Effect of Different Irrigation Patterns and Covering Methods on Soil Temperature of Onions Under Membrane Drip Irrigation

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Abstract. In order to investigate the influence of the soil temperature of onions in the West Hebei Oasis, this paper tested the soil temperature of onions in the Oasis by using the early golden dragon onion as a test material and randomly grouped it into different irrigation modes and cover methods. There were five treatments in the experiment, and the soil temperature of onion was measured in each reproductive period, and the results showed that: The most significant changes in soil temperature were found in the 5 cm soil layer, where the soil temperature was more affected by external influences, and in the 10 and 20 cm soil layers, where the soil temperature was less affected by external influences. The difference in soil temperature was not significant between full irrigation and regulated deficit irrigation. The soil temperature in the black mulch layer was higher than that in the transparent mulch layer and fine sand mulch layer at the seedling and leaf development stages, while the soil temperature in the black mulch layer was higher than that in the transparent mulch layer and fine sand layer at the bulb expansion and maturity stages. The soil temperature of the onion can be best controlled by irrigation while covering the onion with black mulch throughout the growing season, which is of great significance for onion cultivation in the Hexi Irrigation Zone.

1. Introduction
Drought is a global problem, Arid and semi-arid regions of the world account for about 25% and 30% of the world's land area, while rain-fed agriculture in these regions accounts for more than one-third of the world's arable land, and seasonal or unpredictable droughts often occur in humid regions, posing a great threat to world agricultural production. Although China possesses more water resources, the amount of water per capita is small, only 1/4 of the world average, and the conflict between water supply and demand is prominent. At the same time, China, with a large arid and semi-arid area in the world, has arid and semi-arid areas accounting for 52.5% of the country's land area and 38% of the country's arable land. Since the 1970s, the greenhouse effect has become increasingly pronounced, not only raising the atmospheric temperature by about 3°C, but also changing the atmospheric circulation pattern, with temperature and precipitation being altered to varying degrees [1]. Precipitation is mainly manifested in time and geographical changes, some studies show that since the 20th century, autumn precipitation in the southeast of China's northwest region has a tendency to increase [2]. At present,
the Party Central Committee and the State Council have listed food, oil and water as China's three strategic resources, and if strong measures are not taken, China is likely to have a serious water crisis in the future. Water resource issue has become a major issue that must be seriously addressed in the process of China's strategy to achieve sustainable development. Therefore, it is of great significance to understand the current status of China's water resources utilization, gain insight into the main reasons for the current status of China's water resources utilization, and propose solutions to the water problems and countermeasures that plague China's socio-economic development. Surface cover can effectively improve the soil temperature environment, and different cover types have different effects on the soil heat regulation. Zhang S.M. et al[3] found that conventional polyethylene mulch had a significant warming effect in the pre-productive stage of potatoes, while black-and-white mulch had a significant temperature control effect in the starch accumulation stage with a small daily change in temperature. Wang H.L. et al[4] studied the effect of black mulch on soil temperature in the semi-arid northwest region with potatoes as the experimental object, and the results showed that black mulch can increase soil temperature by 1.5°C from 0 to 25 cm during the whole reproductive period of potatoes. The results show that black mulch can increase soil temperature by about 1.5°C in 0–25 cm of the whole reproductive period of potatoes. As a traditional cover material, the warming effect of fine sand has been recognized by many researchers. In this experiment, we divided the reproductive stages of onion into seedling, leaf development, bulb expansion and maturity stages, carried out water control during each reproductive stage, analyzed the soil temperature in the growing environment of onion, and searched for the optimal cover material and water control scheme to provide a theoretical basis for the development of local water-saving and efficient onion production.

2. Materials and Methods

2.1. Overview of the test site
The experiment was conducted from March to September 2018 at the experimental farm of the Agricultural Extension Center of Minqin County, Gansu Province, and harvested on September 10, 2018. The area is located in the northeastern part of the Hexi Corridor and the downstream part of the Shiyang River Basin in Gansu Province, at latitude 38°3′ north and longitude 101°49′ east. The test area is a temperate continental arid climate zone with an extreme maximum temperature of 39.5°C, an extreme minimum temperature of -27.3°C, an average annual temperature of 8.3°C, an elevation of 1472m, an annual precipitation of 127.7mm, a reproductive period of 102.7 mm, an evaporation of 2623mm, 3073.5 hours of sunshine, and a frost-free period of 162 days. According to the rainfall data of the last 50 years, the average annual precipitation in this area is generally about 116.5 mm. The main soil type was silt-filled soil from 0 to 60 cm, and the soil below 60 cm was sandy loam, with an average weight capacity of 1.54 g·cm⁻³, the nutrient content of the soil was 4.89 g·kg⁻¹ of organic matter, 0.48 g·kg⁻¹ of total nitrogen, 1.33 g·kg⁻¹ of total phosphorus, 18.92 g·kg⁻¹ of total potassium, and the pH value of the test plot was 4.998 g·kg⁻¹, 0.9 g·kg⁻¹ of total nitrogen, 1.9 g·kg⁻¹ of total phosphorus, and 1.9 g·kg⁻¹ of total potassium. 8.02, total salt 1.685 g·kg⁻¹, irrigation water mineralization 0.86 g·L⁻¹.

2.2. Test Design and Method
The test onion variety is "Early Golden Dragon", provided by Jiuquan Great Dunhuang Agricultural Products Co. The seedlings were sown in the daylight greenhouse on March 9, 2018, and transplanted to the field on May 10, 2018. The seedlings were transplanted in rows 15 cm apart and plants 10 cm apart, with 8 rows of one film, one plant per hole, and transplanting depths of 2 to 3 cm, with a test plot area of 30 m² (2 m×15 m). In spring, 50 kg of calcium superphosphate, 22 kg of diammonium phosphate, 25 kg of potassium sulfate and 20 kg of urea were applied as base fertilizer. 8 kg of urea was irrigated with head water on May 26, 17 kg of urea was irrigated with secondary water on June 9 and 25 kg of nitrogen-phosphorus compound fertilizer was irrigated with tertiary water on July 7 after the onion slowing period. Under black mulch, the test can be divided into full irrigation (T1, local
irrigation amount), light deficit irrigation (T2, about 75% of full irrigation), moderate deficit irrigation (T3, about 65% of full irrigation), and medium deficit irrigation (T3, about 65% of full irrigation). Mulch (T4), fine sand cover (T5). The test treatments are shown in Table 1 and the irrigation amount and irrigation times are shown in Table 2.

### Table 1 Experimental design

| Treatments          | Black film mulching | White film mulching | Fine sand mulching |
|---------------------|---------------------|---------------------|--------------------|
| Copious irrigation  | T1                  | T4                  | T5                 |
| Mild DRI            | T2                  | -                   | -                  |
| Moderate DRI        | T3                  | -                   | -                  |

### Table 2 The parameters under drip irrigation for onion

| Treatments | May 12th | May 27th | June 11th | June 26th | July 11th | July 26th | August 10th | August 25th | Irrigation quota (m³·hm⁻²) |
|------------|----------|----------|-----------|-----------|-----------|-----------|-------------|-------------|--------------------------|
| T1         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 650         | 5300                     |
| T2         | 900      | 425      | 425       | 450       | 450       | 450       | 450         | 450         | 4000                     |
| T3         | 900      | 350      | 350       | 380       | 380       | 380       | 380         | 380         | 3500                     |
| T4         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 650         | 5300                     |
| T5         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 650         | 5300                     |

### 2.3. Soil temperature measurement method

The ground temperature was measured with a right-angle geothermometer (Shanghai Titan Base Precision Instrument Factory) at depths of 5, 10 and 20 cm. 5 d of observations were made at random during each determination date, and the observations were made every 3 h from 7:00 a.m. to 21:00 p.m.

### 2.4. Statistical Analysis of Data

The measured data were calculated using EXCEL 2010, and ANOVA and significance tests were performed using the SPSS 16.0 data processing system.

### 3. Results and Analysis

#### 3.1. Soil temperature variation in 5 cm soil layer

From Figure 1, it can be seen that the soil temperature in the 5cm soil layer increased and decreased throughout the reproductive period of the onion. The soil temperature in the 5cm layer was affected differently by different irrigation patterns and mulching methods. The soil temperature was lowest in each treatment on May 2 (seedling stage), ranging from 16.8°C to 18.2°C, and was highest in T4, 1.1°C and 0.5°C higher than that in T1 and T5, respectively. As the fertility process progressed, the soil temperature gradually increased and reached its maximum on July 6 (leaf development stage), ranging from 32.4°C to 34.1°C, with the highest soil temperature still in the transparent mulch treatment T4, which was 1.7°C and 1.4°C higher than T1 and T5, respectively. After that, as the leaf area of the onion increased and blocked the direct sunlight to the surface, the temperature showed a decreasing trend. The soil temperature dropped most significantly from August 6 to August 21, with the black mulch cover showing the most significant change of 8.0°C~8.2°C, while the temperature difference between transparent mulch T4 and fine sand T5 was 6.3°C and 6.9°C respectively, significantly lower than the black mulch cover.
Figure 1. Effect of different irrigation and cover methods on the seasonal changes of soil temperature in the 5cm soil layer.

3.2 Soil temperature variation in 10 cm soil layer.

Figure 2 shows that the soil temperature in the 10 cm soil layer and the 5 cm soil layer showed the same trend throughout the reproductive period of the onion, with both increasing and decreasing over the reproductive period. The soil temperature in the 10 cm layer was affected differently by different irrigation and cover patterns. The soil temperature was lowest at May 2 (seedling stage), ranging from 17.0°C to 17.7°C, and was higher in T4 than in T1 and T5 by 0.7°C and 0.2°C, respectively. As the fertility process progressed, the soil temperature gradually increased and reached its maximum on July 6 (leaf development stage), ranging from 30.3°C to 32.3°C. After that, as the leaf area of the onion increased and blocked the direct sunlight to the surface, the temperature showed a decreasing trend. The soil temperature dropped most significantly from August 6 to August 21, with the black mulch cover showing the most significant change of 4.6°C, while the temperature difference between transparent mulch cover T4 and fine sand cover T5 was 6.1°C and 7.8°C respectively, which was significantly higher than the black mulch cover treatment.

Figure 2. Effect of different irrigation and cover methods on the seasonal changes of soil temperature in the 10cm soil layer.
3.3 Soil temperature variation in the 20 cm soil layer.
Figure 3 shows that the soil temperature in the 20 cm layer followed the same trend as that in the 5 and 10 cm layers throughout the reproductive period, with both increasing and decreasing over the reproductive period of the onion. Different irrigation patterns and coverings had different effects on the soil temperature in the 20 cm layer. The soil temperature was lowest in each treatment on May 2 (seedling stage), ranging from 15.8°C to 16.5°C, and was higher in T4 than in T1 and T5, respectively. As the fertility process progressed, the soil temperature gradually increased and reached its maximum on July 6 (leaf development stage), 27.1°C~32.3°C. After that, as the leaf area of the onion increased and blocked the direct sunlight to the surface, the temperature showed a decreasing trend. The soil temperature dropped most significantly from August 6 to August 21, with the black mulch cover showing the most significant change of 5.5°C, while the temperature difference between transparent mulch cover T4 and fine sand cover T5 was 4.9°C and 4.8°C respectively, which was significantly lower than the black mulch cover.

![Figure 3. Effect of different irrigation and cover methods on the seasonal changes of soil temperature in the 20cm soil layer.](image)

4. Discussion
Soil temperature in the 5 to 25 cm soil layer increased or decreased throughout the entire reproductive period of the onion. Soil temperature was lower on May 2 (seedling stage) in all treatments, but it was higher in T4 (transparent mulch) than in T1 and T5 (water deficit irrigation). As the reproductive process progressed, the soil temperature gradually increased and reached its maximum on July 6 (leafing stage). Then, as the leaf area of the onion increased, it blocked the direct sunlight to the surface, and the temperature tended to decrease. Soil temperature decreased most significantly from August 6 to August 21, with the most significant change in soil temperature between the two periods being in the black mulch cover, while the temperature difference between the transparent mulch cover T4 and the fine sand cover T5 was significantly lower than that between the black mulch cover treatments. The results of Zhang Q. et al[5] showed that soil temperature was significantly lower in black mulch than in white mulch, and the difference was more pronounced in the highest temperature period of the day. Xu H.M. et al[6] found that both white and black mulch significantly increased the soil temperature in the tillage layer compared to no-mulch planting, but the black mulch treatment in the early reproductive period significantly decreased the soil temperature in the tillage layer, and there was no significant difference between black mulch and white mulch in the middle and late reproductive period, which is consistent with the conclusion of this experiment.
5. Conclusion
The most significant changes in soil temperature were found in the 5 cm soil layer, where the soil temperature was more affected by external influences, and in the 10 and 20 cm soil layers, where the soil temperature was less affected by external influences. The difference in soil temperature was not significant between full irrigation and regulated deficit irrigation. The soil temperature in the black mulch layer was higher than that in the transparent mulch layer and fine sand mulch layer at the seedling and leaf development stages, while the soil temperature in the black mulch layer was higher than that in the transparent mulch layer and fine sand layer at the bulb expansion and maturity stages. The soil temperature of the onion can be best controlled by irrigation while covering the onion with black mulch throughout the growing season, which is of great significance for onion cultivation in the Hexi Irrigation Zone.

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