyze the relationship between soil temperature and air temperature, and predict the soil temperature based on the easier to obtain air temperature, it is of practical significance for kiwi garden soil management to increase kiwi production and income. This study attempts to establish a regression equation between the two, predict the soil temperature of kiwifruit orchards based on atmospheric temperature, and provide valuable data accumulation.
Figure 6. The soil sample (Liuhe Nanjing) temperature in 10cm and 15 cm depth and observation one time by 11:00-12:00 from 1st May to 18th September (not incontinuity, mainly June and July).

Figure 6 is a randomly selected date from June to July. The measured values of the 10cm and 15cm temperature of the kiwi orchard soil samples were measured at 7 am. From the two columns of data, there is a good consistency in the graph with the temperature data obtained simultaneously. The weather at 6.15 and 7.24 is cloudy or cloudy at night and early morning, and the temperature and soil temperature observed in the morning are higher than those at night, because the clouds at night and in the morning have an influence on the long-wave radiation diffusion.

A total of 17 random observations of valid data mainly from June to July are used, soil samples of kiwifruit orchards had a relationship between soil temperature and air temperature at a depth of 10 cm and 15 cm at 7 am. Using the soil temperature and temperature observation data, a regression equation is established. The simultaneous observation of the soil temperature at a depth of 10 cm is the regression equation: \( y = 0.8306x - 0.2539 \) (4). Test the regression equation (4), \( r = 0.705 \), there is a significant linear relationship between x and y at a confidence level of 75\%, and the determination coefficient \( R^2 = 0.4968 \). The regression equation has a higher approximation to the objective reality.

Similarly, the 15cm depth regression equation is:

\[ y = 1.2857x - 7.8571 \] (5)

Test the regression equation (5), \( r = 0.8960 \), there is a significant linear relationship between x and y at the 75\% confidence level, and the determination coefficient \( R^2 = 0.8028 \). The regression equation has a higher approximation to the objective reality.

Observation of the Chahe control soil sample. Soil temperature data at a depth of 5 cm were obtained at 7 am. The correlation coefficient of soil temperature and air temperature was 0.569, \( n = 41 \). The regression equation:

\[ y = 0.6316x + 9.378. \] (6)

Test the regression equation (6), \( r = 0.5690 \), there is a significant linear relationship between x and y at the 75\% confidence level, the determination coefficient \( R^2 = 0.3238 \), the approximation of the regression equation to the objective reality is better than (4), (5) difference.

The soil temperature observation at a depth of 5 cm was performed at 7 am, and the observation time was between March and May 2016. The soil temperature changes little and the temperature changes greatly. In most cases, the 5cm soil temperature is higher than the 2m altitude temperature obtained simultaneously. The temperature on March 21 was 9\(^\circ\)C, the minimum value for this series, and the soil sample temperature corresponding to the low temperature was also low. Soil temperature and temperature gradually increased with time.
The above-mentioned simulation study of the regression relationship between soil temperature and air temperature in Nanjing Lvhang Kiwi Orchard shows that the soil temperature and air temperature change are consistent. Regression equations are used to estimate soil temperature facilitates the management of soil during the whole growth period and promotes the normal growth and development of kiwi, especially in the seasons with frequent cold and heating activities in spring and autumn and large daily changes in temperature. The feasibility of this research method is illustrated by referring to the soil temperature regression equation of Chahe River.

**Conclusion**

First, judging from the daily variation of the temperature of the soil samples in the kiwi garden, the overall trend is in good agreement with the temperature. The highest soil temperature at 10 cm in April occurred at 21˚C on April 30 at 14:00; and the lowest temperature was 4˚C, 5 times in early April, 2 times in mid-April, and 3 times in late April; The data was obtained three times a day at a depth of 15 cm, with a maximum of 29˚C, which occurred at 14:00 on April 30; a minimum of 11˚C, which occurred 3 times in early April.

Second, the soil temperature management of the kiwi orchard in April should be strengthened at 24 o’clock in the depth of 10cm and 14 o’clock in the depth of 15cm.

Third, the overall trend of soil sample temperature in the kiwi garden in autumn (September-October) gradually decreased with time, from about 30˚C to about 15˚C (Figure 5). From Table 1 (Table 1 3) of soil temperature measurement, the arithmetic mean values of Liuhe soil samples are lower than the reference soil samples at 10cm and 15cm, and the median and mode are the same. The standard deviation of soil samples of Liuhe kiwifruit orchard was less than 15cm at 10cm depth, while the standard deviation of reference soil samples was opposite.

Fourth, understand the temperature changes in the kiwi orchard. In order to change the soil temperature management strategy at any time, improve kiwi planting.

Fifth, the application of the regression equation can use the air temperature (x) to estimate the soil temperature (y) of the Lvhang Kiwi Orchard, which provides a scientific basis for soil temperature management.

10cm Kiwi Orchard Soil Temperature Prediction Equation (7):

\[ y = 0.8306x - 0.2539 \]  

15cm Kiwi Orchard Soil Temperature Prediction Equation (8):

\[ y = 1.2857x - 7.8571 \]  

Reference equation for temperature prediction at a depth of 5 cm from the soil of Chahe (3):
y=0.6316x+9.378

Sixth, this study uses a cylindrical soil bed simulation method to preliminary study the temperature change of the soil sample. Many individual factors affecting soil temperature are not considered, which is different from the actual situation in the field. The conclusion of this article needs to be further demonstrated by field experiments.

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References


