Study on the changes of soil thermal conductivity of sugarcane field under different tillage methods

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Abstract. The smash-ridging tillage (T) treatment and no-tillage (NT) treatment were set up in the sugarcane planting area of the Lijian Research Science Base of Guangxi Academy of Agricultural Sciences. The soil moisture content at 5, 20 and 40cm depths were obtained by location monitoring, and the soil thermal conductivity was calculated combined with some basic soil properties. The results showed that the soil thermal conductivity of T treatment at different depths were 40 cm>20 cm>5 cm. And in the site of NT treatment of that were 40 cm>5 cm>20 cm. In a few words, the thermal conductivity above 20 cm layer of soil at T treatment were basically significantly higher ($P<0.05$) than NT during the experiment period, but were not significant difference between T and NT treatment at the 40 cm depth. These laws were mainly due to the ability of smash-ridging tillage of storing water greater than the no-tillage pattern, which indicating the smash-ridging tillage in this study can improve soil thermal conductivity better.

1. Introduction
The heat energy in the soil is a huge available energy reservoir. It is of great significance to study the changes and laws of soil thermal properties [1]. How to obtain the soil thermal conductivity value quickly and accurately is one of the important contents of studying soil thermal properties. The soil thermal conductivity can affect the material migration in the soil, which will relate to the utilize and evolution of soil. Also, it is an important evaluation index to judge the soil health and high quality or not. In general, the thermal conductivity of soil are affected by basic soil properties such as soil water content, texture and bulk density [2]. It has been proved that conservation tillage has the effects of restoring soil structure, improving soil physical properties and its thermal conditions [3]. However, problems such as crop emergence and poor drainage may also occur [4], and maybe reduce the efficiency utilization and transfer of heat. Appropriate tillage ways can effectively reduce soil bulk density and improve soil hydrothermal conditions [5]. Analyzing the variation laws and reasons of the changes in soil thermal conductivity under different tillage methods in the sugarcane planting area can provide a scientific basis for farmland management, scientific use of soil resources and economic crop cultivation in dryland in Guangxi.
2. Materials and methods

2.1. Study site description

The research was carried out on a long-term experiment established at the Lijian Scientific Research Base of Guangxi Academy of Agricultural Sciences (23°14'N, 108°02'E), with an average annual rainfall of 1304.2 mm that mainly concentrated from May to September. Sugarcane cultivation in the research base were mainly adopted by smash-ridging tillage (T) treatment and no-tillage (NT) treatment. The method of smash-ridging tillage was using the spiral special agricultural machinery with the tillage depth of 30 cm. No-tillage was a method of no farming for 6 years. Each treatment had a length of 20 m, a width of 10 m and a row spacing of 0.9 m. Each treatment excavates 3 replicate soil profiles for monitoring. The research period was May to September 2017.

2.2. Soil sampling and analyses

In this case study, at each site the moisture probes were installed at the 5, 20 and 40 depths of soil, these probes were connected to one solar powered automatic data-logger. At the same time, soil samples of the same layers were collected, which for analyzing some basic soil properties and the results are list in Table 1. For more detailed information about the calculate method of soil thermal conductivity, please see the literature [6].

Table 1. Basic physical and chemical properties of sugarcane soil

| Plot | Depth | Sand(%)  | Silt(%)  | Clay(%)  | BD(g·cm⁻³) | TP(%)  | SOM(g·kg⁻¹) |
|------|-------|----------|----------|----------|------------|--------|-------------|
| T    | 5     | 39.14±4.03a | 33.16±1.44b | 27.70±2.60a | 1.50±0.017a | 43.48±0.67a | 4.99±0.23c  |
|      | 20    | 40.74±3.07a | 34.08±0.37ab | 25.19±3.12a | 1.48±0.016a | 43.97±0.59a | 3.74±0.22b  |
|      | 40    | 35.45±0.97a | 36.93±0.96a | 27.62±0.10a | 1.48±0.022a | 44.16±0.82a | 13.66±0.07a |
| NT   | 5     | 41.30±1.89b | 33.65±0.28b | 25.05±1.72ab | 1.51±0.030a | 43.02±0.51a | 4.35±0.05b  |
|      | 20    | 46.68±1.39a | 31.63±0.77c | 21.70±0.72b | 1.47±0.022a | 44.66±0.83a | 3.79±0.20b  |
|      | 40    | 33.86±1.13c | 39.24±0.54a | 26.91±1.52a | 1.50±0.013a | 43.50±0.51a | 11.69±0.53a |

Note: Different lowcase letters indicate the significant difference between depths at the same tillage treatment (p < 0.05).

2.3. Changes of soil thermal conductivity

Fig. 1 shows the daily changes of soil thermal conductivity at 5, 20 and 40cm depths under different tillage treatment. During the whole monitoring period, the paired t-test results showed that the soil thermal conductivity at the 5 cm depth between different treatments was not significantly different (P>0.05, the same below). However, from June 1 to September 30, it was the T treatment significantly higher (P<0.05, the same below) at the NT. The reason of that may the low water content in the early stage of the T treatment, indicating that the smash-ridging tillage has a better ability to maintain soil moisture and thermal conductivity after precipitation supplement. Similarly, throughout the monitoring period, the soil thermal conductivity at 20 cm depth of T treatment was significantly greater than that of the NT. At the 40 cm depth, there were no significant difference between the two treatments. Meanwhile, in the T treatment region, the soil thermal conductivity of at 40 cm depth was significantly higher than that of other depths but were not significantly different between the 5 and 20 cm depths. In the site of NT treatment, the thermal conductivity at different depths were 40 cm>5 cm>20 cm.

As can be seen from Fig 1, the soil thermal conductivity increases rapidly when rainfall occurs and decreases after the precipitation ends, while the difference of it between the T and NT treatment were gradually increases and at 20 cm depth was the most obvious (Fig. 1). These laws shows that the precipitation can affect soil thermal conductivity by changing soil water content. During the June 1st
Figure 1. Changes of soil thermal conductivity under different tillage methods

To 16th the precipitation reached 233.6mm. The soil thermal conductivity was higher at T treatment than NT when rainfall took place. With the decrease in precipitation such as from July 28 to August 7 and September 15-25, the changes of soil thermal conductivity were the same: whether rainfall occurs or not, it was T treatment higher at 5 cm and 20 cm depths than NT, and at 40 cm depth had an opposite law. These phenomena show such a fact that, smash-ridging tillage is beneficial to the soil to store rainwater and to improve soil thermal conductivity.

The rainfall was 95.0 mm on July 2, and the soil thermal conductivity value of each depth reached the maximum on July 3. Before July 3, the soil thermal conductivity rised or fell at 5 cm depth of NT treatment was lags behind T treatment. However, after the day of July 3, the changes of T treatment slower than the NT. At the 20 cm depth the changes of soil thermal conductivity was also the T treatment slower during the whole research period but the value of it was higher at T treatment than NT. The phenomenon of above hysteresis is about 1 day, and there is no obvious hysteresis at the 40 cm depth under different patterns.

3. Discussion

The soil thermal conductivity are affected by soil water content, texture, bulk density, porosity and organic matter [6]. Under natural conditions, the amount of soil water content can determine soil thermal conductivity value. At the site of NT treatment of this research, the relationship of soil thermal conductivity between different depths were 40 cm>5 cm>20 cm. At 20 cm depth of it was the lowest mainly due to the high sand content of this soil layer (Table 1). A higher sand content of soil can accommodate more water volume but it is not easy to store and lose quickly [7], there are the reasons why the soil thermal conductivity value of 20 cm depth is lowest. At the same time, the reasons of 40 cm>5 cm is mainly because the surface of soil are more susceptible to external influences and evaporation, while 40 cm depth can maintain more soil moisture and improve thermal conductivity. At the site of T treatment, the soil thermal conductivity relationship is 40 cm>20 cm>5 cm, it is due to the
rainwater can be better stored in deeper layers under smash-ridging tillage, which improves the thermal conductivity also.

The soil thermal conductivity was higher at T treatment than NT with the rainfall occurs. The reasons are that smash-ridging tillage may make the soil turn into loose and porous, which is conducive to water infiltration [8]. With the rainfall decrease, the soil thermal conductivity of T treatment above 20 cm depths was higher, indicating that the smash-ridging tillage has a better effect on the storage and protection of farmland water resources. Before July 2, since the weeds on the surface of NT treatment would delay the infiltration of water, the changes of soil thermal conductivity behind T. And after July 2 the changes of soil thermal conductivity was slower at T treatment than NT was due to samsh-ridging tillage can improve the structure and water conservation capacity of soil to a certain extent [9].

Studies have shown that long-term tillage may result in damage to soil structure [10]. Conservation tillage like no-tillage may also cause in a decrease in soil temperature in spring and the formation of soil plows bottom [11,12]. In this research, the soil thermal conductivity of T treatment at 5 and 20 cm depths were basically higher than that of NT; while at the 40 cm depth was not significantly different. The analysis shows that the smash-ridging tillage can better improve the soil hydrothermal condition of sugarcane field than no-tillage.

4. Conclusion
Soil thermal conductivity is mainly affected by natural factors such as rainfall, but human factors such as different tillage patterns will also affect it to some extent. The soil thermal conductivity was higher at T the smash-ridging tillage (T) treatment than no-tillage (NT) treatment with the rainfall occurs. The soil thermal conductivity of T treatment at different depths were 40 cm>20 cm>5 cm, while the NT treatment were 40 cm>5 cm>20 cm which influenced by its texture at 20 cm depth. It was found that the T treatment can improve soil thermodynamic properties in soil layers above 20 cm, and its thermal conductivity is higher than that of the NT. Therefore, the smash-ridging tillage pattern can be used as an effective means for efficient planting of sugarcane in Guangxi.

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