Effect of remained stem height on yield, quality of *Inula helenium* L. and on soil water content

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**Abstract**

To explore the reason causing low yield, poor quality of *Inula helenium* L., this paper investigated the influence of different remained stem heights on the yield, quality and water consumption of *Inula helenium* L. in Gannan plateau area using field single factor randomized block method. Research results showed that *Inula helenium* L. which was cut before blooming period in the last ten-day of July with remained stem height of 25 cm had the lowest water consumption, the best underground root traits (including main root length, root diameter, and root dry weight per plant), and the highest yield which was higher that control group by 18.73% (P < 0.01). Moreover, *Inula helenium* L. with remained stem height of 25 cm had the lowest ash content while the highest alantolactone content, therefore its quality was the best. The water use efficiency (WUE) of *Inula helenium* L. with remained stem height of 35 cm at September was the highest (1.12 kg h m⁻² mm⁻¹). However, in terms of biological yield WUE and economic yield WUE, *Inula helenium* L. with remained stem height of 15 cm was the highest. Therefore, it can be concluded that remained stem height from 15 to 25 cm is an ideal solution, which can not only save water, but also improve yield and quality of *Inula helenium* L.

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1. Introduction

*Inula helenium* L., known as “Ma Na Ba Zha” in Tibetic language (1991), belonging to the composite family and inula flower genus, is the dried root of *Inula racemosa* Hook. f. and *Inula helenium* L. (2003). This plant has acrid flavour, mild and non-poisonous nature. It contains volatile oil, resin, Saussurine, synanthrin, etc, thus smelling a special aroma (Gogoba et al., 2017). This plants has therapeutic effects including promoting qi circulation, easing pain, invigorating spleen, promoting digestion, neutralizing stomach & chest pain. *Inula helenium* L. is a cold-resistant deep-rooting plant grown in mountainous area, which does not have strict requirement of fore-rotating crop and can be grown both in uncultivated land or cultivated land, especially in mountainous area in elevation of 1500 m ~ 3000 m where the growth situation is the best (Kudus et al., 2017).

Currently, there are more researches on the chemical composition (Re et al., 2008; Bi et al., 2009), identification, pharmacology, pesticide effect (Zou, 2006; Hai, 2009; Ullah et al., 2016), and clinical effect of *Inula helenium* L., and there are seldom reports on the cultivation of *Inula helenium* L. (He et al., 2012a; He et al., 2012b; He et al., 2012c). With the growing usage amount, researches on manual cultivation of *Inula helenium* L. are extremely urgent. The cultivation area of *Inula helenium* L. in genuine producing area of tibet plateau area is continuously growing, local herbalists gradually more and more urgent in needing techniques to improve yield and quality of *Inula helenium* L. However, there have been no reports on the influence of remained stem height of *Inula helenium* L. on its growth condition and water use efficiency. In this test, we cut the stem of *Inula helenium* L. during growth stage, and investigated the effect of different remained stem heights on water use efficiency, water consumption, yield, quality of *Inula helenium* L., so as to figure the optimal remained stem height and provide
with organic matter content as high as 138.6 g/kg at plateau area, the decomposition rate of organic matter is slow, meadow soil. Due to high elevation, lower temperature, rainness chilling and humid region of south Gansu province. The fore-capacity is about 24.85%. The test site locates at high-elevation mean annual precipitation of 547 mm. The field water-holding to plateau-climate, with large diurnal temperature variation and rainfall was given during the whole growth period.

2. Materials and method

2.1. Test area profile

Tests were conducted at Tibetan Medicine Introduction and Domestication Test Base of Gansu Normal University For Nationalities from April 2015 to October 2016. The average elevation of test site is over 3000 m, annual mean temperature is 1.7 °C, belonging to plateau-climate, with large diurnal temperature variation and mean annual precipitation of 547 mm. The field water-holding capacity is about 24.85%. The test site locates at high-elevation chilling and humid region of south Gansu province. The fore-rotating crop is highland barley. The soil of test site is subalpine meadow soil. Due to high elevation, lower temperature, rainness at plateau area, the decomposition rate of organic matter is slow, with organic matter content as high as 138.6 g kg⁻¹.

2.2. Test apparatus

The test apparatus used in this research was a weighing lysimeter made of plastics, with length of 4 m, width of 3 m, depth of 1.5 m. The side wall and bottom surface was seal and water-proof. Leakage holes were set at base angle, which were connected via aqueduct and lysimeter. The aqueduct mouth was placed in a water tub which was sealed. At the bottom of lysimeter, a 0.5 m thick layer of gravels was paved, above which a 0.5 m thick layer of coarse sands was paved, after that fill lysimeter with original soil.

2.3. Test materials

Annual seeds of Inula helenium L., without diseases or injuries in uniform size, were cultivated in Institution of High-cold Ecosystem of Gansu Normal University For Nationalities from Jan to Apr 2015 and selected as research objects. The selected seeds were transplanted at weighing lysimeter on May 8 th, 2015. First, we ditched 30 ~ 35 cm furrows, then obliquely put seeds into furrows by a plant, with planting spacing of 30 cm, 45 cm, 50 cm, 60 cm, and ending point.

2.4. Test design

At the end of June when the stem of Inula helenium L. reached 60 cm, we started to cut them. With randomized block design, there were total 5 treatments with different remained stem heights such as 25 cm, 35 cm, 45 cm, 15 cm and CK. Each treatment was repeated conducted 3 times. In each block, there were 150 Inula helenium L. plants, with planting spacing of 40 cm × 40 cm.

2.5. Test items and test method (Sun et al., 2005; Yormaz et al., 2017)

2.5.1. Water storage of soil

Difference of mass water contents (%) in soil between starting and ending point.

2.5.2. Water consumption of soil

\[ \text{WC} = R + I - P - \Delta W \]

Where WC, R, I, P and \( \Delta W \) represent soil water consumption, rainfall capacity, irrigation volume, leakage volume and variation of soil water storage (mm).

2.5.3. Water use efficiency of Inula helenium L

\[ \text{WUE}_b = \frac{Y}{WC} \]

Where \( \text{WUE}_b \) is water use efficiency (kg/h·m⁻²·mm); Y is biological yield of dried roots Inula helenium L. (kg/h·m⁻²); WC is water consumption (mm).

2.5.4. Water consumption of Inula helenium L

Water consumption of Inula helenium L. (mm) = soil water storage before transplant (mm) + natural precipitation during growing period (mm) + irrigation amount (mm) – soil water storage volume during harvest time (mm).

2.6. Sampling and test methods

From June 28 th, samples were collected once every other month, and then test plant height, root diameter, main root length and test quality of plant. After the aboveground parts died away (at middle ten days of November), we harvested the plants and counted the production per each block. By randomly selecting 10 plants from each block, we measured economic indexes of Inula helenium L. such as main rood length and root diameter. After natural withering, we weighed the dried root yield and calculated the dried root weight per plant. The method of gas chromatographic method proposed by Re Zeng Cai Dan and Wang Yingfeng (Re et al., 2008; Gao et al., 2017) was adopted to measure content of Alantolactone in Inula helenium L.

2.7. Data analysis

The calculation results were expressed by mean ± standard deviation (X ± S), DPS7.05 statistical software was used for drawing and variance analysis, and Duncan's method was employed for multiple comparisons.

3. Results and analysis

3.1. Effect of remained stem height of Inula helenium L. on soil water consumption

The test results in Table 1 show that an appropriate stem cutting can effectively reduce soil water evaporation, maintain soil water content, and significantly reduce soil water consumption. Among the five treatments, treatment with remained stem height of 25 cm has the largest soil water storage (744.66 mm) and the smallest water consumption 423.75 kg·h⁻¹·m⁻² which is significantly decreased by 50.67% as compared with CK treatment (P < .01). The water consumption of Inula helenium L. with remained stem height of 15 cm is significantly decreased by

| Remained stem height (cm) | Soil storage amount (mm) | Water consumption (kg·h·m⁻²) |
|---------------------------|--------------------------|-----------------------------|
| CK                        | 268.74                   | 859.05 ± 5.14a              |
| 45                        | 576.93                   | 560.18 ± 7.21b              |
| 35                        | 620.22                   | 536.38 ± 10.32b             |
| 25                        | 744.66                   | 423.75 ± 11.01d             |
| 15                        | 683.39                   | 489.08 ± 15.53c             |

Note: Difference of lowercase letter represents the intergroup difference reach significant level P < .05; difference of capital letter represents the intergroup difference reach significant level P < .01.
43.86% compared with that with CK treatment. In terms of soil water consumption from large to small, the five treatments can be ranked as CK > 45 cm > 35 cm > 25 cm > 15 cm./

3.2. Effect of remained stem height of Inula helenium I. on soil water use efficiency

Table 2 shows that during growing period, stem cutting treatment can significantly increase soil water use efficiency. Since cutting in June, the soil water use efficiency shows tend of first increasing and then decreasing from July to October, during which the soil water use efficiency reaches top level at September for all treatments. During all periods, with the increase of remained stem height, the soil water use efficiency always first increases and then decreases (Samad et al., 2017). It is worth noting that the soil water use efficiencies of plants with remained stem height of 35 cm in all treatments are always the highest, which are 0.99 kg h m⁻² mm⁻¹, 1.26 kg h m⁻² mm⁻¹, 1.38 kg h m⁻² mm⁻¹, 1.12 kg h m⁻² mm⁻¹. In terms of water use efficiency from large to small, the five treatments can be ranked as 35 cm > 25 cm > 15 cm > 45 cm > CK.

3.3. Effect of remained stem height of Inula helenium I. on underground root

Table 3 shows that stem cutting treatment can significantly affect underground root development of Inula helenium I. including increased root length, increased root thickness, increased dried root weight per plant, and increased number of branch roots compared with those with CK treatment. It is worth noting that Inula helenium I. with remained stem height of 25 cm has the longest main root (18.74 cm), largest root diameter (26.47 mm), largest number of branch roots (4.22) and largest dried root weight per plant (159.19 g/plant), which are respectively increased by 38.85%, 16.91%, 90.09% and 12.73% compared with those with CK treatment. In terms of underground root indexes (above mentioned), the five treatments can be ranked as 25 cm > 15 cm > 35 cm > 45 cm > CK.

3.4. Effect of remained stem height of Inula helenium I. on its yield and quality

Research results in Table 4 show that stem cutting treatment can significantly improve yield and quality of Inula helenium I. In terms of yield of Inula helenium I. from large to small, the five treatments can be ranked as 25 cm > 15 cm > 35 cm > 45 cm > CK, in which the yield of plant with remained stem height is increased by 18.73% than that with CK treatment, and the difference between treatments is of statistical significance (P < .05). In terms of ash contents from large to small, the five treatments can be ranked as 15 cm < 25 cm < 35 cm < 45 cm < CK, wherein the Inula helenium I. with remained stem height of 15 cm has the lowest ash content, followed by that with remained stem height of 25 cm, both of which are respectively decreased by 12.42%, 7.8% compared to those with CK treatment, and the difference between treatments is significant (P < .05); In terms of alantolactone contents from large to small, the five treatments can be ranked as 25 cm > 15 cm > 35 cm > 45 cm > CK, in which the plant with remained stem height of 25 cm has the lowest alantolactone content, followed by that with remained stem height of 15 cm, both of which are respectively increased by 2.39% and 1.87% as compared to that applied with CK treatment, and the difference between treatments is significant (P < .05).

3.5. Effect of remained stem height of Inula helenium I. on its water consumption and water use efficiency

Table 5 shows that with the increase of remained stem height of Inula helenium I, the water consumption gradually increases, while

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**Table 2**

| Remained stem height (cm) | Water use efficiency (kg h m⁻² mm⁻¹) |
|--------------------------|-------------------------------------|
|                         | July | August | September | October |
| CK                      | 0.23 ± 0.04dD | 0.30 ± 0.03eD | 0.36 ± 0.04dD | 0.26 ± 0.03eE |
| 45                      | 0.52 ± 0.04cC | 0.62 ± 0.06eC | 0.74 ± 0.04cC | 0.56 ± 0.06dD |
| 35                      | 0.99 ± 0.09aA | 1.26 ± 0.07aA | 1.38 ± 0.08aA | 1.12 ± 0.06aA |
| 25                      | 0.80 ± 0.07bB | 0.96 ± 0.05bB | 1.06 ± 0.04bB | 0.91 ± 0.03bb |
| 15                      | 0.65 ± 0.06cBC | 0.82 ± 0.10cb | 1.01 ± 0.08bb | 0.74 ± 0.033cc |

**Table 3**

| Remained stem height (cm) | Main root length (cm) | Root diameter (mm) | Number of branch roots (stripes) | Dried root weight per plant (g/plant) |
|--------------------------|-----------------------|-------------------|----------------------------------|--------------------------------------|
|                         | 14.00 ± 0.20eE | 22.64 ± 0.07eD | 2.22 ± 0.58bB | 136.89 ± 1.19eE |
| 45                      | 15.33 ± 0.06dD | 23.69 ± 0.33dC | 2.99 ± 1.00cA | 142.20 ± 0.33dD |
| 35                      | 15.99 ± 0.21cC | 24.01 ± 0.15cC | 3.22 ± 0.58bA | 151.62 ± 0.62cC |
| 25                      | 18.74 ± 0.08aA | 26.47 ± 0.04aA | 4.22 ± 0.58aA | 159.19 ± 0.06aA |
| 15                      | 16.99 ± 0.15bB | 25.45 ± 0.09bB | 3.56 ± 0.58abA | 154.31 ± 0.06bB |

**Table 4**

| Remained stem height (cm) | Yield per block (kg m⁻²) | Yield (kg h m⁻²) | Ash content (%) | Alantolactone content (%) |
|--------------------------|--------------------------|----------------|----------------|--------------------------|
| CK                       | 1.51 ± 0.02dD | 15113.52 ± 20.12dD | 3.30 ± 0.01aA | 13.65 ± 0.03eE |
| 45                       | 1.38 ± 0.01cC | 15816.51 ± 25.51cC | 3.23 ± 0.02bB | 14.01 ± 0.08eE |
| 35                       | 1.69 ± 0.03eB | 16934.78 ± 29.33bB | 3.16 ± 0.05cB | 14.84 ± 0.11cC |
| 25                       | 1.79 ± 0.04aA | 17945.64 ± 3.04aA | 3.04 ± 0.02dC | 16.04 ± 0.05aA |
| 15                       | 1.73 ± 0.02bB | 17262.69 ± 26.12bB | 2.89 ± 0.01cD | 15.52 ± 0.09bB |
biological yield WUE and economic yield WUE gradually decrease. The *Inula helenium* I. with remained stem height of 15 cm has the lowest water consumption (423.32), which is decreased by 32.28% than that with CK treatment; while has the largest biological yield WUE (59.87 kg·m⁻²·mm⁻¹) and economic yield WUE (53.57 kg·m⁻²·mm⁻¹), which are respectively increased by 46.52% and 62.57% than that with CK treatment.

### 4. Results and discussions

#### 4.1 There are mainly three factors affecting water consumption of *Inula helenium* I., including remained stem height, climate, and irrigation. Climate can affect the length growth period of plant, precipitation amount, and evapotranspiration capacity of soil; irrigation can increase soil water content, thus affecting evapotranspiration effect. *Inula helenium* I. with short remained stem an effectively reduce water evaporation and increase water use efficiency, to accelerate the growth of *Inula helenium* I. and improve yield and quality of *Inula helenium* I. This paper investigated the effect of remained stem height on soil water consumption under condition of identical precipitation and no irrigation. Results showed that under identical precipitation, soil water consumption varies upon difference of remained stem height. In this research, soil water consumption and water consumption of *Inula helenium* I. increase with the remained stem height. When the remained stem height of *Inula helenium* I. was 15 cm, the water consumption was the lowest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. There is a report (Sun et al., 2005 Shahidah et al., 2017) showing that the water consumption of Medicago sativa with remained stem height of 25 cm was the largest. 

#### 4.2 With the increase of remained stem height, the water use efficiency of *Inula helenium* I. shows a variation trend of first increasing and then decreasing. The plant with remained stem height of 35 cm has the highest soil water use efficiency. The biological yield WUE and economic yield WUE both decrease with the increase of remained stem height, which provide theoretical basis for water conservation in standardized cultivation of *Inula helenium* I. In plateau area of south Gansu, September is the period during which the *Inula helenium* I. growth is the most vigorous and the rainfall is relatively large, therefore, the water use efficiency during September is also the highest.

#### 4.3 Cutting stem when the stem of *Inula helenium* I. reaches 60 cm high and controlling them within 15 ~ 25 cm can effectively improve the yield, soil water use efficiency and quality of *Inula helenium* I., and in particular reduce soil water consumption under dry-farming condition. This conclusion is of guiding significance for cultivation of *Inula helenium* I. in mountainous area, which should be promoted in actual production.

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