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Study on the Growth of Thick-Skinned Muskmelon in Different Periods through Changing of Soil Microorganism Caused by Irrigation Schedule

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The soil micro-environment in the root zone of "soil-root system-microorganism and enzyme" is a complicated system. The interaction of various factors determines the material exchange and energy flow between the soil and the ground plant, and ultimately affects the crop growth and yield. Soil moisture is the most important factor, which effects root-zoon soil microbial environment. In this experiment, the muskmelon cultivar "Western Region No. 1" was used as the test material for pot cultivation under the same environmental conditions in the solar greenhouse. By means of drip irrigation, changing the soil microbial environment, we set up five muskmelon treatments. Under different treatments, the upper and lower limits of irrigation were preset in the four main periods of muskmelon growth. The results showed that the morphological indexes of the muskmelon have an increasing trend with the rise in irrigation upper limit in the same growth period. By comparing the effects of different irrigation treatments on the external morphological indexes and internal physiological indexes of muskmelons, we find the relatively suitable irrigation treatment for greenhouse muskmelon growth: T3 treatment, with 60% -70% germination stage, 70% -80% tendril elongation stage, 80% -90% flowering stage, and 60% -70% fruit setting stage.

1. Introduction

The muskmelon (Cucumis melo L., honeydew, casaba, etc.) is a kind of cucurbitaceous annual trailing herbs (Zhang et al., 2013). Native to African and Asian subtropical regions, the muskmelon belongs to photophilous heat-resistant melon vegetables. With "Western Region No.1" as the representative, thick-skinned muskmelons are well-received by consumers due to its supreme taste and rich nutrients. The traditional production region of muskmelons is in western China, witnessing an eastward-moving trend in recent years though. Supported by protective facilities, the early Spring and late Autumn cultivation of muskmelons have been realized in southeastern coastal China (Zhou et al., 1983; Li et al., 2015). At present, the facility-supported cultivated area has reached 2.5 million square hectares. In recent years, muskmelon production has developed rapidly, offering consumers much more kinds of fruits and basically ensuring annual supply (Zhao et al., 2013; Yuan et al., 2015; Niu et al., 2013). The healthy and sustainable development of the muskmelon industry is of great significance to increase farmers' income and promote new rural construction. Over the past decades, the proportion of greenhouse muskmelons in muskmelons is growing. However, the demand for water and fertilizer management is much higher in the high-temperature high-humidity greenhouse than in the open air, which exposes muskmelons to more diseases and pests and causes a reduction in muskmelon quality as well. In light of such problems, how to improve greenhouse melon quality and water and fertilizer utilization rate without the diminution in production becomes an urgent need in greenhouse melon production (Li et al., 2012; Qi et al., 2004; Wang et al., 2010, Patel and Rajput, 2013; Sahrawat, 2012).
In this experiment, to comply with the water consumption characteristics, the irrigation indexes in the four major melon growth stages were set up in different gradients. We collected the statistical data of melon growth, analysed them with scientific methods, and thus obtained the most suitable irrigation amounts in different growth stages. Accordingly, an appropriate irrigation system was drawn up.

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2. Materials and methods

2.1 Test materials

The "Western Region No. 1" was selected as our test material. This hypoxic susceptible mid-early maturing variety grew from the Nanyuanzhuang Production Park (N38 ° 37'46.92 ", E115 ° 31'40.33") in Qingyuan County, whose seedlings were neat, robust and lesser affected by diseases or pests.
The experiment was conducted during March and May 2016, which was close to the spring greenhouse melon cultivation period. The test site is the solar greenhouse of the Agricultural Science Park of Hebei Agricultural University (N38 ° 48'29.39 ", E115 ° 24'41.91"). The parameters of this short adverse grade solar greenhouse of high back wall are: the ridge is 3.5 meters high; the back wall is 2 meters high; the adverse slope is about 1.5 meters long; the greenhouse length is 50 meters; the greenhouse span is 9 meters; the greenhouse interval is about 6 meters.

2.2 Experimental design and methods

2.2.1 Substrate ratio

At the ratio of 3:1, we mixed peat with vermiculite. The mixture was then blended with organic fertilizer at the ratio of 5:1 to facilitate seedling growth. The PH value of the substrates is between 5.5 and 6.5, and the main physical parameters is shown in Table 1 below.

Table 1: Table of main physical properties of the matrix

Substrate bulk density (g/cm3)	Total porosity (%)	Aeration porosity (%)	Water holding porosity (%)	Void ratio (%)
0.52	68.71	8.1	60.58	0.13

2.2.2 Community design

In this experiment, with irrigation amount as the index, five irrigation treatments (T1, T2, T3, T4 and T5) were set up according to randomized blocks design, as shown in Table 2.

Table 2: Experiment treatments Irrigation index design

Treatment	Seedling Stage (%)	Tendril elongation stage (%)	Flowering stage (%)	Fruit setting stage (%)
T1	80~90	80~90	80~90	80~90
T2	70~80	70~80	70~80	70~80
T3	60~70	70~80	80~90	60~70
T4	60~70	80~90	70~80	60~70
T5	70~80	80~90	70~80	60~70

2.3 Determination of indicators and methods

2.3.1 Determination of morphological indicators

(1) Muskmelon plant height and stem diameter
For each treatment, we tested the plant height and stem diameter of five muskmelon seedlings in uniform growth conditions every 2 days. The plant height was measured from the plant base by tape, and the stem diameter was equal to the diameter of the plant base by Vernier calliper. Afterwards, we averaged the five value sets.
(2) Dry-and-wet weights, root-to-stem length ratio, and root-to-shoot ratio
These values could be obtained with seedlings in the various stages of muskmelon growth. The root-to-stem length ratio was obtained by measuring the root length and stem length of the muskmelon seedlings; while the root-to-shoot ratio was equal to the ratio of the dry weight to the wet weight of the muskmelon plants, both underground and above the ground.
(3) Plant height growth rate
The plant height growth rate was equal to the ratio of the net growth between the two measurements to the previous measured value, in which the latter one was regarded as 100%.

2.3.2 Determination of physiological indicators

(1) Leaf moisture content

Five healthy leaves were selected randomly in the same plant node in the fruit setting stage. After being rinsed and weighed the fresh weight, the leaves were placed in an electrothermal blowing dry box for 20 min fixation at 105°C, and then the temperature was lowered to 80°C to dry the leaves until their weight remains unchanged. This weight is called dry weight. The following formula was used to calculate leaf moisture content:

Leaf moisture content = (leaf fresh weight - leaf dry weight) / leaf fresh weight × 100%

2.4 data analysis and processing

SPSS and EXCEL software was used for analysis of variance and map drawing.

3 Results and analysis

3.1 Effects of different irrigation treatments on growth of muskmelons

3.1.1 Effects of different irrigation amounts on plant height and stem diameter

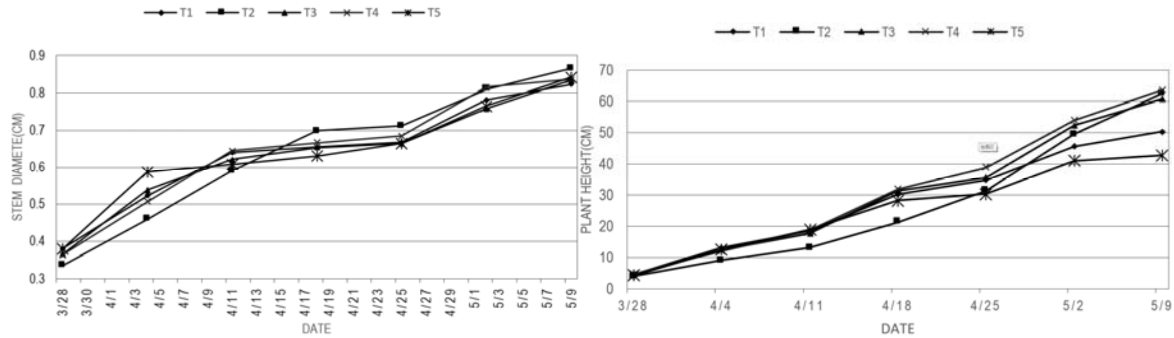

Figure 1: Effect of different irrigation treatments on plant height and diameter of muskmelon

As can be seen from Figure 1, with the elongation of the muskmelon growth period, plant height showed a gradual increase trend. At the seedling stage, the treatments had little effect on the plant height of muskmelons. The plant height grew at a stable but low rate, which was possibly related to the water consumption requirement of the seedlings. After entering the tendril elongation period, the muskmelon plants were mainly vegetative growth, which had faster growth rate and larger required quantity of water. As a result, the growth rate of plant height in the tendril elongation stage increased. During the late tendril elongation stage and the early flowering stage, the growth rates by T3 and T4 treatment were faster than the rest, indicating the positive effect of moderate water shortage in the seedling stage on the later rise in plant height. Therefore, the 60% -70% irrigation index is feasible in the seedling stage. In the early stage of flowering, the trend of plant height growth was slowed down. This was due to the beginning of reproductive growth in this period, featuring higher nutrient consumption and lower rate of plant height change. The trend of stem diameter change of muskmelon plants was similar to that of plant height change. As the growth period was extended, the stem diameter increases gradually.

3.1.2 Effects of different irrigation amounts on root / shoot ratio of muskmelon plants

Table 3: Effects of different irrigation treatments on the muskmelon root and shoot of plants

Treatment	Roots dry weight(g)	Shoot dry weight(g)	Root-shoot ratio	Root-stem length ratio
T1	0.57±0.08c	12.9±0.36b	0.10±0.03c	0.24±0.01a
T2	0.94±0.15b	26.44±3.42a	0.13±0.03b	0.15±0.01c
T3	1.39±0.08ab	27.52±2.09ab	0.18±0.07ab	0.18±0.02c
T4	1.43±0.1a	28.43±1.98a	0.21±0.05a	0.19±0.01bc
T5	0.72±0.11bc	12.32±0.99b	0.14±0.03b	0.23±0.01ab

It can be seen from Table 3 that in terms of root dry weight, the T4 treatment outcome was significantly different from the other ones, achieving the optimal root growth condition. According to the data of root / shoot ratio, the difference between T1 treatment and other treatments was significant. T1 treatment achieved the smallest root / shoot ratio but the relatively large value of root and stem lengths, indicating that the high-water content of the 80%-90% irrigation treatment inhibits the root system growth in favour of the growth of aboveground plant parts. The root and shoot of T3 and T4 treatments were relatively large, which indicated that the early water shortage treatment can promote root system growth and provide a good foundation for the later growth of the plant.

3.2 Study on water consumption requirement of greenhouse muskmelon at different levels of growth

3.2.1 Effects of different irrigation amounts on the growth of muskmelon seedlings

Table 4: Effect of different irrigation treatments on the growth of muskmelon seedlings

Treatment	Plant height (cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width (cm)
T1	7.60±1.27a	0.47±0.02a	6.90±0.17a	6.80±0.52ab
T2	6.00±0.50a	0.39±0.02a	6.23±0.18a	5.83±0.38b
T3	7.43±1.59a	0.44±0.02a	6.13±0.54a	6.10±0.62ab
T4	7.87±1.23a	0.42±0.06a	6.37±0.44a	6.13±0.18ab
T5	9.33±1.02a	0.48±0.02a	6.90±0.35a	7.33±0.22a

It can be seen from the table that the irrigation treatments exert insignificant impact on muskmelon plant height, stem diameter and other external morphological indicators in the seedling stage. The causes of this phenomenon are divided into two main aspects: internal and external factors. Considering the small size of plant and leaf area, week transpiration and small amount of water consumption in the seedling stage, T3 and T4 treatment of 60% -70% irrigation index can meet the water consumption requirements.

3.2.2 The effect of different irrigation amounts on the growth of muskmelon in the tendril elongation stage

Table 5: Effect of different irrigation treatments on growth of muskmelon out vines

Treatment	Plant height(cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width(cm)
T1	32.00±1.15b	0.66±0.02ab	9.60±0.12b	11.10±0.31b
T2	30.67±1.45b	0.56±0.03b	9.50±0.21b	10.73±0.29b
T3	41.33±4.48ab	0.67±0.06ab	10.17±0.68ab	12.00±0.64ab
T4	46.67±0.67a	0.71±0.01a	11.50±0.35a	12.67±0.34a
T5	29.00±1.00b	0.64±0.04ab	10.33±0.18b	11.07±0.38b

It can be seen from Table 5 that the growth rate of the plants is accelerated in the tendril elongation stage, and the external morphological indexes such as plant height and stem diameter are gradually widened in value. Despite the little difference between T3 and T4 treatments, their morphological indexes are pretty different from those in the other treatments, indicating that the high-water content of substrates in the seedling stage and the early tendril elongation stage is detrimental to the normal seedling growth, while the early-stage water shortage treatment is significantly positive to later-stage plant growth.

3.2.3 Effects of different Irrigation amounts on muskmelon growth in the early flowering and fruit setting stage

Table 6: Effect of different irrigation treatments on the growth of muskmelon fruit early

Treatment	Plant height(cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width(cm)
T1	60.67±3.76c	0.78±0.03bc	10.23±0.13b	12.07±0.09b
T2	56.00±3.02c	0.86±0.02ab	10.67±0.37b	11.50±0.40b
T3	105.33±7.96b	0.87±0.05ab	12.47±0.15ab	13.77±0.44ab
T4	116.00±8.38a	0.94±0.01a	13.37±0.35a	14.37±0.38a
T5	55.00±3.51c	0.79±0.04bc	10.63±0.07b	12.20±0.77b

In the early stage of flowering and fruit setting, the growth of muskmelon plants is gradually transited from vegetative growth to reproductive growth, and the growth rates of plant height and stem diameter gradually decrease. It can be seen from Table 6 that the difference of plant height between T3 and T4 treatments and other treatments reaches the maximum level in the early flowering and fruit setting stage, which demonstrates that the overly high-water content is a possible inhibitory factor in normal plant growth, and that the substrate physical property factors (like poor air permeability) cannot be excluded. In terms of the data of stem diameter, the rise in irrigation amount greatly promotes the stem thickening to similar degrees among different treatments. The difference of stem diameter between T3 and T4 treatments is insignificant.

3.2.4 Study on the accumulated irrigation amount in different growth stages of muskmelons

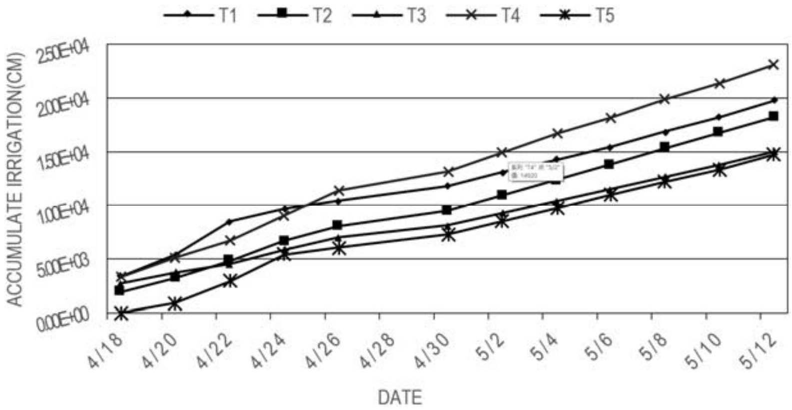

Figure 2: Accumulation stages in the growth period of muskmelon irrigation

It can be seen from Figure 2 that the accumulated irrigation amount is the largest in T4 treatment and the smallest in T5 treatment from the end of the seedling stage to the early flowering and fruit setting stage. Through a comprehensive consideration of muskmelon growth conditions, the muskmelon plant grows to the best states in T3 and T4 treatments, with insignificant differences. Nevertheless, the accumulated irrigation amount in T3 treatment is less than in T4 treatment, demonstrating the better performance of T3 treatment.

4. Discussion and summary

(1) The water shortage treatment of greenhouse muskmelons in the seedling stage has a significant effect on the late growth of stem diameters and roots; in view of the change of leaf area (including the upper limits of leaf length and leaf width), T3 and T4 treatments vary from the other ones in the late stage, with relatively large leaf area that promotes photosynthesis; in terms of the root-shoot ratio, the shoots in T3 and T4 treatments are large, and the root system has relatively strong water absorptivity to support aboveground plant growth, laying benign foundation for the plant's development into reproductive growth.

(2) Processed by water shortage in the early stage, the greenhouse muskmelon enters the reproductive growth which requires more irrigation amounts. Considering the lack of water in the fruit setting stage will affect fruit quality, the plants should be hydrated in time, which is consistent with the research findings of C. Fabeiro et al. The 80% -90% irrigation treatment (T3 treatment) in the flowering and fruit setting stage achieves better result than the T4 treatment does. According to Wells and other experts and scholars, after the muskmelon fruit goes ripe, or in the late stage of fruit setting (i.e. fruiting growing period), overly high soil moisture will significantly reduce the yield and quality of muskmelons.

5. Conclusion

In this experiment, the optimal irrigation treatment combination is obtained by comparing the plant height and stem diameter of each muskmelon. In addition, the experiment also studies on the water consumption requirement of greenhouse muskmelons during the growth period, achieving a series of results. According to the above two points, we develop a feasible irrigation system for the greenhouse muskmelon variety "Western Region No.1", providing a reference for technical personnel at the production line and related experts and scholars. The test results are as follows:

Greenhouse muskmelons require small amount of water in the seedling period, which can be met by 60% -70% irrigation index; the water consumption amount in the tendril elongation stage and, particularly, in the flowering and fruit setting stage rockets due to the quick growth of muskmelon plants, and thus the respective 70% -80% and 80% -90% irrigation indexes should be used; in the maturity stage, in order to improve fruit quality, increase sugar content and reduce the possibility of fruit cracking, we should minimize the amount of irrigation to an appropriate value of 60% -70% irrigation index

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