The Influences of Different Irrigation Water on Spatial Distribution of Cotton Bolls and Yields

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Abstract. Taking the jujube orchard intercropping cotton as experimental material in southern Xinjiang to study the influences of different irrigation water on spatial distribution of cotton bolls and yields. Setting the moderate water stress W1 (250 m3/667m2), mild water stress W2(300 m3/667m2), the appropriate moisture W3(350 m3/667m2), the sufficient water supply W4(400 m3/667m2), in total four different irrigation water processing. The results show that: (1) The cotton boll’ shedding rate in different water processing in order W4 > W1 > W3 > W2, the shedding rate of upper and lower is much higher than the middle fruit spur.(2) The effective boll of cotton are mainly in the middle part. (3) The total boll weight of cotton middle fruit spur greater than the total boll weight of fruit spur in the upper and lower. And the lower part’ weight is slightly higher than the upper.(4) The boll weight of upper fruit spur have bigger fluctuations than the lower, each part of the cotton boll weight as W2 > W3 > W4 > W1. (5) Four water treatment have a little effect on lint percent, seed cotton and ginned cotton showed the same trend as W2 > W3 > W4 > W1. Comprehensive consideration in many aspects, the drop irrigation amount 300-350m3/667m2 could as the reference standard of this locality jujube orchard intercropping.

Keywords: Jujube cotton intercropping, Irrigation water, Shedding rate, Spatial distribution, Production

1. Introduction
The Tarim area, which is rich in light and heat resources and has a unique climate type, is one of the best producing areas of red dates in China. The area is located in the southern part of Xinjiang and is a typical continental extreme arid desert climate. The annual average rainfall is less than 50mm, the annual average evaporation is 2110.5mm, the annual frost-free period is about 200d, the annual average radiation is 9733MJ/m2, the annual sunshine hours are 2650-3100 hours, and the accumulated temperature of ≥10°C is 3800-4700°C. These have created unique natural conditions for the production of high-quality commercial cotton in China. In recent years, in order to promote the rapid development of Xinjiang’s forest fruit industry, at the same time, it is necessary to make the existing cotton and grain planting area and output unaffected. The Xinjiang Production and Construction Corps promoted the three-dimensional cultivation of fruit cotton intercropping, fruit and food intercropping. Under the premise of not affecting the normal growth of young trees within a certain period of time, the yield of intercropped crops can be increased, and the production efficiency is greatly increased [1].
There have been a lot of researches on the intercropping. Zhang Jianxiong et al. [2] showed that intercropping can not only make better use of spatial light energy. Moreover, the conditions of field light, CO2, temperature, water, fertilizer and the like can be improved to different extents, thereby achieving the purpose of improving crop photosynthetic efficiency and yield. Zhao Guanglei et al. [3] showed that the combination of forest farmers and fruit farmers can not only give play to the symbiosis, complementarity and group characteristics of forest fruits and crops, but also improve the microclimate of farmland and improve the utilization of land, light and heat and fertilizer. Studies by Jiang Wenwei et al. [4] have shown that fruit farming can increase farmers’ income. With the maturity of the three-dimensional planting mode, how to determine the most suitable irrigation amount under the condition of fruit-cotton intercropping has become an important topic in Xinjiang’s new high-yield cotton planting.

In the process of cotton growth and development, the appropriate amount of irrigation can make the cotton plant ideal, with more bells, less shedding and higher yield. Different irrigation amounts not only have a certain impact on cotton growth characteristics [5], but also have significant correlation with cotton economic output [6]. There have been a large number of studies on the amount of cotton irrigation, but most of them are cotton for single use [7-8]. The effects of different irrigation rates on the spatial distribution and yield of cotton bolls under the intercropping conditions of jujube and cotton in the Tarim Basin. Considering various impact factors comprehensively, the mode of irrigation with low water consumption, reasonable distribution of cotton, ideal plant type, relatively high yield and good quality is selected, and this provides a reference standard for the control of the crop irrigation amount of jujube cotton intercropping in southern Xinjiang, and also provides a theoretical basis for further research on high-yield cultivation techniques.

2. Materials and Methods

2.1 Experiment Materials.
In this study, crop cotton and red dates were used as research objects. When the date was broadcast, the cotton variety was Zhongmian 41.

2.2 Experiment Design.
The experiment was conducted in 2011 at the Agricultural Research Base outside the Tarim University. The jujube live broadcast garden, the planting mode is the main planting pattern of red dates in the Tarim Basin, that is, the row spacing is 3m and the plant spacing is 25cm. Plant cotton at a distance of 1m from the red dates. The row spacing configuration of cotton is the same as the current main cultivation mode of Datian, namely (66+10) cm. According to the characteristics of water demand in the whole growth period of jujube and cotton, moisture control was carried out in each growth stage of red dates and cotton. The total irrigation amount during the growth period was set to W1: moderate water stress, the irrigation amount was 250m$^3$/667m$^2$; W2: mild water stress, the irrigation amount was 300m$^3$/667m$^2$; W3: suitable water, the irrigation amount was 350m$^3$/667m$^2$; W4: Fully water supply, the amount of irrigation is 400m$^3$/667m$^2$. Among them, W3 (350m$^3$/667m$^2$) is the conventional management irrigation amount for the whole growing season. As the control irrigation amount (CK), there are 4 treatments in total, and the irrigation method is drip irrigation under the membrane. The area of the cell is 25m×4.5m, and 3 repetitions are set, and a random block design is adopted. The test plots were irrigated before wintering, and the irrigation amount was the same. Fertilization was based on red jujube and cotton fertilization standards. The amount of red jujube fertilization and cotton fertilization were the same in each treatment. The other management measures in the test site were consistent with Daejeon.

2.3 Test Method.
The cotton was tested on September 23, 2011, and the seed cotton yield in each plot was determined based on the actual harvested cotton. A representative cotton was selected in each test plot (5 plots per plot, 2 replicates, total 10 plots), and the indoor test was carried out to determine the cotton distribution, number of bolls, and single boll weight of individual fruit branches. After the test is completed, cotton is picked from the sample cotton plant for ginning, and the lint is weighed.
2.4 Statistical Analysis Method.

The data was processed with the software Microsoft Office Excel 2003, and the cluster analysis was performed with DPS7.05.

3. Results and Analysis

3.1 Effect of Different Water Treatments on Spatial Distribution of Cotton Bolls.

3.1.1 Effect of Different Moisture Treatments on Spatial Distribution of Cotton Boll Shedding Rate.

In the process of cotton growth and development, cotton bolls fall off inevitably. Generally, the field cotton bolls fall off 60%-70%, and in special cases, it can reach more than 90%, which seriously affects cotton yield [9].

![Figure 1. The cotton boll shedding rate in different water processing](image)

It can be seen from Figure 1 that different water treatments have different effects on the shed rate of cotton buds per plant. W1 water treatment single cotton detachment rate is higher fruit branch 4, fruit branch 13 and fruit branch 15, respectively, 88.89%, 89.3% and 91.67%; the relatively low rate of detachment is fruit branch 7 and fruit branch 11, respectively, 50% and 52.17%. The higher rate of cotton per plant in W2 community was fruit branch 4 and fruit branch 15, which reached 94.44% and 83.33%, respectively; the lowest rate of shedding was fruit branch 11, which was 47.62%. The highest rate of cotton shedding in the W3 plot was fruit branch 3 and fruit branch 4; the lowest was fruit branch 16, and the shedding rate was only 25%. The highest rate of single plant exfoliation in W4 plot was fruit branch 3 and fruit branch 4, both of which reached 100%; fruit branch 6 and fruit branch 10 had a relatively low rate of shedding. Overall, under the different water treatment conditions, the bud rate of single cotton buds was: W4>W1>W3>W2. It can be seen from Figure 1 that the rate of detachment of the upper and lower fruit branches of the bud bell is much higher than that of the middle fruit branch. The detachment rate of the upper part of the cotton in the W1 and W2 communities is higher than that of the lower part, while the W3 and W4 communities are opposite.

3.1.2 Effects of Different Water Treatments on the Spatial Distribution of Cotton Bolls.

During the indoor test, the number of cotton bolls sampled by different cells is counted, and the data is preprocessed with EXCEL. Then it is classified by DPS7.05, and the system clustering graph (variable class averaging method) is used to find out the law of spatial distribution of existing cotton bolls under different water treatment conditions.
Figure 2. The number of each fruit spur boll in different water processing

In Figure 2, 1-18 fruit branches can be classified into 3 types at D = 3.23. The first category includes: fruit branches 1, 2, 17, 18, 3, 16; the second category includes: fruit branches 4, 14, 10, 13, 15; the third category includes: fruit branches 5, 9, 11, 8, 6, 12, 7. As seen in Figure 2, fruit branches 1, 2, 17, 18, 3, 16 are automatically grouped into one category, mainly at the bottom (1-3 fruit branches) and top (16-18 fruit branches) of cotton plants. The number of effective bells on these fruit branches is zero. The second and third categories are mainly concentrated on 4-15 fruit branches, and the most effective bells are the 8th, 11th, 9th and 5th fruit branches. Thus, the upper part of the cotton fruit branch is defined as the 12-15th fruit branch, the middle part is the 8-11 fruit branch, and the lower part is the 4-7 fruit branch. From the spatial distribution of cotton effective bells, the number of effective branches is increasing, the number of effective bells is almost an irregular parabola, the number of effective bells in the middle of cotton is more, and the number of effective bells in the lower and upper branches is relatively less.

3.2 Influence of Different Irrigation Amount on the Distribution Law of Bell Weight in Each Treatment Community.

3.2.1 Effect of Different Irrigation Amount on Fruit Weight of Individual Plants in Each Treatment Area.

Figure 3. The single plant fruit spur boll weight in different districts

It can be seen from Figure 3 that different water treatments have a certain influence on the boll weight of each fruit branch. The highest point of the fold line appeared in the 9th fruit branch of W2. The weight of the whole fruit branch reached 7.97g, followed by the 11th fruit branch, and the boll weight was 7.55g. The lower weight of the fruit branch was the 4th, 13th, 14th and 15th branches. The bell weights were 2.99g, 3.71g, 3.90g and 2.82g, respectively. The maximum weight of the fruiting branch of W3 treated in W3 appeared in the 11th fruiting branch, which was 6.71g. Relatively speaking, the lower boll weight is the 5th, 12th, and 15th fruit branches, which are 3.89g, 3.78g, and 3.79g, respectively. The 8th fruiting branch of the W4
The community had the largest boll weight of 6.72g, while the lower value was the 12th, 13th, 14th and 15th fruit branches, and the boll weights were 3.18g, 3.04g, 2.48g and 0g, respectively. The highest fruiting weight of the W1 community was 6.32g of the 8th fruit branch, and the lower value was the 4th, 5th, 12th, 13th, 14th and 15th fruit branches. Overall, the average boll weight of each fruit branch in W1 and W4 cells is quite different; while the average boll weight of fruit branches in W2 and W3 cells is very stable, especially in W3 cells. There are far more bells in the middle fruit branches than in the upper and lower parts. Another study by Zhou Shuwu [10] showed that the weight of the boll and the seed finger are different due to the different weights of the ringing part, and the bell is early and heavier than the bell. Therefore, in terms of the whole fruit branch, the total bell weight of the fruit branch in the middle part of the cotton plant is greater than the total boll weight of the upper and lower fruit branches, while the weight of the lower fruit branch is slightly higher than the upper part.

3.2.2 Effects of Different Irrigation Amounts on the Vertical Distribution of Fruit Weight of Individual Plants

![Figure 4. The single cotton boll weight of each part in different irrigation water](image)

It is known from Figure 4 that each fruit branch is observed longitudinally, and it is found that the weight of each part of cotton per plant is different under different irrigation conditions. For the same irrigation amount, the weight of the cotton bolls in the upper fruit branches is much higher than that in the upper and lower parts, while the total weight of the upper and lower cotton bolls is equivalent. The weight of middle-central fruiting bells in W1 treatment was 22.5g, and the weights of upper fruit branches and lower non-fruit branches were 10.9g and 13.1g, respectively. The weight of middle fruit branches in W2 treatment was 26.5g, and the weights of upper fruit branches and lower fruit branches were respectively 18.6g and 17.3g; the weight of the central fruit branch of W3 was 24.0g, and the boll weight of the upper fruit branch and the lower fruit branch were 17.7g and 18.1g, respectively. In the middle of W4, the weight of the central fruit branch was 23.3g, and the weight of the upper fruit branch and the lower fruit branch was 14.1g and 15.1g, respectively. The upper fruit branches are slightly more volatile than the lower fruiting bells, which may be related to the short growth period of the upper cotton bolls and dysplasia. For different irrigation amounts, the weight of each part of the boll is W2>W3>W4>W1.

3.2.3 Effect of Different Irrigation Amount on the Lateral Distribution of Cotton Boll.

|                | W1   | W2   | W3   | W4   |
|----------------|------|------|------|------|
| Inner/g        | 42.44| 58.65| 53.58| 42.99|
| Periphery/g    | 3.96 | 3.67 | 6.32 | 6.32 |
| Inner/Periphery (%) | 9.32%| 6.25%| 11.80%| 22.13%|

Table 1. The total weight of outer and inner in different districts

Horizontal observation of individual fruit branches, from inner bells (1, 2 fruit nodes, middle fruit branches 2, 3 fruit nodes, upper fruit branches 1, 2 fruit nodes) to the outer bells (the cotton bolls outside the inner circumference are recorded as peripheral bells). As a result, it can be seen from Table 1 that the total
weight of the inner bell is much larger than the total weight of the outer bell. The total weight of the peripheral bell/inner bell is: \( W_4 > W_3 > W_1 > W_2 \), and the proportion of the outer bell of the \( W_2 \) cell is small, indicating that the \( W_2 \) cell bell is mainly grown in the inner circumference. The ratio of the peripheral cotton bolls to the inner cotton bolls in the \( W_4 \) community is much higher than that in the other three communities, indicating that the cotton bolls on the cotton branches of the \( W_4 \) community are distributed on the inner periphery. In general, the compactness of the four irrigation volumes to treat cotton bolls is: \( W_2 > W_1 > W_3 > W_4 \).

3.3 Effects of Different Irrigation Amounts on Seed Cotton and Cotton in Each Treatment Area.

| Treatment | Seed cotton weight/g | Lint percentage/% | Ginned cotton weight/g |
|-----------|----------------------|-------------------|-----------------------|
| W1        | 46.36                | 38.96             | 18.06                 |
| W2        | 62.32                | 39.81             | 24.81                 |
| W3        | 59.88                | 39.15             | 23.45                 |
| W4        | 52.51                | 38.88             | 20.42                 |

It can be seen from Table 2 that the seed cotton of a single plant shows a trend of \( W_2 > W_3 > W_4 > W_1 \). Among them, the highest value of seed cotton is that \( W_2 \) has reached 62.32g per plant, the smallest is \( W_1 \), and the weight of single seed cotton is only 46.36g. There was no significant difference in the rate of clothing per plant under \( W_1 \), \( W_2 \), \( W_3 \) and \( W_4 \) water treatment, which was \( W_2 > W_3 > W_1 > W_4 \). The weight of single cotton lint was the same as that of seed cotton.

4. Discussion

In the lifetime of cotton, cotton bolls fall off as normal. The main reason is related to hormones, nutrients and environmental factors \(^{11-13}\). The rate of shedding of cotton bolls under different water treatments is very different. Among them, the main reason for the higher rate of \( W_4 \) cotton bolls may be excessive water supply, poor soil ventilation, insufficient oxygen, root respiration, and limited absorption of fat. In addition, when the temperature is high, the fertilizer effect will be too strong, causing the cotton plant to grow up, and the cotton bolls will fall off due to insufficient nutrients. The reason for the cotton shedding rate of the upper and lower fruit branches is much higher than that of the middle fruit branches, which may be related to environmental factors and growth period. Compared with the central cotton, the upper cotton has a shorter growth period and insufficient nutrients, while the lower cotton has insufficient light, photosynthesis decreases, and nutrient deficiency causes the boll to fall off. In addition, the lack of ventilation in the lower part of the cotton and the high temperature in the bottom of the summer caused by the high temperature in the bottom space is also one of the causes of the boll. In other words, the middle fruit branch is the main body of the yield \(^{14}\), so it is necessary to ensure the quantity of the central cotton in the cultivation and lay a good foundation for high yield.

The weight of the bell is different due to the different bellowing parts. Different irrigation amounts have an effect on the weight of individual fruiting branches in each treatment area. It is shown that the single-bell weight bell in the middle of the cotton plant is more important than the single-bell weight in the upper and lower parts. This is the same as the research results of Geng Tao \(^{15}\). The total bell of the fruit branches in the middle part of the cotton plant is mainly caused by the spatial position of the total bell weight of the upper and lower fruit branches. The light and ventilation of the central fruit branches are suitable, and the nutrition and development time are sufficient, so the boll weight is higher than that of the upper and lower fruit branches. The weight of the lower fruiting bells is higher than that of the upper cotton bolls. From the perspective of optimizing cotton bolls, the potential of central cotton bolls should be fully exploited to improve the quality of cotton \(^{16}\). And further tap the potential of the upper and lower cotton bolls and peripheral bolls to increase cotton production. The formation mechanism of the upper fruit branches with higher fluctuations in the lower fruiting bells needs further study.

The effects of four different irrigation amounts on cotton dressing rate were not obvious, but the trend of yield factors was: \( W_2 > W_3 > W_4 > W_1 \), indicating that mild water stress (300m\(^3\)/667m\(^2\)) was conducive to the formation of high cotton yield.
This experiment is mainly concerned with the influence of different irrigation amount on the spatial distribution and yield of cotton bolls under the condition of jujube-cotton intercropping in Tarim Basin. Four different irrigation volumes were set up under the same conditions (including cotton varieties, farming practices and management measures). According to various data processing results, the bud rate of single cotton buds under different water treatment conditions was: \( W_4 > W_1 > W_3 > W_2 \). The average boll weight of each fruit branch in \( W_2 \) and \( W_3 \) cells is very stable, and the weight of each part of the boll is \( W_2 > W_3 > W_4 > W_1 \). The compactness of cotton bolls is: \( W_2 > W_1 > W_3 > W_4 \). The weight of individual seed cotton and lint showed a trend of \( W_2 > W_3 > W_4 > W_1 \). Considering various factors comprehensively, the \( W_2 \) treatment, i.e. \( 300 \text{m}^3/667\text{m}^2 \) irrigation, meets the growth requirements of cotton in the jujube-cotton intercropping area of southern Xinjiang, and can be used as a reference standard for the control of crop water quantity in jujube intercropping mode in southern Xinjiang.

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