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Effects of Drought Stress and Rehydration on Growth Indexes of Different Varieties of Mint Seedlings

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Abstract

Mint (Mentha haplocalyx) is a perennial herb of Mentha haplocalyx belonging to Labiatae family, and has been widely used in the configuration of aromatic urban garden plants. Five varieties of mint cuttings including Melissa officinalis, Mentha suaveolens, Mentha spicata, Mentha pulegium and Mentha piperita were used as the experimental materials to determine the plant height, crown width, root-crown ratio, root length and biomass after natural drought for 0d, 7d, 12d and 17d and rehydration for 0d and 3d, and to analyze the effects of drought and rehydration on the growth indexes of different varieties of mint cuttings. The results showed that: 1) Drought-treated water had different effects on the crown width of five varieties mint. The crown width of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata all reached the maximum after 7d of drought. Natural drought stress for 12d was beneficial to the growth of Mentha piperita crown width.7-day of natural drought stress was conducive to the crown growth of Mentha suaveolens, while long-term drought stress could affect the crown growth of Mentha suaveolens and Mentha piperita, and they could not be recovered after rehydration. Under drought stress, the crown width of Mentha spicata could still grow normally, but the longer the drought stress was, the smaller the crown width increment was, and the crown width could be restored to normal after rehydration for 3 d. 2) The responses of seedling root lengths of five varieties mint to natural drought stress were different.The seedling root length of Mentha piperita and Mentha suaveolens tended to increase, while those of other varieties of mint, tended to decrease. The seedling root lengths of the other four varieties of mint all recovered to normal except for Mentha spicata after rehydration. 3) The inhibition effect of drought stress and rehydration on the blew-ground biomass of the seedlings of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata was greater than that on the above-ground biomass. The total biomass of the seedlings of the five varieties of mint had an increasing trend under drought stress. We can speculated that Melissa officinalis had the strongest drought resistance, while Mentha piperita was the weakest.Melissa officinalis had the strongest recovery ability, and Mentha spicata was the weakest.

Keywords

Drought stress; Rehydration; Mint seedlings; Growth indexes.

1. INTRODUCTION

Mint is a perennial herb of Mentha of Labiatae, which can be used for home gardening, greenhouse cultivation, and urban landscaping. At present, it is widely used in the plant disposition of garden in aromatization city. The whole plant of mint has special fragrance, has the effects of refreshing, repelling mosquitoes and avoiding harm, and can be used for medicinal purposes, The stems and leaves of mint can be extracted with substances such as essential oil, aromatic alcohol and Menthol, so that the plant has a wide range of uses. In recent years, with the global warming, the drought problem becomes more and more serious, which seriously restricts the growth and development of plants and greatly limits the application of garden plants. Most countries and regions are threatened by drought to different degrees, Reasonable use of water resources has become a worldwide problem. In addition, the drought and less rain in Shanxi Province, is located in the loess plateau area, complex terrain, special geographical environment, is China's ecological environment fragile zone, poor water resources, severe agricultural drought [1], so it is particularly important to choose good drought tolerance of plants and landscaping in the application, but also for landscaping later cultivation and maintenance management to provide convenience. Drought stress can affect plant external morphology, endogenous hormones, and photosynthesis in many ways [2–3]. Under short-term or mild drought stress, water potential of plant leaves decreased, stomata closed, and CO2 uptake and photosynthesis were decreased, Long-term and severe drought stress can inhibit plant growth, cause changes in appearance morphology and biomass, and even cause plant death [4–8]. With the increase of the degree of water stress and the prolongation of stress time, the plant height increment of mint, showed a downward trend, The ratio of root to shoot increased with the aggravation of stress, chlorophyll a, chlorophyll b, total chlorophyll and carotenoid showed similar change laws with the increase of stress degree and the prolongation of time, showing the trend of increase or decrease first, and reached the maximum after 14 days of stress. Besides, the physiological response of underground part to drought stress was more sensitive than that of aboveground part [9]. However, after short-term drought stress and rewatering, some physiological indexes could be restored to different degrees [10], which not only maintained the growth and development of plants but also achieved water conservation, and has become a hot research topic in recent years. At present, many scholars have conducted a large number of studies on plant morphology, physiological and biochemical responses, and chlorophyll content under drought stress [10–17]. The research on drought stress of mint, mainly focused on its response to morphological and physiological changes of mint [18], while the related research on the response of different varieties of mint, to drought stress and rehydration growth indexes were rarely reported. In this study, the cutting seedlings of five mint varieties, Melissa officinalis, Mentha suaveolens, Mentha spicata, Mentha pulegium and Mentha piperita, were used as experimental materials. The effects of drought and rehydration on the growth indexes of different varieties of mint were analyzed by measuring the plant height, crown width, root-crown ratio, root length, and biomass of five varieties of mint seedlings under natural drought conditions of 0d, 7d, 12d, and 17d and after rehydration of 0d and 3d, aiming to reveal the effects of drought stress and rehydration on the growth and development of different varieties of mint, and provide a theoretical basis for improving the water use efficiency of mint and selecting suitable varieties of mint for landscape application in arid areas.

2. MATERIALS AND METHODS

2.1. Experimental Sites

The experiment was carried out in the Ornamental Horticulture Practice Teaching Base of College of Horticulture in Shanxi Agricultural University and the Experimental Center of College of Horticulture.

2.2. Experimental Materials

The experimental materials were from Qingdao Baicaoxiang Aromatic Plant Co.Ltd in China and were cutting seedlings of five varieties of mint. (Melissa officinalis, Mentha suaveolens, Mentha spicata, Mentha pulegium, Mentha piperita)

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2.3. Material Culture and Processing Methods

On September 9, 2020, each variety of mint was uniformly planted in basins made of clay with the height of 20cm, the upper diameter of 20cm and the lower diameter of 10cm, with the cultivation soil being sandy loam with the same amount, and one plant of mint per basin for normal water and fertilizer management.

On November 27, 2020, 20 basins of mint with basically identical growth conditions were selected for each variety, and the watering was stopped after waterlogging, so that the varieties were naturally subjected to drought.

2.4. Determination of Indexes and Methods

The plant height, crown width, root length, and biomass of different varieties of mint were measured under natural drought stress for 0d, 7d, 12d, 17d, and rehydration for 1d and 3d, respectively, with five replicates for each index.

2.4.1 Plant height and crown width

The plant height and crown width of five varieties of mint, were measured in three basins (measuring 00.00cm) at 4: 00 p. m on 0d, 7d, 12d, 17d, and rehydration for 1d and 3d, and each basin was repeated three times.

2.4.2 Root-crown ratio and root length

The whole plant of mint was dug out, that above-ground and blew-ground part of mint were washed, and the surface moisture was dry by using filter paper. The length of the root lenth was measure by a ruler. The above-ground and below-ground were wrapped respectively and put into an oven for drying to constant weight, and the dry weight of the above-ground and the dry weight of the below-ground were weighed.

Root-crown ratio= Dry weight of below-ground/Dry weight of above-ground

2.5. Data Processing

One-way ANOVA was performed using SPSS26.0 And multiple comparisons were made using Ducan method. The data were all expressed as mean standard deviation, and the figures were all plotted using Origin2019b.

3. CONCLUSION

3.1. Effects of Drought and Rehydration on Plant Height and Crown Width of Five Varieties of Mint Seedlings

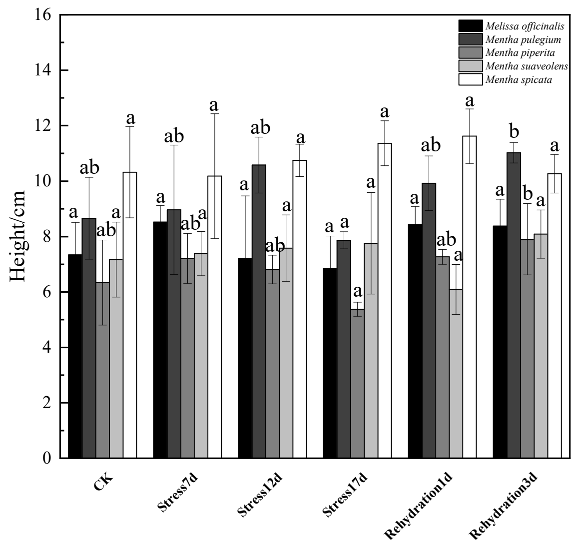

Figure 1. Effects of Drought-Rehydration on plant height of five mint seedlings

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Note: Different lowercase letters indicate significant difference at the 0.05 level between treatments, the same as below

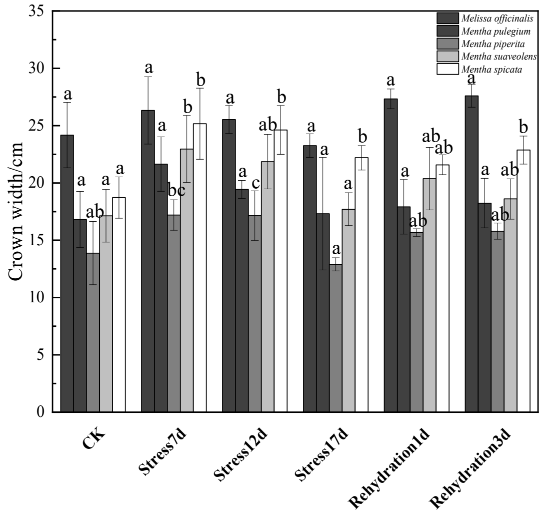

Figure 2. Effects of Drought-Rehydration on crown width of five mint seedlings

As shown in Figure 1, with the onset of drought stress and rehydration, although the change trends of plant height of five varieties of mint were different, the differences among the treatments were not significant (P>0.05). As shown in Figure 2, the crown width of Melissa officinalis and Mentha pulegium did not change significantly under drought stress and treated water. On the other hand, the crown width of Mentha piperita reached its maximum on 7d of drought stress, when it exhibited a significant difference from CK on 12d of drought stress (P<0.05), with the value increased by 23.61%, while it exhibited no significant difference from CK on 17d of drought stress and on 1d and 3d of rehydration (P>0.05).Mentha suaveolens showed significant difference in crown width (P<0.05) on 7d of drought, with an increase of 34.07% and reaching the maximum value, while it was not significantly different from CK on 12d, 17d, 1d and 3d after rehydration (P>0.05),Mentha spicata exhibited significant differences (P<0.05) on days 7d, 12d, 17 of drought and 3d of rehydration, with the growth rates of 34.40%, 31.47%, 18.53% and 22.15%, respectively, reaching the maximum on day 7 of drought.

3.2. Effects of Drought and Rehydration on Root Length of Five Varieties of Mint Seedlings

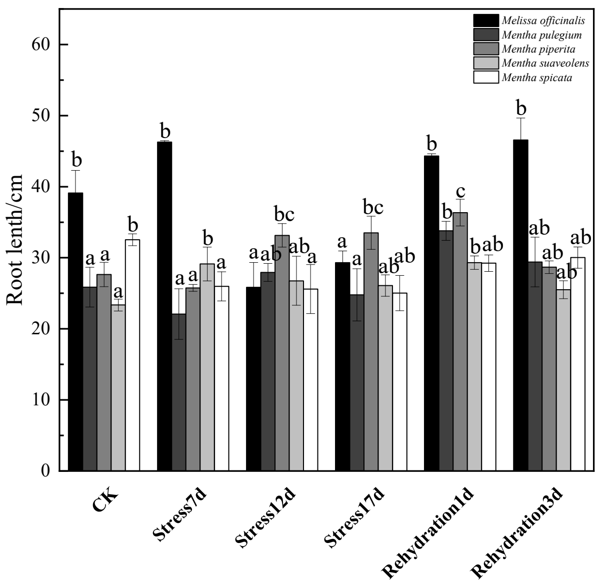

Figure 3. Effects of drought-rehydration on root length of five varieties of mint seedlings

As shown in Figure 3, Under stress, the root length of Melissa officinalis increased first and then decreased, and gradually returned to its original length after rehydration. The root length on 12d and 17d after drought were significantly different from those of CK (P<0.05), decreased by 33.96% and 25.10%.Compared with CK, the difference in root lenth of Mentha pulegium on 1d of rehydration was significant (P<0.05), increased by 30.68%.Compared with CK, the root lenth of Mentha piperita exhibited significant differences on 12d, 17d of drought stress and 1d of rehydration (P<0.05), with increases of 19.92%, 21.18% and 31.49%.After 7d of drought and 1d of rehydration, the root lenth of Mentha suaveolens showed significant differences compared with CK (P<0.05), with increases of 24.75% and 25.53%. Under drought stress and rehydration, the root system of Mentha spicata tended to decrease, with significant differences (P<0.05) to CK between 7d and 12d under drought stress.

3.3. Effects of Drought and Rehydration on Root-Crown Ratio and Biomass of Five Varieties of Mint Seedlings

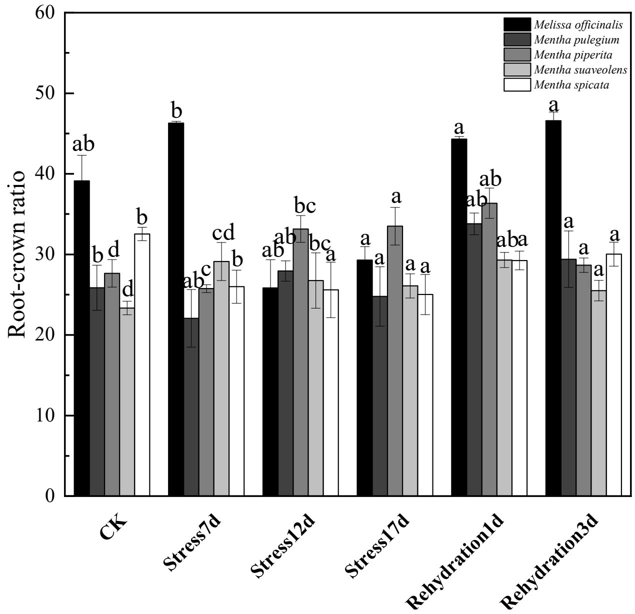

Figure 4. Effects of drought-rehydration on root-crown ratio of five mint seedlings

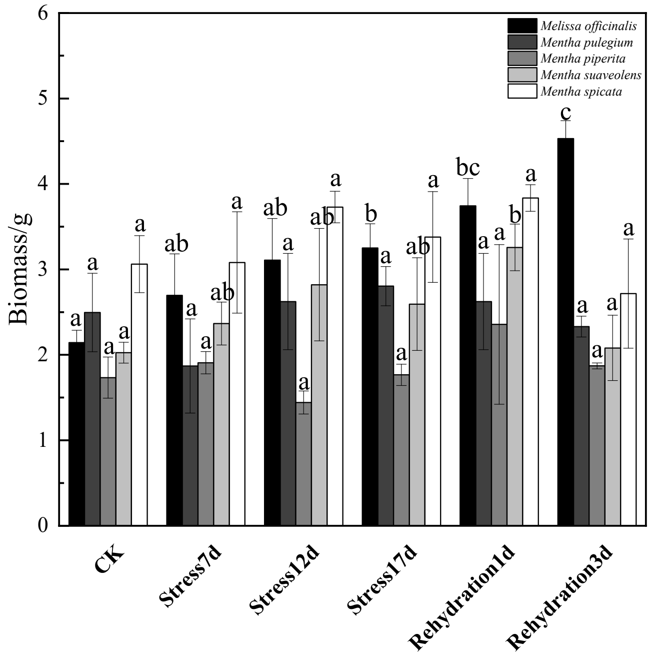

Figure 5. Effects of drought-rehydration on total biomass of five mint seedlings

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As shown in Figure 4, the root-crown ratio of Melissa officinalis showed no significant difference among the treatments (P>0.05). During the experiment, the root-crown ratio of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata generally decreased first, then increased and finally decreased. Compared with CK, the root-crown ratio of Mentha pulegium after drought for 17d and rehydration for 3d were significantly different, with the root-shoot ratios decreased by 62.98% and 58.65%.Compared with CK, the root-crown ratio of Mentha piperita after 7d, 12d, 17d of drought and 1d and 3d of rehydration were significantly different (P<0.05), which were decreased by 41.93%, 47.91%, 81.47%, 71.08% and 74.06%.After 12d of drought stress, the root-crown ratio of Mentha suaveolens and Mentha spicata were significantly different (P<0.05), which was 5 days later than that of Mentha piperita. Theroot-crown ratio of Mentha suaveolens after 12d and 17d of drought stress and 1d and 3d of rehydration were significantly different from those of CK (P<0.05), which were decreased by 15.99%, 31.66%, 67.74%, 59.17% and 67.34%.On days 12 and 17 of drought and 1d and 3d of rehydration, the root-crown ratio of Mentha spicata were significantly lower than those of CK(P<0.05), whitch were decreased by 43.09%, 67.25%, 48.60% and 67.48%.

Table 1. Effects of drought-rehydration on above-ground and below-ground biomass of 5 mint seedlings

Varieties	Stress0d	Stress7d	Stress12d	Stress17d	Rehydration1d	Rehydration3d
Above-ground biomassg						
Melissa officinalis	1.30±0.14a	1.53±0.33ab	1.97±0.15bc	2.30±0.23c	2.49±0.17c	3.03±0.41d
Mentha pulegium	1.48±0.28a	1.27±0.14a	1.77±0.35ab	2.23±0.22b	1.78±0.35ab	2.16±0.01b
Mentha piperita	0.85±0.05a	1.19±0.02ab	0.95±0.14a	1.48±0.11ab	1.8±0.65b	1.48±0.09ab
Mentha suaveolens	1.25±0.09a	1.56±0.21a	2.01±0.60ab	2.16±0.47ab	2.60±0.29b	1.73±0.36ab
Mentha spicata	1.77±0.27a	1.77±0.14a	2.66±0.39ab	2.72±0.47ab	2.78±0.22b	2.20±0.57ab
Blow-ground biomassg						
Melissa officinalis	0.84±0.04a	1.16±0.25ab	1.13±0.34ab	0.95±0.08ab	1.26±0.15ab	1.50±0.38b
Mentha pulegium	1.01±0.30a	0.67±0.32a	0.85±0.25a	0.57±0.02a	0.85±0.25a	0.62±0.11a
Mentha piperita	0.88±0.19c	0.71±0.11bc	0.49±0.08abc	0.28±0.07a	0.56±0.30abc	0.39±0.05ab
Mentha suaveolens	0.78±0.04b	0.80±0.13b	0.81±0.08b	0.43±0.08a	0.66±0.01b	0.35±0.02a
Mentha spicata	1.30±0.11b	1.31±0.47b	1.07±0.24ab	0.65±0.08a	1.06±0.07ab	0.51±0.09a

Note: Different lowercase letters indicate significant difference at the 0.05 level between treatments

As shown in Figure 5, the total biomass of Melissa officinalis was significantly different from that of CK on 17d of drought and 1d and 3d of rehydration (P<0.05), increased by 51.71%, 74.73% and 111.47%. With the prolongation of drought stress, the biomass of Melissa officinalis increased. But it increased more rapidly after rehydration. Drought stress and rehydration treatment had little effect on the biomass of Mentha pulegium, Mentha piperita and Mentha spicata. The biomass of Mentha suaveolens was significantly different from that of CK only on 1d of rehydration (P<0.05).

Referring to Table 1, the above-ground biomass of Melissa officinalis was significantly different from CK on 12d and 17d of drought, 1d and 3d of rehydration (P<0.05). The above-ground biomass reached its maximum on 3d of rehydration. While the below-ground biomass showed a significant difference only on 3d of rehydration (P<0.05).The above-ground biomass of Mentha pulegium was significantly different from CK on 17d of drought and 3d of rehydration (P<0.05).The above-ground biomass reached its maximum on 17d of drought, but there was no significant difference in below-ground biomass (P>0.05). The above-ground biomass of Mentha piperita was significantly different only on 1d of rehydration (P<0.05). And the below-ground

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biomass was significantly different on 17d of drought and 3d of rehydration (P<0.05).Both of which had a decreasing trend. The above-ground biomass of Mentha suaveolens showed significant difference (P<0.05) on 1d of rehydration and reached the maximum value. While the below-ground biomass showed significant difference (P<0.05) on 17d of drought and 3d of rehydration. The above-ground biomass of Mentha spicata reached the maximum value on 1d of rehydration and the below-ground biomass showed significant difference (P<0.05) on 17d of drought and 3d of rehydration.

4. DISCUSSION

4.1. Effects of Drought and Rehydration on Plant Height and Crown Width of Five Varieties Mint Seedlings

The results of this experiment showed that drought and rehydration treatment had little effect on the plant height of five varieties of mint seedlings, but different effects on the crown width. The crown width of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata all reached their maximum values on 7d of drought stress. The crown width of Mentha piperita changed significantly only on 12d of drought stress. It could be speculated that natural drought stress on 12d was beneficial to the growth of the crown width of Mentha piperita. However, if the stress was continued, the crown width and plant height did not increase significantly and they could not return to normal after rehydration. The crown width of Mentha suaveolens changed significantly only after 7d of natural drought. It could be speculated that 7d of natural drought stress was beneficial to the growth of the crown width of Mentha suaveolens, and further long-term drought stress would affect the normal growth of Mentha suaveolens, which might be due to the inhibition of the crown width growth of Mentha haplocalyx seedlings under the continuous drought stress conditions, which showed that the drought stress would affect the leaves and stems of the plants, making the leaves droop and the stems grow poorly. This was consistent with the plant performance of Chen Baoer [19] when conducting the drought stress test on mint and Gynostemma pentaphyllum. The crown width of Mentha spicata changed significantly on 7d, 12d, 17d day of drought stress and 3d after rehydration, which indicated that the crown width of Mentha spicata could still grow normally under drought stress. However, the longer the drought stress lasted, the smaller the crown width increment was. And the crown width could return to normal 3d after rehydration. After rehydration, the crown width increment of Mentha spicata seedling was increased. Rehydration under continuous drought stress promoted the growth of Mentha spicata seedling above-ground which was consistent with the research result of Festuca elata and Stenotaphrum helferi under drought stress by Ge Jingang et al [20]. That is to say, the root system grew in depth under drought stress. And its photosynthetic capacity was strengthened after rehydration. The growth of aerial part was restored, and the plant showed strong recovery capacity.

4.2. Effects of Drought and Rehydration on Root Length of Five Varieties Mint Seedlings

The root lenth is an important organ for the plant to absorb soil moisture and nutrients [21], and its growth and development determine the ability of the plant to absorb and utilize and transport moisture and nutrients [22]. Therefore, the plant root lenth is extremely sensitive to changes in soil moisture environment. The total root length is one of the important indexes for evaluating the drought resistance of plants [23–24]. This study showed that the responses of root length to natural drought stress were different for 17d among the five varieties of mint seedlings. And the root lenth of Mentha piperita and Mentha suaveolens tended to increase, which was consistent with the research result of Pan Yumei [25] on morphological changes of alfalfa root lenth under drought stress. That is to say, under drought stress, plants increased the

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root length to improve the utilization of soil effective resources. Thus responded to environmental changes. The root length of other varieties of mint seedlings showed a downward trend with the decrease amount Melissa officinalis > Mentha spicata > Mentha pulegium, which indicates that drought stress inhibited the growth of the root lenth of the three varieties of mint seedlings, which might be due to the decrease in the photosynthetic capacity of mint seedlings and the decrease in the synthesis of photosynthetic products under water stress, resulting in the corresponding decrease of organic substances transported to the roots [26]. After rehydration, the seedling root length of four other varieties of mint were restored except for seedling root length of Mentha spicata.

4.3. Effects of Drought and Rehydration on Root-crown Ratio and Biomass of Five Varieties Mint Seedlings

Biomass allocation strategy is an important manifestation of plant response to the environment. Plants adapt to environmental changes by adjusting their above-ground and blow-ground biomass [27]. Root-crown ratio is one of the important indexes of plant growth status. Root-crown ratio is an important index reflecting the growth balance between root and above-ground.Its changes reflect the utilization of soil water by plants [28–30]. The results of this experiment showed that the above-ground growth increment of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata was greater than the below-ground growth increment under drought stress and rehydration conditions, indicating that the inhibition effect of drought stress and reclaimed water treatment on the below-ground biomass of these four varieties of mint was greater than its inhibition effect on the above-ground biomass. This study also showed that, with the prolongation of drought stress, the total biomass of five varieties mint seedlings all had an increasing trend, with the increasing amount of Melissa officinalis>Mentha suaveolens>Mentha spicata>Mentha pulegium>Mentha piperita. The results showed that 17-day natural drought stress was beneficial to the growth of above-ground and unfavorable to the growth of below-ground of Melissa officinalis, Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata.It could be speculated that Melissa officinalis had the strongest drought resistance and Mentha piperita was the weakest. On 3d after rehydration, the total biomass increase of five varieties mint seedlings was Melissa officinalis>Mentha pulegium>Mentha piperita>Mentha suaveolens>Mentha spicata.we can guess that Melissa officinalis had the strongest recovery ability after drought stress, while Mentha spicata was the weakest.

In this experiment, five varieties of mint were planted in basins, so the experimental conditions had certain limitations. Due to the limitation of containers, the experimental soil environment was small, which might affect the growth of mint root, and there existed certain differences between the measured data and the actual open field cultivation, which could be further used for verification and analysis of the open field cultivation experiment. In addition, only some growth indexes were selected for this study. But other indexes could be further study, such as the physiological and biochemical indexes of soluble substances, SOD activity, photosynthetic pigment, relative water content, and relative conductivity of five varieties of mint under drought stress and rehydration conditions for further analysis. In order to make the experimental results more convincing and provide a theoretical basis for the drought resistance evaluation and garden application of five varieties mint.

5. CONCLUSION

1) Drought stress and treated water had no significant effect on plant height of five varieties mint, but different effects on crown width. The crown width of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata all reached the maximum under drought stress

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of 7d. Natural drought stress of 12d was beneficial to the crown width growth of Mentha piperita. Natural drought stress of 7d was beneficial to the crown width growth of Mentha suaveolens. However, long-term drought stress affected the crown growth of Mentha suaveolens and Mentha piperita, and they could not be recovered after rehydration. Under drought stress, the crown width of Mentha spicata could still grow normally, but the longer the drought stress was, the smaller the crown width increment was, and the crown width could be restored to normal after rehydration for 3 d.

2) After 17 days of natural drought stress, the root length responses of the five varieties mint seedlings were different. The seedling root lengths of Mentha piperita and Mentha suaveolens tended to increase, while those of other varieties of mint seedlings showed a decreasing trend, with the decreasing amount ofMelissa officinalis>Mentha spicata>Mentha pulegium. After rehydration, the seedling root length of four other varieties of mint were restored except for seedling root length of Mentha spicata.

3) Drought stress and treated water had more inhibitory effect on the below-ground biomass of seedling of Mentha pulegium, Mentha piperita, Mentha suaveolens and Mentha spicata than on the above-ground biomass. The total biomass of seedling of five varieties of mint had an increasing trend under drought stress, which could be speculated that Melissa officinalis had the strongest drought resistance, while Mentha piperita had the weakest drought resistance. Melissa officinalis had the strongest recovery ability after drought stress, and Mentha spicata was the weakest.

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