Effect of Different Irrigation Patterns and Covering Methods on Onion Water Consumption Characteristics

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Abstract. In order to investigate the influence of the water consumption characteristics of onions in the Hexi Corridor, this paper tested the water consumption 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 water consumption of onion was measured in each reproductive period, and the results showed that: (1) the soil water storage decreased with the increase of water loss, i.e. the soil water storage size was T1 > T2 > T3. The difference in soil water storage between black mulch and transparent mulch was smaller, but significantly larger than that of fine sand mulch. (2) The water consumption and water intensity of onion showed a decreasing trend with the increase of the adjustment deficit, and the water consumption of fine sand cover > transparent mulch cover > black mulch cover. (3) The water consumption and water intensity of onions decreased with the increase of the regulation deficit, and the water consumption of fine sand mulch was more than that of transparent mulch and black mulch.

1. Introduction

Minqin County, Wuwei City is located in the northeastern part of the Hexi Corridor in Gansu Province, and is known as "the place where people live beyond the Great Wall, and the first of all summer". The climate is typical of temperate continental arid climate, with little precipitation (annual precipitation is about 127.7 mm). In addition, the area is rich in light resources and has long sunshine hours, with up to 3073.5 h of sunshine throughout the year, which is very favorable to the growth and development of crops. In 2018, Minqin County will allocate sufficient water resources, and at the same time adhere to an efficient water conservation mechanism based on the scale of water, industry and structure, and vigorously develop efficient water-saving agriculture. In 2018, with the adjustment of Minqin County's rural industrial structure, the onion industry played an important role in the county's poverty alleviation process. A pivotal role. At present, the relationship between crop water preferences and soil water content in field production practice is not clear, so water cannot be fully utilized by crops, and the quantitative farm management indexes have not been systematically formed, resulting in water waste is still serious. The drip irrigation control loss set precision, uniform irrigation in one, greatly improve the crop growth water environment, so that crop water demand fertility period and water supply period coincide, to make up for the lack of water supply leading to crop yield, quality reduction
defects, to avoid the adverse effects of too much water on the crop anaerobic fertility period. Therefore, drip irrigation can provide sufficient water supply in the water-loving fertility stage and moderate water deficit in the water-averse fertility stage, which greatly improves soil moisture content and promotes good crop growth and development. Yang, H.Y. et al [1] used sub-membrane drip irrigation to analyze the soil moisture environment of field sunflower. The test results showed that sub-membrane drip irrigation can significantly reduce ineffective evaporation between trees and improve the soil moisture environment more than conventional border irrigation, and at the same time has a good effect on moisture conservation, stable changes in soil moisture, low water consumption and daily water intensity throughout the reproductive period of the crop, significantly improving water utilization. Sheng, X.J. et al[2] compared the effects of different amounts of drip irrigation on the soil water environment, and showed that submembrane drip irrigation has a better effect of maintaining the soil water environment. When the amount of drip irrigation is large, the crop yield increase effect is not significant and water waste, and the water utilization efficiency decreases significantly with the increase of drip irrigation, while when the amount of drip irrigation is small, the crop yield is severely reduced, which is not conducive to crop biomass accumulation, and the water utilization efficiency is still low. Therefore, when using sub-membrane drip irrigation, the appropriate amount of irrigation can not only maintain the water environment for crop growth, but also achieve higher yields and improve water use efficiency.

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 Experiment 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 |
|------------|----------|----------|-----------|-----------|-----------|-----------|-------------|-------------|
| T1         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 5300        |
| T2         | 900      | 425      | 425       | 450       | 450       | 450       | 450         | 4000        |
| T3         | 900      | 350      | 350       | 380       | 380       | 380       | 380         | 3500        |
| T4         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 5300        |
| T5         | 900      | 600      | 550       | 650       | 650       | 650       | 650         | 5300        |

2.3. Measurement indicators and methods

2.3.1 Soil water content. The soil was drilled before sowing, after harvesting, and during each fertility period. Before and after irrigation and precipitation, the sampling depth is 0-60 cm, each 20cm is a layer. After sampling, it is put into the aluminum box to weigh the fresh soil, and then it is placed in the oven preheated to 110 °C and dried to constant weight and weighed to calculate the weight and moisture content of soil.

2.3.2 Soil storage water content. Formula:

\[ SWS (\text{mm}) = h \times \rho \times \omega \times 10 \]

In the formula, SWS is soil water storage (mm); \( h \) is soil depth (cm); \( \rho \) is soil bulk density (g·cm\(^{-3}\)); \( \omega \) is soil water content (%).

2.3.3 Water consumption. Water Consumption (ETa): \( ETa = I + P - R - F \pm \Delta W \)

In the formula, \( I \) is the amount of irrigation (mm), \( P \) is the amount of effective precipitation (mm), \( R \) is the surface runoff (mm), \( F \) is the amount of groundwater recharge (mm), and \( \Delta W \) is the change of water storage in the soil before sowing and after harvesting. Since the test site is flat, without irrigation, and the water table depth is greater than 10m, the visible surface runoff and groundwater recharge are zero.

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 The effect of different irrigation patterns and mulching methods on soil water storage

3.1.1 Soil water storage in 0-20 cm soil layer. The soil water storage in the 0-20 cm soil layer of each treatment showed a similar trend of decreasing, increasing and decreasing over the reproductive period.
(Table 3). It can also be seen that the effect of each treatment on the soil water storage of the onion at each reproductive period was significantly different. The smallest soil water storage was found on August 1 and the largest on May 17 throughout the whole fertility period. For the three irrigation treatments, the average soil water storage volume was $T_1 > T_2 > T_3$, and the average soil water storage volume was 13.07 mm and 7.61 mm, respectively. $T_2$ and $T_3$ were 15.08% and 43.86% higher, respectively. For the three different cover treatments, there was no significant difference between the black mulch $T_1$ and transparent mulch $T_4$ in terms of soil water storage, which was due to sufficient irrigation and consistent crop water consumption at the fertility stage. The average soil water storage of $T_1$ and $T_4$ was 15.78% and 13.21% higher than that of $T_5$, and at maturity, $T_1$ and $T_4$ had 31.29% and 28.76% higher soil water storage than that of $T_5$. At the mature stage, the soil water consumption was $T_3 > T_2 > T_1 > T_4 > T_5$, and the soil water storage of each treatment decreased by 17.60, 11.52, 10.34, 10.21 and 9.45 mm, respectively, compared with that of the seedling stage.

### Table 3 Changes in 0-20cm soil water storage on different growth stages of onion (mm)

| Treatment | May 17th | June 1th | June 16th | July 1th | July 16th | August 1th | August 16th | August 31th | Average |
|-----------|----------|----------|-----------|----------|-----------|------------|-------------|-------------|---------|
| $T_1$     | 57.22a   | 44.37a   | 43.15a    | 46.74a   | 41.38a    | 38.74a     | 54.16a      | 49.30a      | 46.88a  |
| $T_2$     | 52.94b   | 38.86bc  | 33.35c    | 40.70b   | 37.94b    | 35.19bc    | 49.57b      | 42.84b      | 41.42b  |
| $T_3$     | 51.41bc  | 32.44c   | 28.76d    | 31.82c   | 31.21c    | 22.34c     | 38.25d      | 34.27d      | 33.81c  |
| $T_4$     | 56.05ab  | 43.23ab  | 42.08ab   | 45.29ab  | 40.39ab   | 38.10ab    | 53.24ab     | 48.35ab     | 45.84ab |
| $T_5$     | 49.94c   | 40.30b   | 38.10b    | 40.22bc  | 37.76bc   | 35.39b     | 44.68c      | 37.55c      | 40.49bc |

3.1.2 Soil water storage in 20-40 cm soil layer. The changes of soil water storage in 20–40 cm soil are shown in Table 4. The trends of soil water storage in the 20-40 cm soil layer of each treatment were similar as the fertility period progressed, showing a fluctuating trend of slowly decreasing - increasing - decreasing. It can also be seen that the effect of each treatment on the soil water storage of onion in each reproductive period was significantly different. The soil water storage was minimum on August 1 and maximum on May 17, which was the same time as the extreme value of 0-20 cm soil water storage. For the three irrigation treatments, the average soil water storage was smaller as the deficit level increased, namely the average soil water storage was $T_1 > T_2 > T_3$ throughout the reproductive period. $T_2$ and $T_3$ were 18.71% and 44.68% higher, respectively. The average soil water storage of $T_1$ and $T_4$ was 10.54% and 10.87% higher than that of $T_5$ respectively during the whole reproductive stage. At the mature stage, the soil water consumption of $T_1$ and $T_4$ was 21.12% and 22.29% higher than that of $T_5$, respectively. At maturity, the soil water consumption of $T_5 > T_1 > T_3 > T_4 > T_2$ was 17.13, 14.14, 13.16, 12.61, and 11.97 mm less than that of $T_5$ and $T_4$, respectively.

### Table 4 Changes in 20-40cm soil water storage on different growth stages of onion (mm)

| Treatment | May 17th | June 1th | June 16th | July 1th | July 16th | August 1th | August 16th | August 31th | Average |
|-----------|----------|----------|-----------|----------|-----------|------------|-------------|-------------|---------|
| $T_1$     | 67.01a   | 52.63a   | 49.27a    | 43.76ab  | 48.96ab   | 43.15ab    | 61.51ab     | 56.67ab     | 52.87ab |
| $T_2$     | 56.30b   | 47.43bc  | 39.78d    | 39.47bc  | 39.78e    | 34.58c     | 49.57c      | 47.74c      | 44.33c  |
| $T_3$     | 52.02c   | 38.25c   | 36.11e    | 35.80c   | 36.72d    | 31.82c     | 41.00d      | 39.17e      | 38.86d  |
| $T_4$     | 65.64ab  | 51.28ab  | 46.29b    | 45.16a   | 50.15a    | 45.20a     | 63.29a      | 57.22a      | 53.03a  |
| $T_5$     | 64.96ab  | 47.96b   | 42.38c    | 40.30b   | 45.78b    | 41.24b     | 53.24b      | 46.79bc     | 47.83b  |
3.2 Effect of Different Irrigation Patterns and Covering Methods on Water Consumption at Onion Stage

3.2.1 Phase Water Consumption and Modulus of Water Consumption. As shown in Table 5, the water consumption of onions was different between different treatments and reproductive stages. The water consumption in the seedling stage was small, ranging from 103.85 to 135.58 mm, with T1 consuming the most water, 113.83 mm, followed by T3 and T2, and T1 consuming significantly more water than T2 and T3, followed by T3 > T2 > T1, T5, T4 and T1 were the most water-consuming of the three cover treatments, followed by T5 > T4 > T1; with increasing temperature, T5 > T4 > T1 was the most water-consuming of the three cover treatments, followed by T4 and T1. The water consumption of onions increased significantly from seedling stage to leaf stage, from 164.93 to 218.75 mm, with T1 consuming the most water, 215.61 mm, followed by T2 and T3, and T1 consuming significantly more water than T2 and T3. The coefficient size is T1 > T2 > T3, T5 water consumption is the largest of the three cover treatments, followed by T1 and T4; On the bulb expansion stage, onion water consumption reached the maximum, from 264.15 to 344.43 mm, of which T1 water consumption was the highest among the three moisture treatments, 319.08 mm, followed by T3 and T2, and T1 water consumption was significantly higher than that of T2 and T3. The size of the water consumption mode coefficient is T3 > T1 > T2, T5 is the most water-consuming of the three cover treatments, followed by T4 and T1, and the size of the water consumption mode coefficient is T4 > T5 > T1; At maturity, water consumption of onions decreased significantly, making this stage the period with the lowest water consumption in the whole reproductive period, from 40.67 to 56.78 mm, with T1 consuming the most water, 56.78 mm, followed by T2 and T3, and T1 and T2 consuming significantly more water than T3. The water consumption mode coefficient size in the order of T2 > T1 > T3, T1 water consumption is the largest of the three cover treatments, followed by T4 and T5.

Table 5 Effect of different water deficit on periodical water consumption of Onion

| Treatment | Seeding stage | Leaf stage | Bulb expansion stage | Mature stage |
|-----------|---------------|------------|----------------------|--------------|
|           | WC /mm        | WM %       | WC /mm               | WM %       | WC /mm  | WM %       | WC /mm  | WM %       |
| T1        | 113.83c       | 16.14      | 215.61ab             | 30.57      | 319.08b | 45.24      | 56.78a  | 8.05       |
| T2        | 103.85de      | 17.11      | 183.79c              | 30.28      | 264.15d | 43.52      | 55.18ab | 9.09       |
| T3        | 105.33d       | 18.13      | 164.93d              | 28.39      | 270.03c | 46.48      | 40.67d  | 7.00       |
| T4        | 121.44b       | 17.25      | 199.57b              | 28.35      | 333.68ab| 47.40      | 49.27b  | 7.00       |
| T5        | 135.58a       | 18.21      | 218.75a              | 29.38      | 344.43a | 46.26      | 45.79c  | 6.15       |

Note: Water consumption is expressed by WC, water consumption model coefficient is expressed by WM.

3.2.2 Daily water consumption intensity. Different treatments had different effects on the daily water consumption intensity of onions at different reproductive stages (Table 6). During the seedling stage, due to low outside air temperature and precipitation, onion growth was slow, individuals were small, and leaf area was small, making this stage the period with the lowest daily water consumption intensity, 3.35 to 4.37 mm·d⁻¹, with T1 having the highest daily water consumption intensity of 3.67 mm·d⁻¹, followed by T3 and T2, and the daily water consumption intensity of T1 was significantly higher than that of T2 and T3, with the highest daily water consumption intensity of T5, followed by T4 and T1, where T1 had the highest daily water consumption intensity of 6.34 mm·d⁻¹, followed by T2 and T3, and T1 and T2 consuming significantly more water than T3. The water consumption intensity of T1 was significantly higher than that of
T2 and T3, with T5 having the highest daily water consumption intensity of 9.06 mm·d⁻¹, followed by T4 and T1. During maturation, the reproductive growth of onions ceased, and the daily water consumption intensity decreased significantly, from 3.13 to 4.37 mm·d⁻¹, with T1 having the highest daily water consumption intensity of 4.37 mm·d⁻¹, followed by T2 and T3. The daily water consumption intensity was significantly higher for T1 than for T3, followed by T4 and T5 among the three cover treatments.

Table 6. Effect of different water deficit on periodical water consumption intensity of Onion

| Treatment | Seedling stage | Leaf stage | Bulb expansion stage | Mature stage |
|-----------|----------------|------------|---------------------|------------|
| T1        | 3.67c          | 6.34ab     | 8.40b               | 4.37a      |
| T2        | 3.35de         | 5.41c      | 6.95cd              | 4.24ab     |
| T3        | 3.40d          | 4.85d      | 7.11c               | 3.13d      |
| T4        | 3.92b          | 5.87b      | 8.78ab              | 3.79b      |
| T5        | 4.37a          | 6.43a      | 9.06a               | 3.52c      |

4. Discussion

Soil water storage in the 0-60 cm soil layer under three different moisture treatments and three different cover treatments showed a similar trend of decreasing-rising-decreasing as the fertility period progressed, and the effect of each treatment on soil water storage in each fertility period was obviously different. The changes of soil water storage in the whole fertility period were influenced by the amount of irrigation, and the difference between black mulch and transparent mulch was smaller, significantly larger than that of fine sand mulch. For the three irrigation treatments, the average soil water storage volume was lower as the deficit level increased, i.e., the average soil water storage volume was T1 > T2 > T3, and the average soil water storage volume was 52.17 and 21.19 mm for the medium deficit treatment T3. Deng, H.L. et al[3] compared the soil moisture dynamics of different tillage layers under different deficit irrigation conditions and showed that the larger the deficit, the lower the soil water storage, which was consistent with the findings of this experiment. The average soil water storage of T1 and T4 was 13.81% and 13.05% higher than that of T5, respectively, while the average soil water storage of T1 and T4 was 13.81% and 13.05% higher than that of T5 at the whole reproductive stage. The soil water storage was 26.32% and 24.84% higher than that of T5, respectively. At the same time, it was found that the soil water storage in the post-harvest soil layer at the depth of 20-40 cm had the greatest decrease of 11.97 to 17.13 mm, which was significantly higher than that of 0-20 and 40-60 cm, indicating that most of the onion roots were distributed in the 20-40 cm soil layer. ~This indicates that most of the roots of onions are distributed in the 20-40 cm soil layer, and the source of water consumption for growth is mainly 20-40 cm, while deep soil 40-60 cm consumes less water. Zong, R. et al[4] compared the size and dynamics of soil water storage under transparent mulch and black mulch, and showed that mulching could increase soil water storage in 0-30 cm soil layer compared with open field seeding, and there was no significant difference between transparent mulch and black mulch, which was consistent with the conclusion of this experiment. Wang, H.L. et al[6] planted crops through fine sand cover in a dry area in northwest China, and showed that soil water storage in fine sand cover was greater than that in transparent mulch cover, which was different from the findings in this experiment, which might be related to the location, method and crops planted.

5. Conclusion

Soil water storage tended to decrease with the increase of the adjustment deficit, namely the water storage size was T1 > T2 > T3. The difference in soil water storage between black mulch and transparent mulch was small, which was significantly larger than that between fine sand mulch. The water consumption and water intensity of onion showed a decreasing trend with the increase of water loss, and the water consumption of fine sand cover > transparent mulch cover > black mulch cover. Onion bulb expansion stage consumed the most water, followed by leaf development and seedling stage, and the least water intensity at maturity stage.
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