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EFFECTS OF DIFFERENT WATER AND FERTILIZER TREATMENTS ON LEAF AREA AND YIELD OF JUJUBE (*ZIZIPHUS JUJUBA* Mill.)

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Key words: Jujube tree, Bubbled-root irrigation, Water and fertilizer treatments, Leaf area index, Yield

Abstract

Effects of different water and fertilizer concentrations on the leaf area index, fruit development and yield of jujube trees under bubbled-root irrigation during the growth period were analyzed. The leaf area index of different water and fertilizer treatments reached a peak at the fruit enlargement stage of the jujube tree. The leaf area index reached maximum with high water and medium fertilizer treatment (W_1N_2). The highest number of fruits per unit branch length appeared in medium water and medium fertilizer treatment (W_2N_2), while the lowest appeared in low water treatment (W_3N_0). The highest yield of all treatments was with medium water and medium fertilizer treatment (W_2N_2) having a yield of more than 30 000 kg/hm^2, while the lowest was with low water and high fertilizer treatment (W_3N_1) having a yield of less than 15 000 kg/hm^2. Therefore, medium water and medium fertilizer treatment can be recommended to obtain the highest yield of jujube trees.

Introduction

At present, irrigation under different water and fertilizer methods has been widely used in agricultural production. Different irrigation and fertilization rates have important effects on crop growth and yield (Su *et al.* 2002, Huang and Zhang 2016, Zhang and Huang 2016). The effects of water and fertilizer on crop growth are not isolated, but instead interact with each other, and show a coupling effect (Ma *et al.* 2017). Compared with conventional irrigation and fertilization, the coupling of water and fertilizer can significantly improve the utilization efficiency of water and fertilizer, thus promoting crop growth and increasing yield (Jin *et al.* 2005, Xing *et al*. 2024). The results of water-fertilizer coupling model study on watermelon in sandy land showed that the effect of water supplement on yield was greater than that of organic fertilizer (Guo *et al.* 2013).

That bubbled-root irrigation is a micro-irrigation technology suitable for mountain jujube trees. It can directly supply irrigation water to the root system of fruit trees, which greatly improves the water utilization rate. At present, domestic research on bubbled-root irrigation has made some progress, but most of them are studied on the characteristic value of bubbled-root irrigation moist body (Zhang *et al.* 2010, Wang *et al.* 2012, Che *et al*. 2013). Leaf area is the main organ of jujube synthesizing substances, and the effective leaf area is positively correlated with its yield. In actual production, the growth of jujube leaf area is affected by water and fertilizer conditions.

Therefore, the present study was carried out to compare and analyze effects of different water and fertilizer treatments on the leaf area index(LAI), fruit growth and yield of jujube trees in bubbled-root irrigation during the growth period. This finding would provide a scientific basis for the rational formulation of water and fertilizer coupling systems for jujube trees in northern Shaanxi.

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Materials and Methods

The experiment was carried out from May to October 2014 at the Northwest Agriculture and Forestry University Test Base (37°40′~38°06′N, 100°15′~110°16′E) in Yuanzhi Mountain, Mizhi County, Shaanxi. The climate in the test area was warm temperate semi-arid. The annual average and maximum rainfall in the area was 451.6 and 704.8 mm, respectively. The minimum annual rainfall was 186.1 mm. The average slope was 30° and the terrain was flat and uniform. The soil was dominated by loess soil, with an average soil bulk density of 1.29 g/cm^3, and the roots of five-year-old jujube trees were mainly distributed in the 0-60 cm soil layer. The field water holding capacity of the planned wet layer of 0~60 cm was 22% the available nitrogen, phosphorus and potassium contents were 34.739, 2.909 and 101.900 mg/kg, respectively, and the organic matter content was 0.21%. The pH was 8.6. The data used in this experiment were collected from the Mizhi Experiment Station of Northwest Agriculture and Forestry University in 2014.

The red jujube tree was five-year-old, and the row spacing was 2 m ×3 m.1 650 plants/hm^2. Each jujube tree was buried with 1 bubbled-root irrigator, location 20 cm away from the trunk in the due east direction of the tree, the irrigation device was buried at a depth of 15 cm. The flow rate was 7 l/hrs. The schematic diagram of bubbled-root irrigation is shown in Fig. 1.

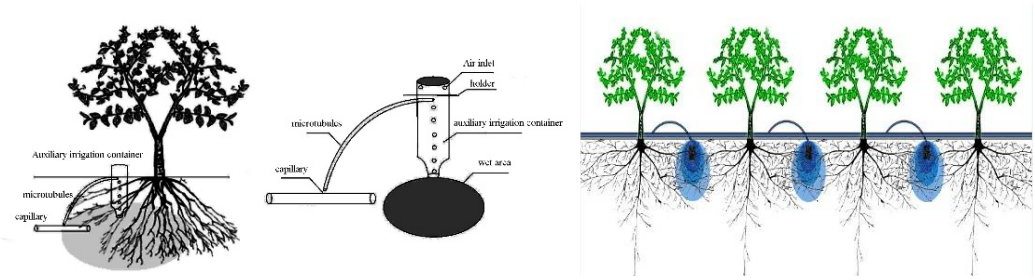

Fig. 1. Sketch map of bubbled-root irrigation of jujube tree.

The growth period of jujube trees varies from year to year. Usually, the budding and leaf development period was from April to May, the flowering and fruit setting period was from June to July, the fruit expansion period was from July to September, and the fruit maturity period was from September to October, but in May 2014, the first buds of jujube trees suffered severe frost and insect damage, so the growth period began from 18 May. The specific division of the growth period: the budding and leaf development period was from May 18 to June 20, the flowering and fruit setting period was from June 21 to July 31, and the fruit expansion period was from August 1 to September 15 and maturity period was from September 16 to October 10.

The design of irrigation and fertilization rates in different treatments and growth period is presented in Table 1. Pruning, ring cutting, spraying and weeding were same among treatments.

The LAI-2000 plant canopy analyzer was used to measure the jujube tree once every 7 days during the budding, leaf-spreading period, the flowering and fruit-setting period, and once every 15 days after the jujube tree entered the fruit expansion period. The leaf area index of jujube trees was recorded at different time periods under different water and fertilizer treatments. From 20 days after fruit setting, 2 jujube hangings were randomly selected for each tree in the four directions of east, west, south and north to mark, and 1 fruit was randomly selected on each marked jujube hanging. The longitudinal diameter (H) and transverse diameter (R) of the vernier caliper were recorded keeping the measurement of the upper, middle and lower parts of the fruit, and counted them as R_1, R_2, R_3 and taking the average of the three values. The volume is calculated as $V = H\pi (R/2)^2$. To measure the yield of jujube trees the number of fruit hanging on

the whole jujube tree was first counted, and then 100 jujube fruits with uniform size and representativeness in the fruit maturity period were selected. They were then put in a sealed bag and weighed them immediately to obtain the average single fruit weight and finally thereby calculating yield was obtained, and the measurement time was September 26.

Table 1. Different water and fertilization treatments on different growth stages of Jujube tree.

Treatments	Irrigation volume (l/tree)			Nitrogen fertilizer (g/tree)
	Budding stage	Flowering and fruit setting	Fruit expansion period	
W_1N_1	105	0	105	360
W_1N_2	105	0	105	240
W_1N_3	105	0	105	120
W_1	105	0	105	0
W_2N_1	80	0	105	360
W_2N_2	80	0	105	240
W_2N_3	80	0	105	120
W_2	80	0	105	0
W_3N_1	0	0	105	360
W_3N_2	0	0	105	240
W_3N_3	0	0	105	120
W_3	0	0	105	0

W_1: 105 l/plant, W_2: 80 l/plant, W_3: 0 l/plant, N_1:360 g/plant, N_2:240 g/plant and N_3: 120 g/plant.

Results and Discussion

Many scholars have studied the relationship between the amount of water, fertilizer and yield of jujube (Guo *et al.* 2013, Che *et al.* 2013, Zhang *et al.* 2010, Wang *et al.* 2012). The present study have been consistent with those study. Variation trend of leaf area index of jujube with growth cycle under different water and fertilizer treatments were observed (Fig. 2a-c). The LAI of jujube trees under different water and fertilizer treatments showed a trend of rapid increase a slow increase and gradual decline in the whole growth period (Fig. 2a-c). The overall performance was that the leaf area index of jujube peaked at the fruit expansion stage and continued to be stable until the end of fruit ripening, after which the leaf area index of jujube had different degrees of attenuation. Within a certain range, increasing nitrogen fertilizer application and increasing irrigation amount in the soil can increase the LAI. Under the same irrigation conditions, the treatment with 240 g/plant of fertilization had the largest LAI of jujube, indicating that proper fertilization could promote the growth of jujube leaves. The treatment with 360 g of fertilization/plant had the smallest LAI, indicating that under the appropriate condition of water, excessive fertilizer concentration can inhibit the growth of jujube leaves. Under the same fertilization conditions, the LAI of jujube increased with the increase of irrigation amount. This might be because the canopy of jujube grows rapidly and the LAI increases sharply from the fruit expansion period to the early fruit maturity, indicating that good water conditions are more

conducive to Jujube canopy development. Experiments on moisture and fertilization of tomato under drip irrigation were carried out in laboratory (Sun *et al.* 2005). Results showed that the tomato yield was mostly affected by potassium fertilizer, followed by the the effect of nitrogen fertilizer on tomato growth.

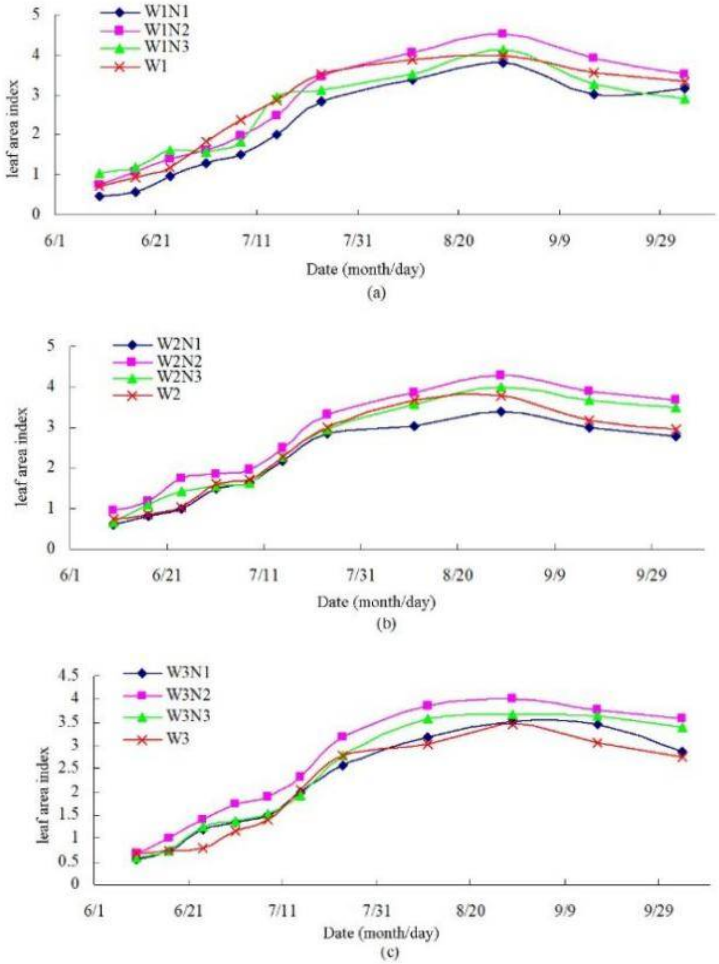

Fig. 2. Effects of different water and fertilizer treatments on leaf area index of jujube.

The estimated amount of nitrogen fertilizer plays a leading role in the growth and yield of maize (Sun *et al.* 2006). The field experiment of drip irrigation under cotton film found that the effect of water and fertilizer was good for increasing cotton yield, but the content of water and fertilizer should not be too large (Hu *et al.* 2005).

Within the design level of this experiment, under different water and fertilizer concentrations, the average LAI during the growth period of jujube trees increased with the increase of the irrigation quota. Among all the treatments, the highest LAI of jujube observed in the high-water fertilizer treatment (W_1N_2), and the lowest in the low-water no-fertilization treatment (W_3N_0).

Influence on the volume of jujube fruit showed that different water and fertilizer treatments have a certain effect on the volume of jujube fruit (Fig. 3). With the increase of growth cycle, the fruit volume of jujube increased under different water and fertilizer treatments (Fig. 3a-c). The average fruit volume of high water and low fertilizer treatment (W_1N_3) was the largest (Fig. 3a). Under the high irrigation quota treatment, the fruit volume of jujube decreased with the increase of the fertilization amount, while the fruit volume of the high water fertilizer treatment (W_1N_2) and the high water and low fertilizer treatment (W_1N_3) were larger than those with no fertilizer treatment, the high water and high fertilizer treatment (W_1N_1) fruit volume was smaller than no fertilization treatment, indicating that under high irrigation treatment, the amount of fertilization is negatively correlated with the growth of jujube fruit volume, and excessive fertilization is not conducive to fruit expansion (Fig. 3a). Under medium irrigation treatment, no fertilization treatment (W_2N_0). The fruit volume was the largest and the fertilizer treatment in medium water (W_2N_2) was significantly higher than that in the treatment with medium water and high fertilizer (W_2N_1) and the treatment with low fertilizer in medium water (W_2N_3) (Fig. 3b). The fruit volume of the treatment (W_3N_2) was significantly smaller than that of the no-fertilization treatment (W_3N_0), and the fruit volume of the jujube tree of the low-water and low-fertilization treatment (W_3N_3) was larger than that of the no-fertilization treatment (W_3N_3) (Fig. 3c).

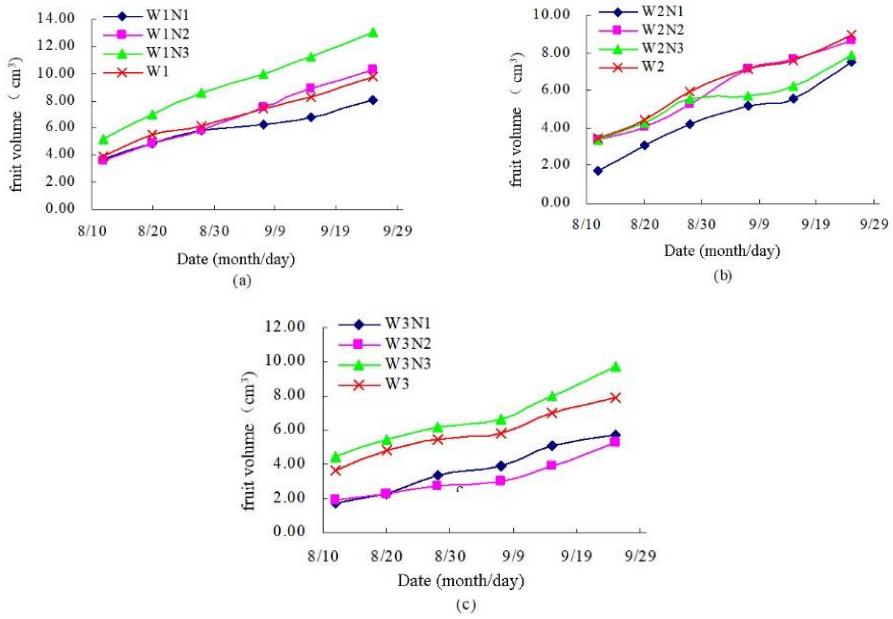

Fig. 3. The volume of jujube fruit under different water and fertilization treatments.

Treatment W_3N_0, indicates that after entering the fruit expansion stage, fertilization has an effect on fruit growth and mass production. This might be due to the fact that the fertilized jujube trees have lot of fruits and the jujube trees have insufficient nutrients after entering the fruit expansion period. Under certain fertilization conditions, the volume of fruit increased with the increase of irrigation quota, indicating that irrigation can promote fruit expansion.

It is apparent from Fig. 3 that total number of fruits and the number of fruits per unit branch length gradually decreased with the passage of time, and gradually stabilized during the fruit maturity period and other factors, resulting in different degrees of fruit drop. The late fruit drop

rate of all fertilized jujube trees was significantly lower than that of no fertilization treatment. Under the same fertilization conditions, the medium water treatment (W_2) had the largest total number of fruits, and the low water treatment (W_3) had the least total number of fruits; under the high water treatment (W_1) and medium water treatment (W_2), the greater the amount of fertilization, the greater the total number of jujube fruits. Under the low water treatment (W_3), the medium fertilizer treatment (W_3N_2) had the highest number of fruits. The final number of fruits per unit branch length was the maximum in the middle water fertilizer treatment (W_2N_2), and the average number of jujube fruits on the branch was about 4/cm; the least is the low water and no fertilization treatment (W_3N_0). There were about 2 jujube fruits/cm on the branch. It showed that within a certain range, proper fertilization can promote the increase of the number of fruits per unit branch length, but the excessive concentration of the fertilizer solution will inhibit the increase.

Water and fertilizer are the two main factors of input in jujube production, and at the same time, they are also two important technical measures that can be regulated. The impact on the yield of jujube trees is mainly reflected in the level of water and fertilizer supply, which is mainly reflected in the different yields of jujube trees under different water and fertilizer conditions. It can be seen under different water and fertilizer treatments, the standard yield of medium water and medium fertilizer treatment (W_2N_2) was the highest, exceeding 30 000 kg/hm^2. Low water and high fertilizer treatment (W_3N_1) had the lowest standard yield, less than 15 000 kg/hm^2. Under the same soil moisture conditions, the application of medium and low fertilizers can increase the fruit yield of jujube trees to varying degrees, and the application of high fertilizers will have an inhibitory effect on the yield of jujube trees. Under different soil moisture conditions, the optimal amount of fertilization to obtain the highest yield of jujube trees was also different.

Under high water treatment and low water treatment, the yield of jujube trees with low fertilizer can reach the highest; under medium water treatment, the yield of jujube fruit can be the highest with medium fertilizer. Under the condition of proper fertilization, irrigation during the budding and leaf-expanding stage can improve the yield of jujube trees. When applying low fertilizer, it should be matched with high irrigation quota to maximize the yield of jujube trees. Therefore, under the conditions of the present experiment, the water fertilizer treatment (W_2N_2) can be selected, which can results the highest yield of jujube.

In the present study, the LAI, jujube fruit growth and yield of jujube trees under different water and fertilizer conditions were studied and analyzed. The results showed that under certain conditions, the leaf area index of each treatment first increased and then tended to increase during the whole growth period of jujube trees. The leaf area index increased with the increase of the amount of irrigation in the budding and leaf-expanding stage, the leaf area index of jujube trees treated with high water and medium fertilizer treatment (W_1N_2) was the highest. Excessive fertilizer concentration will inhibit the increase of jujube leaf area index. The optimal amount of fertilization corresponding to different irrigation treatments was different. The combination of high irrigation, low irrigation and low fertilizer had the largest fruit volume; under the medium irrigation treatment, the fruit volume was the largest when no fertilization was applied. This may be due to the fact that the jujube tree contains a lot of fruit, and not enough nutrients are added in time during the process of fruit expansion. Among all the treatments, the number of fruits per branch length was the highest in the medium water fertilizer treatment (germination and leaf development stage).

Under certain conditions, fertilization can significantly increase the final yield of jujube trees. Among all the treatments, the highest yield was with medium water and medium fertilizer treatment (W_2N_2) having a yield of more than 30 000 kg/hm^2. The lowest yield was with low water and high fertilization treatment (W_3N_1) having a yield of less than 15 000 kg/hm^2. Therefore, the maximum yield can be obtained by treating jujube trees with medium water and medium fertilizer.

Acknowledgements

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