Study on Water Requirement Pattern and Aboveground Biomass Change of Glycyrrhizauralensis Under the Water Stress Conditions

Zhanqi Liang, Dan Shan, Jingli He, Tiegang Zhang, Limin Zhao, Hao Rong and Ende Xing

ABSTRACT

Water saving irrigation was conducted on artificially cultivated Glycyrrhizauralensis based on the principle of insufficient irrigation. Water saving technical system was constructed considering the actual situation of large area planting Glycyrrhizauralensis in arid area. The research was an importance to improve the utilization efficiency of limited water resources in sand area. Water requirement of Glycyrrhizauralensis was researched and the influence of water shortage in different stages on the aboveground biomass of Glycyrrhizauralensis and water sensitive period of Glycyrrhizauralensis were studied in the desert ecological recycling industry park of Elion Resources Group. The industry park was located in the heart of the Kubuqi desert. The results showed that the water requirement rule in the whole life circle was a two times parabola of single peak value, the maximum daily water consumption in flowering period was 4.5mm/d which was the moisture sensitive period of Glycyrrhizauralensis. Water shortage at flowering period had greatest impact on aboveground biomass under moderate drought conditions, the yield was reduced by 48.7% and the effect of the turning green period was minimal.1

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INTRODUCTION

Glycyrrhizauralensis was a perennial herb and was a leguminous plant. Glycyrrhizauralensis was distributed widely in the arid, semi-arid and semi-desert regions of northwest China[1]. Glycyrrhizauralensis was one of the most important medicinal plants, which was used in medicine, food, chemical industry and other fields widely. In recent years, the cultivation of Glycyrrhizauralensis was increased greatly because of the decrease of wild varieties resources and the environmental degradation caused by digging Glycyrrhizauralensis[2,3]. Glycyrrhizauralensis was an excellent medicinal and wind-proof plant in semi-arid desert regions due to the characteristics of drought resistance, alkali resistance and poor resistance. Glycyrrhizauralensis root developed which was strong vitality and high coverage, Glycyrrhizauralensis was suitable for growing in arid and semi-arid sandy soil[4-6]. Irrigation was one of the main methods to ensure the growth and development of crops. It could make up for the lack of water distribution, which is beneficial to the normal growth of crops. The effects of irrigation on crop growth, yield and water use efficiency were mainly concentrated on crops grown in large areas such as grain and vegetables[7-9]. Many studies showed that irrigation could promote the growth of crop nutrition organs significantly, and the increase of plant height, tiller number, branch number and leaf area were positively correlated with irrigation water[10-12]. Generally, crop water use efficiency was higher when moderate deficit, which had certain biological compensation effect[13]. Lu Lihua et al. showed that the appropriate water stress not only did not affect the wheat yield, but improved the efficiency of water use[14]. Liu Changli et al. showed that some degree of drought stress environment could increase the yield of Glycyrrhizauralensis[15]. In recent years, the effects of fertilization, density and planting period on growth and yield of Glycyrrhizauralensis were studied, however, the water requirement of licorice, and the effect of irrigation on the growth and yield of licorice were relatively few in the desert district.

Elion Resources Group mainly engaged in desert ecological restoration and desert ecological industry, adhere to the "eco-friendly, green finance" concept. More than 80,000 hectares of Glycyrrhizauralensis were built in the western Inner Mongolia Kubuqi desert, Elion Resources Group walked out of a green development path to improve the ecological environment and build the desert land[16-17]. Kubuqidesert had less precipitation and water resources were in short supply, therefore, those was necessary to establish a production system which achieved the high yield and high efficiency of Glycyrrhizauralensis, water-saving in Kubuqidesert. It was of great significance to study the water requirement of Glycyrrhizauralensis in Kubuqidesert, make scientific and reasonable water-saving irrigation system, and to ensure the efficient utilization of limited water resources and guide local production practice.
MATERIALS AND METHODS

Nature Survey

The experimental area was located in desert ecological industry park of Elion Resources Group which was located in the hinterland of the kubuqi desert. The experimental area belonged to the typical mid-temperate semi-arid plateau continental climate, the average annual precipitation was 245mm, and the average annual rate of evaporation was 2720mm, with an annual average wind speed of 4.1m/s, with the maximum wind speed of 28.7m/s, with no frost period of about 130d. The natural geomorphology was dominated by flowing and semi-mobile dunes, the soil was sandy soil, the texture was poor, the soil density was 1.42/cm3, and the field water was 10.8%.

Methods

The experiment selected to transplant the Glycyrrhizauralensis growing area of the one annual seedling. Five treatments were set up in the field, and each treatment was repeated three times. The area of each plot was 40m²(5m×8m). The row spacing of Glycyrrhizauralensis was 0.3m×0.5m, with 10 rows per area and 26 plants per row. The ground dropper was used and the pipe arrangement was set to one control two. Onepipe irrigated two lines of Glycyrrhizauralensis and the pipe was laid in the middle of two lines. Two levels were set which were no drought and moderate drought. Soil moisture as the control index soil moisture control index was shown in Table I.

**TABLE I. INDEX OF SOIL MOISTURE CONTROL. UNIT: PERCENTAGE OF HOLDING CAPACITY.**

| Levels                  | Glycyrrhizauralensis |
|-------------------------|----------------------|
| No drought              | 65                   |
| Moderate drought        | 40–50                |

Note: the soil moisture content was the lower limit value in the table, and the upper limit value was the water holding rate in the field.

**TABLE II. TEST DESIGN UNDER THE WATER CONDITIONS.**

| Treatment | Turning green period | Vegetative period | Flowering period | Mature period |
|-----------|----------------------|-------------------|------------------|---------------|
| 1         | no drought           | no drought        | no drought       | no drought    |
| 2         | moderate drought     | no drought        | no drought       | no drought    |
| 3         | no drought           | moderate drought  | no drought       | no drought    |
| 4         | no drought           | no drought        | moderate drought | no drought    |
| 5         | no drought           | no drought        | no drought       | moderate drought |
Data Determine

The starting time and rainfall of successive rainfall were recorded using the reverse bucket self-recording rain gauge. Soil moisture content was automatically recorded by soil moisture monitor, and the soil drying and weighing method could be determined by artificial soil drilling. The aboveground biomass was determined by sample method, Water meters were used to record the irrigation water. During a period of a growth period(t), changes in the water storage in the soil plan wetting layer(h) could be expressed by the following equation of water displacement,

\[ W_t - W_0 = W_r + P_0 + k + M + E_{Ta} \]  

\( W_0 \), \( W_t \)—The amount of water stored in the soil moisture layer at the beginning of time and at any time at time(t), \( W_r \)—As the wet layer increases the amount of water added, if the wet layer does not change during the time period, it is not; \( P_0 \)—Effective rainfall; \( k \)—The amount of groundwater recharge during the growth period(t). The groundwater level was below 5m long in the pilot area so \( k = 0 \); \( M \)—Irrigation water during the period(t); \( E_{Ta} \)—Actual water consumption.

RESULTS

Quality of Licorice Water Requirement

Table III and figure 1 indicated respectively the actual water consumption and water demand rules of Glycyrrhizauralensis under the condition of full irrigation. The result showed that water requirement strength of Glycyrrhizauralensis was more obvious with the change of temperature affected by temperature, soil moisture its physical properties, the change of temperature was from low to high and low, and the change of water requirement intensity was the same as that of temperature. Figure 1 showed that the water requirement strength of Glycyrrhizauralensis was small and the maximum intensity of water requirement was 4.5mm/d. The main reason was that the vegetative growth and reproductive growth in this stage were carried out at the same time, and the roots, stems and leaves grow rapidly. The photosynthesis was strong, the temperature was high and the sunshine duration was long. This stage was the most vigorous growth period of life, the water requirement of Glycyrrhizauralensis also peak intensity, particularly sensitive to water reflect, Glycyrrhizauralensis water requirement was critical period, subsequently, the water requirement of licorice decreased gradually until the fruiting stage.
TABLE III. WATER CONSUMPTION UNDER GROWTH PERIOD ON FULL IRRIGATION CONDITIONS.

| Projects                  | Key technical indicators |
|---------------------------|--------------------------|
| Growth period             |                          |
| Turning green             |                          |
| Vegetative period         |                          |
| Flowering period          |                          |
| Mature period             |                          |
| Whole growth              |                          |
| Rainfall (mm)             | 18.6 97.2 49.5 18.5 182.0|
| Start/end date            | 2/5-21/5 22/5-10/7 11/7-15/8 16/8-8/9 |
| Days                      | 20 50 36 24 130          |
| Soil moisture             | 9.5-10.0 9.7-10.2 9.7-7.6 7.5-7.0 |
| Irrigation water (mm)     | 23 92 92 23 230          |
| Daily water consumption   | 2.0 3.4 4.5 1.8          |
| Intensity (mm/d)          |                          |
| Water consumption (mm)    | 40.0 170.0 162.0 43.2 415.2 |

Figure 1. Average daily water consumption intensity change process under growth period.

The Effect of Water Shortage on The Water Consumption

Different water treatment had a significant effect on water consumption by table IV. The fourth treatment was the water shortage during the flowering period and the total water consumption of the whole growth period was the biggest change. The fourth treatment of Glycyrrhizauralensis water consumption was 80% of the first treatment. The second treatment was water shortage during the turning green period and the change of water consumption was the smallest. The second treatment of Glycyrrhizauralensis water consumption was 89% of the first treatment. When Glycyrrhizauralensis was lack of water at a certain stage of the growth period, the
water consumption of this treatment would increase in the next growth stage which was obvious compensation effect.

According to the results of Figure 2, the water consumption of Glycyrrhizauralensis at different growth stages of all treatments showed a consistent change pattern, which was early stage small, metaphase increases and later period decreases. This rule was the result of the change of growth and development of Glycyrrhizauralensis plant and the comprehensive effect of environmental meteorological factors. Water deficit had a certain effect on the daily water consumption intensity, which could affect the water consumption during the whole growth period. The second treatment was the drought in the turning green period of Glycyrrhizauralensis, when the temperature was low, the Glycyrrhizauralensis seedling was small and the water consumption was small. The maximum amount of water consumed during the flowering period was the maximum water consumption. During the other stages of reproduction, water deficit treatment was carried out, although water consumption increased after the water was rehydrated at this stage, but it was always lower than the first treatment. The main reason for this result was that the turning green period was the peak period of the growth of licorice, and the soil moisture deficit in turning green period seriously affected the growth of the plants, so that the water consumption was less than that of other treatments. On the other hand, even though the turning green period of Glycyrrhizauralensis did not suffer from drought, the subsequent drought caused the plant growth to be affected, which ultimately affected the water consumption intensity and water consumption of the treatment.

| TABLE IV. WATER CONSUMPTION UNDER DIFFERENT WATER TREATMENTS. |
|---------------------------------------------------------------|
| Treatment | Turning green period | Vegetative period | Flowering period | Mature period | Whole growth period (mm) |
|           | Water consumption (mm) | Die coefficient (%) | Water consumption (mm) | Die coefficient (%) | Water consumption (mm) | Die coefficient (%) | Water consumption (mm) | Die coefficient (%) | Water consumption (mm) | Die coefficient (%) | Whole growth period (mm) |
| 1         | 40.0 | 9.6 | 170.0 | 40.9 | 162.0 | 39.0 | 43.2 | 10.4 | 415.2 |
| 2         | 11.2 | 3.0 | 178.4 | 47.7 | 148.8 | 39.8 | 35.7 | 9.5 | 374.1 |
| 3         | 34.4 | 9.9 | 95.8 | 27.5 | 178.7 | 51.2 | 39.8 | 11.4 | 348.7 |
| 4         | 32.3 | 9.7 | 158.9 | 47.8 | 90.6 | 27.3 | 50.4 | 15.2 | 332.2 |
| 5         | 30.3 | 8.9 | 150.4 | 44.1 | 145.2 | 42.5 | 15.4 | 4.5 | 341.3 |
The Influence of Different Water Treatment Conditions on Aboveground Biomass

The reaction of water stress at different stages of growth would be reflected in the differences in aboveground biomass of Glycyrrhizauralensis. The aboveground biomass of Glycyrrhizauralensis was correlated positively with total yield, so the aboveground biomass could be used as the index to analyze the influence of water stress on the yield of Glycyrrhizauralensis. According to table V, due to lack of water, the rate of yield reduction was the highest in the flowering period and the lowest was in the turning green period. The effect of water shortage on aboveground biomass was the fourth treatment was greater than the third treatment and greater than the fifth treatment and greater than the second treatment. The water requirement of Glycyrrhizauralensis was relatively low in the turning green period. After the vegetative period of Glycyrrhizauralensis, the effect of water deficit on aboveground biomass began to increase.

The lack of water in the vegetative period would reduce the aboveground biomass of Glycyrrhizauralensis by 42.6%. When the Glycyrrhizauralensis grew from vegetative to reproductive growth in the flowering period, the leaf area index and water consumption reached the highest value in their lifetime. Glycyrrhizauralensis had stronger reproductive growth and active metabolism in the flowering period, the production efficiency was the highest, and so the water shortage had the greatest influence on the growth of Glycyrrhizauralensis, the lack of water in the flowering period would reduce the aboveground biomass by 48.7%. The effect of water deficit on the aboveground biomass of Glycyrrhizauralensis was gradually reduced in the mature period.
TABLE V. ABOVEGROUND BIOMASS UNDER DIFFERENT WATER TREATMENTS.

| Treatment | Water consumption (mm) | Aboveground biomass (dry weight g/m²) | Yield reduction (%) |
|-----------|------------------------|--------------------------------------|---------------------|
| 1         | 415.2                  | 91.7                                 | --                  |
| 2         | 374.1                  | 77.8                                 | 15.2                |
| 3         | 348.7                  | 52.6                                 | 42.6                |
| 4         | 332.2                  | 47.0                                 | 48.7                |
| 5         | 341.3                  | 68.9                                 | 24.9                |

CONCLUSIONS

Glycyrrhizauralensis was an important plant resource in arid sand area which had the ecological protection effect of wind and sand fixation, so it was the optimal plant for vegetation restoration and construction in soil wind erosion area. However it was impossible to fully irrigate the Glycyrrhizauralensis due to the local water resources. Water requirement of Glycyrrhizauralensis and the influence of water shortage in different stages on the aboveground biomass were researched under different water stress conditions in the desert ecological recycling industry park of Elion Resources Group. The industry park was located in the heart of the kubuqi desert. The result showed that water requirement of Glycyrrhizauralensis was basically a single peak quadratic parabola in the whole growth period and the maximum daily water consumption intensity was 4.5mm/d. Water shortage was the greatest impact to yield during the flowering period, affect the minimum period was the turning green period.

ACKNOWLEDGEMENTS

This work was supported by the National Science and Technology Support Project (No.2015BAC06B01) and the National Key Research Projects (No.2016YFC0500507).

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