Effects of different irrigation quotas on growth characteristics and yield of seed maize in Hexi Corridor

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Abstract. In order to find out the optimal scheme of irrigation quota for seed corn in Zhangye, field experiments were carried out to study the effects of different irrigation quotas on the growth and yield of seed corn. Seed corn was used as test crop, drip irrigation under plastic film was used as water supply mode different irrigation quota treatment T1(4200m³/ha), T2(4650m³/ha), T3(5250m³/ha), T4(5400m³/ha), CK(5850m³/ha) were set up. The results showed that the plant height of T2 was the highest, reaching 154.6 cm, and the ear height of T4 was the highest, reaching 74.8 cm. There was a significant difference in the double ear rate among different treatments, among which the double ear rate of T4 was the highest, reaching 19.12%, followed by T3(17.86%) and CK(15.12%), and the double ear rate of T1 was the lowest, reaching 12.98%. The empty stalk rate of T2 was the largest(7.72%), followed by T3 and T4, and the empty stalk rate of T5 was the smallest. The ear of T3 was the longest(14.74 cm), and the invalid ear length of T4 was the largest(1.64 cm). The grain number per ear of T4 was the largest, followed by T2, CK and T3, and CK was the smallest. Compared with T2 and T3, T4 increased by 0.23% and 4.32%(P>0.05), respectively, and significantly increased by 16.56% compared with T1. Different treatments have different responses to the yield of seed production. Among them, the T4 treatment has the largest yield, reaching 6655.8 kg/ha, followed by T2 and T3, which are 5853.6 and 5661.9 kg/ha, respectively. The T1 yield is the smallest, only 5362.2 kg/ha, T4, T2 increased by 24.12% and 9.15% respectively compared with CK, significant difference. Comprehensive consideration of agronomic traits, ear economic traits, crop yield and yield increase rate and other indicators show that the optimal irrigation quota for corn planting areas in the Hexi Corridor is 5400m³/ha. The irrigation quotas for each growth period are 825 m³/ha at the jointing stage, 825 m³/ha at the big bell mouth stage, 975 m³/ha at the tasseling stage, 975 m³/ha at the flowering stage, 975 m³/ha at the filling stage, and 825 m³ at the milking stage/ha. This research can provide theoretical and technical reference for realizing high-efficiency water-saving cultivation and industrialization development of maize seed production in the oasis irrigation area of the Hexi Corridor.
1. Introduction
Gansu Hexi inland irrigation area is a typical irrigation agricultural area, with flat terrain, sufficient sunshine, large temperature difference between day and night, dry and windy climate. At present, seed production bases in Hexi Corridor have been formed with Wuwei City and Zhangye City as the leading cities[1]. The climate of Hexi Corridor is continental arid climate, and the development of agricultural climate conditions are superior. The problem of water waste in traditional flood irrigation is prominent, and the output efficiency is low. Therefore, it is urgent to develop and introduce new water-saving irrigation technology to realize the efficient utilization of limited water resources and the long-term development of agriculture[2]. Submulched drip irrigation technology is an efficient water-saving and yield-increasing irrigation technology proved by production practice in recent years, and has been widely promoted in maize[3], Isatis indigotica[4], onion[5] and other crops in irrigation areas, and has achieved good yield-increasing and water-saving effects. At present, many scholars mainly study the effect of different mulching cultivation methods on soil water and heat effect and crop yield[6], as well as the exploration of improving water use efficiency[7-11], and the research on maize seed production under drip irrigation in Hexi irrigation area is less[12-13]. In this study, seed maize was taken as the research object. The effects of five different irrigation quotas on plant height, leaf number per plant, leaf area per plant, ear length, ear diameter, row number per ear, grain number per row, single ear weight, single ear grain weight, bald tip length, and seed yield of seed maize were studied under drip irrigation. The effects of different irrigation quotas on the growth and yield of seed maize were explored, and the mechanism of yield increase and efficient water use under different irrigation quotas was revealed. The optimal irrigation system suitable for seed maize in Hexi irrigation area was explored, and the problems such as the mismatch between irrigation period and water requirement of crops, high quotas, and waste of water resources in conventional irrigation were solved, which provided theoretical support and technical guidance for the sustainable development of seed maize industry in Hexi Corridor oasis irrigation area.

2. Materials and Methods

2.1. Overview of the test area
The test field is located in Tianjiazha Village, Dangzhai Town, Ganzhou District, Zhangye City, Gansu Province. It is located at (100°6′-100°52′E, 38°32′-39°24′N), with an altitude of 1474 m, and the area is in a temperate zone. In the continental climate zone, the annual average temperature is 7.25℃, July is the hottest, the monthly average temperature is 23.9℃, the lowest temperature in January is -10.1℃, and the annual average precipitation is 97.6 mm. In 2018, the rainfall was 118.2 mm and the evaporation was 1898.5 mm. In 2019, the rainfall was 207.5 mm and the evaporation was 1736.9 mm. The rainfall, temperature and evaporation conditions during the experiment are shown in Figure.1. The soil type in the test area is sandy loam soil with flat terrain. The basic physical and chemical properties of the 0-30 cm soil layer in the test area are shown in Table 1.
Figure 1. Rainfall, average Temperature and Evaporation during crop growth

Table 1. Soil analysis results of the experimental demonstration site

| Project                  | pH Value | Organic Matter (g/kg) | Alkali-hydrolyzable nitrogen (mg/kg) | Available phosphorus (mg/kg) | Rapidly available potassium (mg/kg) |
|--------------------------|----------|-----------------------|--------------------------------------|-----------------------------|------------------------------------|
| Determination before test | 8.33     | 42.31                 | 42.35                                | 4.45                        | 118.59                             |

2.2. Test material
Test crops: seed corn, variety NC242.
The tested fertilizers were applied with 300 kg/ha Bottom Application of Diammonium Phosphate, 75 kg/ha Urea and 120 kg/ha K$_2$SO$_4$.
Top dressing: Urea 600kg/ha.
2.3. Experimental design

The experiment was carried out by plot experiment and random block arrangement. Area 35(7m×5m) 10-row district, row length 7m, inter-district ditch width 1m, between each district trench membrane isolation, depth 0.6m, each district around the ridge, ridge height 40cm, width 50cm, avoid water and fertilizer. A total of five treatments were set up for different irrigation quota T1:4200m$^3$/ha, T2:4650m$^3$/ha, T3:5250m$^3$/ha, T4:5400m$^3$/ha, CK:5850m$^3$/ha repeated. Base fertilizer combined with pre-sowing soil preparation for one-time application test using plastic film mulching row ratio planting (1:5), irrigation method using drip irrigation under film.

2.4. Irrigation and fertilization management

Plow the ground and fertilize around April 5, 2019, all the base fertilizers are artificially spread; on April 8, press the soil, mulch, and lay the drip irrigation tape on the ground; plant the female parent on April 17; plant the father for the first time on April 26 This was planted for the second time on the 30th. The single-row male parent was planted by row ratio(1:5), planted in stages, and the harvest date was September 25. The row spacing of seed production corn is 0.45m, the plant spacing is 0.2m, each plot is laid with 7 membranes, and each membrane is planted with 2 rows. All treatments are consistent with the conventional fertilization level of local farmers. The irrigation scheme is shown in Table 2.

Table 2. Experimental design scheme of irrigation system for different growth stages of maize seed production (m$^3$/ha)

| Treatment | Seedling stage | Jointing stage | Big flare period | Tasseling period | Blooming stage | Pustulation period | Milk stage | Irrigation requirement |
|-----------|----------------|----------------|------------------|------------------|----------------|-------------------|------------|-----------------------|
| T1        | 0              | 600            | 675              | 720              | 750            | 750               | 675        | 4200                  |
| T2        | 0              | 670            | 750              | 810              | 870            | 810               | 740        | 4650                  |
| T3        | 0              | 750            | 825              | 975              | 975            | 975               | 825        | 5250                  |
| T4        | 0              | 825            | 825              | 975              | 975            | 975               | 825        | 5400                  |
| CK        | 0              | 750            | 975              | 1125             | 1050           | 975               | 900        | 5850                  |

2.5. Determination items and methods

2.5.1. Determination of agronomic traits of plants. The plant height, leaf number per plant, leaf area per plant (length-width measurement method$^{[14]}$), leaf area index (LAI), dry and fresh weight of aboveground part, dry and fresh weight of underground part were measured at different growth stages of maize. The ear height was measured by using a coil ruler with a minimum scale of 1 mm to determine the height from the bottom of the first internode to the top of the plant and the height from the bottom of the first internode to the ear node.

2.5.2. Determination of soil physical and chemical properties. Before the experiment and corn harvest period, 0-20cm soil layer was taken to determine soil chemical properties, in which soil pH was measured by acidity meter method. Organic matter using potassium dichromate method. Total nitrogen was determined by semi-micro Kjeldahl method-flow injection instrument, total phosphorus was determined by NaOH melting-molybdenum antimony anti-color-ultraviolet spectrophotometry, total potassium was determined by NaOH melting-atomic absorption method. Alkaline hydrolysis diffusion method was used for alkaline hydrolysis nitrogen; Quick-acting phosphorus was determined by extraction-molybdenum antimony colorimetric method. The available potassium was determined by neutral extraction-flame photometric method. The electrical conductivity of the extracted solution was determined by conductivity meter, and then the total salt content of soil was converted. The content of soil extract was determined by AAS Zeenit700 atomic absorption spectrometer.
2.5.3. Determination of maize yield and economic traits. Each plot randomly was selected 20 female parent ear, it was harvested, indoor determination of ear length, ear diameter, ear row number, ear grain number, row grain number, single ear weight, single ear grain weight, bald tip length, seed yield, 1000-grain weight and other economic traits; At the end of wax ripe stage, the middle 2-film (4 rows) female parent ear was harvested, and the plant height was measured. The plants were cut apart, killed at 105°C for 30 min, and then dried at 75°C to constant weight to determine straw biomass. Four rows in the middle of each plot were selected for field yield measurement,threshing after natural drying, calculating the yield per plant, and finally converting the yield per unit area.

2.6. Data analysis method
Using EXCEL 2010 software for data processing, SPSS 25 was used for data analysis.

3. Results and Analysis

3.1 Analysis of agronomic traits of plants under different treatments
It can be seen from Table 3 that the responses of maize agronomic traits to different treatments were different. The plant height of T2 was the highest(154.6cm), which was 2.11% and 2.38% higher than that of T1 and T3, respectively (P>0.05), and 15.12% higher than that of CK, respectively (P<0.05). The ear height of T4 was the highest(74.8cm), followed by that of T3, T1, T2 and CK(67~69.5cm). The ear height of T4 was 7.78% higher than that of T1 (P<0.05). The stem diameter varied from 1.97 cm to 2.22 cm in each treatment, and there was no significant difference. There was significant difference in double panicle rate among different treatments. The double panicle rate of T4 was the highest(19.12%), followed by T3 and CK. The double panicle rate of T1 was the lowest(12.98%), and the double panicle rate of T4 was 47.41% and 35.03% higher than that of CK and T2, respectively (P<0.05). The empty stalk rate of T2 was the highest, reaching 7.72%, followed by T3 and T4. The empty stalk rate of CK was the lowest, only 4.06%. The empty stalk rate of T2 was 70.69% and 77.83% higher than that of T1 and CK, respectively, and the difference was significant (P<0.05).

Table 3. Effects of different treatments on agronomic traits of corn plants

| Treatment | Plant acid height (cm) | Ear height (cm) | Stem thick (cm) | Double spike rate (%) | Empty rod rate (%) |
|-----------|------------------------|-----------------|-----------------|-----------------------|-------------------|
| T1        | 151.4ab                | 69.4ab          | 2.22a           | 12.98a                | 4.23b             |
| T2        | 154.6a                 | 68.8ab          | 2.06ab          | 14.16b                | 7.22e             |
| T3        | 151ab                  | 69.5a           | 2.00ab          | 17.86d                | 6.42d             |
| T4        | 145.3abc               | 74.8a           | 1.97b           | 19.12e                | 6.06c             |
| CK        | 134.3c                 | 67.00b          | 1.97b           | 15.12c                | 4.06a             |

Note: Different lowercase letters in the same column indicate significant differences at P<0.05, the same below.

3.2 Analysis of economic traits of maize ear under different treatments
It can be seen from Table 4 that the economic shape of maize ear has different responses to different treatments. The ear of T3 treatment was the longest, reaching 14.74cm, which was 2.06%, 6.81% and 3.29% higher than that of T1, T2 and T4, respectively (P>0.05). The ear diameter of each treatment ranged from 3.26cm to 3.98cm, with no significant difference (P>0.05). The invalid panicle length of T4 treatment was the largest, up to 1.64 cm, followed by CK, T4 and T2, and that of T1 treatment was the smallest, only 1.01 cm, which was significantly reduced by 37.22%, 38.41% and 38.03% compared...
with CK, T4 and T2 (P<0.05). There was no significant difference in the number of grains per row between T2, T3 and CK, but the number of grains per row of T4 and T3 increased by 14.63% and 12.68% respectively compared with CK(P<0.05). The grain number per spike of T4 treatment was the highest, followed by T2, CK and T3, and T1 treatment was the lowest. Compared with T2 and T3 treatment, T4 treatment increased 0.23% and 4.32%(P<0.05), respectively, and 16.56 % (P<0.05), respectively.

### Table 4. Effects of different treatments on economic traits of corn ears

| Treatment | Panicle length (cm) | Ear diameter (cm) | Bare tip (cm) | Kernel number per row | Grain number |
|-----------|---------------------|-------------------|---------------|-----------------------|--------------|
| T1        | 13.99ab             | 3.89ab            | 1.01d         | 20.5c                 | 243.95c      |
| T2        | 13.8ab              | 3.90ab            | 1.63ab        | 22.9ab                | 283.96ab     |
| T3        | 14.74a              | 3.78ab            | 1.29c         | 23.1ab                | 272.58abc    |
| T4        | 14.27ab             | 3.98a             | 1.64ab        | 23.5a                 | 284.35a      |
| CK        | 13.89ab             | 3.26c             | 1.68a         | 22.9ab                | 283.96ab     |

### 3.3 The impact of different treatments on crop yield and yield increase rate

The different irrigation times have different responses to seed production corn yield. Among them, T4 treatment has the largest yield, reaching 6655.8kg/ha, followed by T2 and T3, which are 5853.6 and 5661.9kg/ha, respectively. CK yield is the smallest. It was only 5362.2kg/ha, T4 and T2 were increased by 24.12% and 9.15%, respectively, compared with CK, with a significant difference (P<0.05). T1 was increased by 1.06% compared with CK, with no significant difference (P<0.05). It can be confirmed that treatment 4 and treatment 2 reflect the best test results.

### 3.4 Grey correlation analysis

Comprehensive evaluation and analysis of test treatments are carried out, and the optimal treatment is expected to be selected. Initialize the indicators first.

### Table 5. Standardization of different processing corn

| Treatment | Plant acid height (cm) | Ear height (cm) | Stem thick (cm) | Double spike rate (%) | Empty rod rate (%) | Panicle length (cm) | Ear diameter (cm) | Bare tip (cm) | Kernel number per row | Grain number |
|-----------|------------------------|----------------|-----------------|-----------------------|--------------------|---------------------|------------------|---------------|----------------------|--------------|
| T1        | 0.98                   | 0.93           | 1.00            | 0.68                  | 0.59               | 0.95                | 0.98             | 0.60          | 0.87                 | 0.86         |
| T2        | 1.00                   | 0.92           | 0.93            | 0.74                  | 1.00               | 0.94                | 0.98             | 0.97          | 0.97                 | 1.00         |
| T3        | 0.98                   | 0.93           | 0.90            | 0.93                  | 0.89               | 1.00                | 0.95             | 0.77          | 0.98                 | 0.96         |
| T4        | 0.94                   | 1.00           | 0.89            | 1.00                  | 0.84               | 0.97                | 1.00             | 0.98          | 1.00                 | 1.00         |
| CK        | 0.87                   | 0.90           | 0.89            | 0.79                  | 0.56               | 0.94                | 0.82             | 1.00          | 0.97                 | 1.00         |

Calculate the absolute value of k(ij) for each point Δ(k) = |xo(k) − xi(k)|

### Table 6. Standard deviation of different treatment corn

| Treatment | Plant acid height (cm) | Ear height (cm) | Stem thick (cm) | Double spike rate (%) | Empty rod rate (%) | Panicle length (cm) | Ear diameter (cm) | Bare tip (cm) | Kernel number per row | Grain number |
|-----------|------------------------|----------------|-----------------|-----------------------|--------------------|---------------------|------------------|---------------|----------------------|--------------|
| T1        | 0.02                   | 0.07           | 0.00            | 0.32                  | 0.41               | 0.05                | 0.02             | 0.4          | 0.13                 | 0.14         |
| T2        | 0.00                   | 0.08           | 0.07            | 0.26                  | 0.00               | 0.06                | 0.02             | 0.03         | 0.03                 | 0.00         |
| T3        | 0.02                   | 0.07           | 0.10            | 0.07                  | 0.11               | 0.00                | 0.05             | 0.23         | 0.02                 | 0.04         |
| T4        | 0.06                   | 0.00           | 0.11            | 0.00                  | 0.16               | 0.03                | 0.00             | 0.02         | 0.00                 | 0.00         |
| CK        | 0.13                   | 0.10           | 0.11            | 0.21                  | 0.44               | 0.06                | 0.18             | 0.00         | 0.03                 | 0.00         |
Using the formula $\sum_{i} (k) = \left( a + bp \right) \left[ \Delta i (k) + bp \right]$ Calculation of correlation coefficient, in which, 
\[ a = \min, \min \left| x_c (k) - x_i (k) \right| \] \[ b = \max, \max \left| x_0 (k) - x_i (k) \right| \] is 0.44, $\rho$ is the resolution coefficient, which is 0.5.

Using the formula $r_1 = \sqrt{\frac{1}{n} \sum_{nk} \frac{r}{r_k}}$ Calculation of Equal Weight Correlation Degree and Weight Coefficient of Each Index $w_i, w_i = r_1 / \sum r_k$. After the analysis of T4 treatment for the optimal treatment.

Table 7. Comprehensive score of different treatment corn

| Treatment | Plant acid height | Ear height | Stem thick | Double spike rate | Empty rod rate | Panicle length | Ear diameter | Bare tip | Kernel number per row | Grain number | associated value | Sort |
|-----------|------------------|------------|------------|-------------------|----------------|----------------|--------------|----------|-----------------------|--------------|------------------|------|
| T1        | 0.91             | 0.75       | 1.00       | 0.41              | 0.35           | 0.81           | 0.91         | 0.35     | 0.63                  | 0.61         | 0.67             | 5    |
| T2        | 1.00             | 0.73       | 0.75       | 0.46              | 1.00           | 0.77           | 0.92         | 0.88     | 0.90                  | 0.99         | 0.84             | 2    |
| T3        | 0.90             | 0.76       | 0.69       | 0.77              | 0.66           | 1.00           | 0.81         | 0.49     | 0.93                  | 0.84         | 0.78             | 3    |
| T4        | 0.78             | 1.00       | 0.66       | 1.00              | 0.58           | 0.87           | 1.00         | 0.90     | 1.00                  | 1.00         | 0.88             | 1    |
| CK        | 0.62             | 0.68       | 0.66       | 0.51              | 0.33           | 0.79           | 0.55         | 1.00     | 0.90                  | 0.99         | 0.70             | 4    |

4. Discussion
Crop yield is closely related to the dry matter accumulation process. Irrigation period and irrigation amount will affect the dry matter accumulation and then affect crop yield. Studies have shown that under the condition of water shortage, conventional varieties in irrigation period obtain more water from upper soil than drought-tolerant varieties, and obtain less water from deep soil than drought-tolerant varieties, indicating that drought-tolerant varieties can obtain more water from deep soil under the condition of water shortage. Since the deep soil environment is relatively stable and less affected by external environmental changes, drought-tolerant varieties can effectively utilize the water in deep soil, reduce the adverse effects of drought to a certain extent, and ensure the water supply for plant growth[15]. Crop yield is the result of various life activities carried out in the close relationship between crops and environmental conditions, which is physiologically determined by the three basic processes of photosynthesis, respiration and material distribution. Crop yield formation is a complex physiological process, so from the whole process of crop growth to analyze the yield formation process. The accumulation of dry matter is closely and positively correlated with crop yield. The accumulation of dry matter in plants is the basis of crop yield formation, and its accumulation and transportation process directly affect the yield formation. The water demand of maize is different at different stages of growth period. This study found that high irrigation amount in the early stage of maize development will cause maize to grow excessively, and also affect the root system of maize, which is easy to fall in the late stage, and ultimately leads to reduced yield[16].

Irrigation system according to the law of water demand in each growth period of crops, the implementation of different degrees of irrigation quota adjustment, resulting in changes in crop growth, and thus achieve the purpose of stable yield, water saving, quality control[17], Li Zhenpu et al[18-19], confirmed that drip irrigation under mulch changed soil moisture content in farmland, and then affected crop growth, but the extent of influence was related to crop species, irrigation quota, irrigation period and experimental environment. Irrigation quota of drip irrigation under mulch has a significant impact on seed production growth. High water and high fertilizer can improve ear length, ear diameter and ear row number, reduce bald tip. The ear height of T4 treatment was the highest, reaching 74.8cm, followed by that of T3, T1, T2 and CK, and there was no significant difference in ear height. In this study, it was found that the plant height, ear height, double ear rate and empty stem rate of maize seed production by drip irrigation under mulch were affected by irrigation amount, which showed a trend of first increase and then decrease, and the influence of irrigation at late growth stage was significantly
greater than that at early growth stage. The empty stem rate of T2 treatment was the highest, and the grain number per spike of T4 treatment was the largest, which was due to the weak root system at the seedling stage and the low water requirement. The irrigation amount had little effect on the growth of seed maize, while the seed maize at the late growth stage was in the key period of vegetative propagation, and the water requirement was large. The large irrigation amount would promote the normal growth and development of maize, which was conducive to the formation of maize spike. The water content in the cell increases the respiration rate in a certain range, and then it is basically stable. When the external water is too much, it will make the oxygen supply insufficient, the aerobic respiration rate slow down, inhibit its normal growth and development, and is not conducive to the formation of spikes.

The plant height of maize changed dynamically with time. The maize was treated with water deficit at different growth stages, and the growth of maize showed obvious compensation effect after irrigation. In the study, the plant height of T2 with appropriate water deficit at jointing stage and large bell mouth was the highest, reaching 154.6cm, which was 2.11% and 2.38% higher than that of T1 and T3, respectively, and 15.12% higher than that of CK. The plant height of maize treated with water deficit at jointing–booting stage was the fastest, which was significantly higher than that of other water deficit treatments at other growth stages. The plant height of maize treated with water deficit at booting–filling stage was significantly lower than that of other treatments, and the plant height of maize treated with water deficit after rewatering was not significantly increased[19]. The same degree of water deficit occurred in different growth stages of maize, which had different effects on maize yield. The yield of T4 treatment was the highest, and the sensitivity of maize yield to water deficit in different growth stages. Appropriate water shortage treatment of maize at jointing stage can significantly improve the utilization rate of irrigation water, and maize can improve the yield traits instead of reducing yield. Grain filling stage is the key period of maize yield formation, should be sufficient water supply, maintain yield stability[19].

5. Conclusion
Irrigation quota has a significant effect on the growth and yield of seed corn, timely and appropriate irrigation has a positive effect on improving crop yield and composition factors. The results of this experiment showed that the optimal irrigation quota of seed maize planting area in Hexi Corridor was 5400 m³/ha, and the irrigation quotas of each growth period were 825 m³/ha in jointing stage, 825 m³/ha in big trumpet stage, 975 m³/ha in tasseling stage, 975 m³/ha in flowering stage, 975 m³/ha in filling stage and 825 m³/ha in milk stage. The conclusions of this study play an important role in realizing the sustainable development of seed maize production in Hexi Corridor, stabilizing production and increasing yield, tapping the regional production potential of maize and ensuring food security.

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