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Effect of Different Irrigation Patterns and Covering Methods on Onion Yield in the Hexi Corridor

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Abstract. In order to investigate the influence of the yield and water use efficiency of onions in the Hexi Corridor, this paper tested the yield and water use efficiency 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 dry matter accumulation process of onion was measured in each reproductive period, and the results showed that: The black mulch full irrigation treatment T1 yielded 120393.45 kg·ha^{-1} with an output value of 72236.07 yuan·ha^{-1}, while the black mulch moderate loss adjustment irrigation treatment T3 yielded only 61697.39 kg·ha^{-1}and 37018.43 yuan·ha^{-1}. The yield per square meter, irrigation water use efficiency and water use efficiency decreased with the increase of regulated deficit irrigation degree, and there was no significant difference between black film mulching and transparent plastic film mulching, but they were significantly higher than that of fine sand mulching. The onion yield and water use efficiency indexes were combined, so that the best control of yield could be achieved by covering the onion with black mulch and irrigation throughout the growing season, which is of theoretical guidance and significance for onion cultivation in the Hexi Corridor.

1. Introduction

As the economic pillar of the agricultural industry in Minqin County, although the planting area of onions has decreased slightly in recent years with the adjustment of agricultural planting structure, its development rate still affects the development of the entire agricultural industry. Minqin County has long sunshine hours, abundant sunshine resources, and sufficient irrigation water resources, so it is uniquely positioned to cultivate high-quality onions. Onions produced there have high content of soluble sugar, soluble protein, vitamin C, pyruvate and onion oil, and good appearance. At present, onion planting technology in Minqin County mainly relies on sub-membrane drip irrigation for water supply, although it saves water compared with traditional irrigation methods (flood, furrow and border irrigation), the irrigation system is unreasonable, resulting in unstable yield, low economic benefits and low quality. Therefore, local farmers always insist on high water and high fertilizer to obtain high yield, thus consuming a large amount of water and fertilizer and other resources. This not only leads to low water utilization efficiency, but also to a vicious cycle of high water and fertilizer-high input-low return. Therefore, how to properly irrigate has become an urgent scientific problem for local onion cultivation.

Drip irrigation is a technology that transports irrigation water through a plastic pipe with a diameter of about 10 mm orifice or drip head directly to the roots of crops for localized irrigation in dry farming areas or in crops that require large amounts of water. Drip irrigation is currently one of the most efficient and sophisticated methods of water-saving irrigation in dryland agriculture, with a water utilization rate of up to 95%. The technology originated in Israel, where it was applied mainly for the cultivation of valuable flowers, and gradually spread to cash crops and then to the entire agricultural production due to its labor and water saving advantages and ease of control. Drip irrigation systems do not destroy the soil structure when irrigating water, evaporation losses are small, do not produce surface runoff, and have little impact on the internal cycle of water, fertilizer, air, and heat in the soil, thus creating a stable growth environment for crops. This technology is highly automated, and the soil moisture meter can monitor the water content in the growing environment of crops at any time, and start irrigation automatically when the water content reaches a critical value, making it truly efficient and water-saving irrigation. At present, drip irrigation technology is widely used in field crops such as corn[1], potato[2], and cash crops such as ginger[3] and cotton[4]. The ultimate goal of deficit irrigation is to increase crop yield. At present, many scholars have done a lot of research on the effect of deficit irrigation on crop yield. Liu H.G. et al.[5] studied the effect of drip irrigation deficit adjustment on grape yield by combining deficit adjustment irrigation and drip irrigation techniques, and the results showed that the maximum yield (829.3 kg·667m^{-2}) was achieved when the lower limit of irrigation control was 40% of the field water-holding rate at the germination and tassel stages. The results showed that the maximum yield (829.3 kg·667m^{-2}) was achieved when the water-holding rate was 40% at the budding stage and 40% at the pumping stage, while the minimum yield (699.1 kg·667m^{-2}) was achieved when the water-holding rate was 45% at the pumping stage and 50% at the flowering stage. Kou D. et al.[6] explored whether alfalfa yield was affected by using different levels of subsurface drip irrigation to adjust the deficit, and the results showed that regardless of whether the deficit was adjusted during the whole fertility period or during one fertility period, the yield of alfalfa would be reduced, and the greater the deficit, the greater the reduction. It can be seen that deficit irrigation at different fertility stages of crops has a significant impact on crop yield, but the effect of water regulation varies among crops. Therefore, it is of great significance to study in depth the water deficit status and yield response of different crops at different reproductive stages. In this paper, we comprehensively analyze the effects of different irrigation patterns and cover methods on onion yield components and yield, and clarify the optimal combination of water and cover materials in onion planting patterns in Hexi Corridor, Gansu Province, so as to provide strong technical support for the development of specialty industries and new rural construction in Northwest China's irrigation areas.

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℃, an extreme minimum temperature of -27.3℃, an average annual temperature of 8.3℃, 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 $g \cdot kg^{-1}$ of total potassium. 8.02, total salt 1.685 $g \cdot kg^{-1}$, irrigation water mineralization 0.86 $g \cdot L^{-1}$.

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 m^2 (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 Experimentl 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	Irrigation quota（$m^3 \cdot hm^{-2}$）								Irrigation quota（$m^3 \cdot hm^{-2}$）
	May 12th	May 27th	June 11th	June 26th	July 11th	July 26th	August 10th	August 25th	
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.Growth Indicator measurement method

2.3.1. Yield. After the onions matured, each plot was harvested separately and the average of three replicates was the actual yield of each treatment. At the same time, 20 plants were harvested at random from each plot for bulb diameter, number of scale layers, and fresh dry weight of bulbs and pseudostems. The average yield of each plot was calculated by weighing with an electronic scale with an accuracy of 0.01g, and converted to the standard yield $kg \cdot hm^{-2}$.

2.3.2. water use efficiency. Agricultural water consumption (ETa): ETa=I+P-R-F±ΔW. 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 ΔS is the change of water storage in the soil before sowing and after harvesting. Since the test site was flat, no irrigation, and the water table depth was >10m, the visible surface runoff and groundwater recharge were zero.

Water Utilization Efficiency (WUE): WUE=$Y \cdot ETa^{-1}$, where WUE is water utilization efficiency $kg \cdot hm^{-2} \cdot mm^{-1}$), Y is crop yield ($kg \cdot hm^{-2}$), and ETa is water consumption in the field (mm).

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 Fresh weight of bulb
The fresh weight of onion bulbs showed a continuous increasing trend with the increase of the reproductive period, and its dynamic changes are shown in Table 3. For the three irrigation treatments, the fresh weight of bulbs decreased with the increase of the deficit adjustment, i.e., the average fresh weight of bulbs during the whole reproductive period was T1＞T2＞T3, and the fresh weight of bulbs in the moderate deficit adjustment treatment T3 was significantly lower than that of T1 and T2 due to the large deficit adjustment during the whole reproductive period, with the decrease of 106.82 and 45.67 g, respectively. The fresh weight of bulbs was 42.19% and 76.74% higher in the black mulch treatment T1 and the transparent mulch treatment T4, respectively, with significant difference. At maturity, T1 and T4 bulb fresh weight was 181.97 and 127.99 g higher than T5, respectively. The maximum fresh weight of bulbs was covered by black mulch when irrigated sufficiently at maturity, and the minimum fresh weight of bulbs was covered by moderate deficit and fine sand.

Table 3. The effect of different irrigation patterns and covering methods on fresh weight of onion

Treatments	Date of determination					
	Jun. 25th	Jul. 10th	Jul. 25th	Aug. 10th	Aug. 25th	Sept. 10th
T1	36.75a	115.27a	250.92a	356.38a	430.75a	531.84a
T2	33.06b	93.50c	187.75c	319.01c	347.62b	374.04c
T3	30.33c	80.20de	137.25d	246.32de	285.97d	300.92e
T4	35.11ab	102.42b	230.59b	338.46b	414.33ab	477.86b
T5	30.15cd	83.59d	123.34e	255.04d	316.85c	349.87d

3.2 yield and water efficiency per square
The effects of different irrigation and mulching methods on onion yield, water use efficiency and water efficiency per square meter are shown in Table 4. The yields of each treatment were as follows: black mulch full irrigation treatment T1 (120393.45 kg·ha^{-1}) was the largest, followed by transparent mulch full irrigation treatment T4 (116224.26 kg·ha^{-1}), and black mulch moderate deficit irrigation treatment T3 (61697.39 kg·ha^{-1}) was the smallest, with T1 yielding more than T2, T3 and T4, respectively. T3, T4, and T5 increased by 35.21%, 95.14%, 3.59%, and 80.47%, respectively. The production value of each treatment was the largest for black mulch full irrigation treatment T1 at 72236.07 yuan·ha^{-1}, followed by transparent mulch full irrigation treatment T4 at 69734.56 yuan·ha^{-1}, and the smallest for black mulch moderate loss adjustment irrigation treatment T3 at 37018.43 yuan·ha^{-1}, which was higher than that of T1, T2, T4 and T4 respectively. and T5 decreased by 48.75%, 30.71%, 46.92%, and 7.52%, respectively. The irrigation volume of each treatment was the largest for the fine sand cover full irrigation treatment T5 (5329.8 m^3·ha^{-1}), followed by the transparent mulch cover full irrigation treatment T4 (5314.3 m^3·ha^{-1}), and the smallest for the black mulch cover moderate deficit irrigation treatment T3 (3499.5 m^3·ha^{-1}), which was lower than that of T1, T2, T3 and T5, respectively. The production value of each treatment is represented by the black mulch full irrigation treatment T1, which is the largest, amounting to 13.63 yuan·m^{-3}, followed by the black mulch light deficit irrigation treatment T2, which is 13.36 yuan·m^{-3}, and the fine sand full irrigation

treatment T5, which is the smallest, amounting to only 7.51 yuan·m^{-3}. T1 increased by 2.06%, 28.86%, 3.88% and 81.49% compared with T2, T3, T4 and T5, respectively. The irrigation water utilization efficiency of each treatment was the highest for black mulch full irrigation treatment T1 (22.72 kg·m^{-3}), followed by black mulch light deficit irrigation treatment T2 (22.26 kg·m^{-3}) and the smallest for fine sand full irrigation treatment T5 (12.52 kg·m^{-3}). Reduce 10.20, 9.74, 5.11, 9.35 kg·m^{-3}. The water utilization efficiency of each treatment was the highest for black mulch full irrigation treatment T1 (up to 17.07 kg·m^{-3}), followed by transparent mulch full irrigation treatment T4 (16.51 kg·m^{-3}) and the smallest for fine sand full irrigation treatment T5 (8.96 kg·m^{-3}), with T1 water utilization efficiency increasing compared to T2, T3, T4 and T5, respectively. 16.32%, 60.75%, 3.39% and 90.50%. Overall, onion yield, value of production, value of water per unit, irrigation water use efficiency, and water use efficiency all decreased with increasing loss adjustment, and the difference between black mulch and transparent mulch was not significant, but significantly greater than the fine sand mulch treatment.

Table 4. The effect of different irrigation patterns and covering methods on yield and water efficiency per square of onion

Treatments	Yield (kg·ha^{-1})	Output value (yuan·ha^{-1})	Irrigation amount (m^3·ha^{-1})	Unit yield value (yuan·m^3)	Irrigation water use efficiency (kg·m^{-3})	Water use efficiency (kg·m^{-3})
T1	120393.45a	72236.07a	5299.1ab	13.63a	22.72a	17.07a
T2	89044.51b	53426.71b	4000.6b	13.36ab	22.26ab	14.67b
T3	61697.39d	37018.43d	3499.5c	10.58b	17.63b	10.62c
T4	116224.26ab	69734.56ab	5314.3ab	13.12ab	21.87ab	16.51ab
T5	66711.60c	40026.96c	5329.8a	7.51c	12.52c	8.96d

4. Discussion

The fresh weight of the bulb and the fresh weight on the ground tended to decrease with the increase of the deficit, and the fresh weight of the bulb was significantly lower in the medium deficit treatment T3 than in T1 and T2 due to the larger deficit of the whole fertility, and there was no significant difference between the fresh weight on the ground in the black mulch treatment T1 and the fresh weight on the ground in the transparent mulch treatment T4, while the fresh weight on the ground in the fine sand mulch treatment T5 was significantly lower than that in T1 and T4. The study showed that water deficit caused crop growth to be slow, plant height and total dry matter were significantly reduced, and the decline was greater as the magnitude of water deficit increased, while changes in crop stem thickness showed an increase and then decrease as the magnitude of water deficit increased, crop stem thickness increased under mild water deficit, but decreased significantly as the degree of water deficit increased. Xu F.X. et al.[7] found that black mulch can significantly improve crop leaf number, plant height and above-ground dry matter compared with white mulch, which is consistent with the results of the present study. However, it has also been shown that white mulch is more beneficial to crop growth and biomass accumulation than black mulch, which is related to the climate type, geographical characteristics and crop preferences of the test site.

The output of each treatment was as follows: black mulch full irrigation treatment T1 (120393.45 kg·ha^{-1}), followed by clear mulch full irrigation treatment T4 (116224.26 kg·ha^{-1}), and black mulch medium loss irrigation treatment T3 (61697.39 kg·ha^{-1}). Zhang X.X. et al.[8] showed that deficit irrigation reduced crop yield compared with full irrigation, and the reduction tended to decrease as the degree of deficit increased, which was consistent with the results of this experiment. Lei J. et al.[9]

showed that black mulching could increase crop yield and hence value of production compared to white mulching. In this experiment, black mulch with full irrigation increased the yield compared with white mulch with full irrigation, which is consistent with the results of the former study.

5. Conclusion

Black mulch was fully irrigated with maximum fresh weight bulb, while black mulch was fully irrigated with moderate deficit and fine sand cover with the minimum deficit, both moderate deficit and fine sand cover were unfavorable for accumulation of fresh weight bulb. The black mulch full irrigation treatment T1 yielded 120393.45 kg·ha^{-1} with an output value of 72236.07 yuan·ha^{-1}, while the black mulch moderate loss adjustment irrigation treatment T3 yielded only 61697.39 kg·ha^{-1}and 37018.43 yuan·ha^{-1} with the lowest output value. T2, T3, T4, and T5 increased by 35.21%, 95.14%, 3.59%, and 80.47%. The black mulch full irrigation treatment T1 has the highest irrigation water use efficiency, water use efficiency and unit water production value of 22.72, 17.07 kg·m^{-3} and 13.63 yuan·m^{-3}, while fine sand full irrigation treatment T5 has the lowest irrigation water use efficiency of 12.52, 8.96 kg·m^{-3} and 7.51 yuan·m^{-3}, T1 is more efficient than T2, T3, T4 and T5. The irrigation water use efficiency increased by 2.07%, 28.87%, 3.89% and 81.51%, and the water use efficiency increased by 16.32%, 60.75%, 3.39% and 90.50%, respectively, and the unilateral water production value increased by 2.06%, 28.86%, 3.88% and 81.49%, respectively. Water production value, irrigation water use efficiency, and water use efficiency all decreased with the increase of the deficit adjustment, and the difference between the black mulch and transparent mulch was small, but greater than that of the fine sand mulch. The onion yield indexes were combined, so that the best control of yield could be achieved by covering the onion with black mulch and irrigation throughout the growing season, which is of theoretical guidance and significance for onion cultivation in the Hexi Corridor.

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