Effects of Water and Fertilizer Coupling on Growth Indexes of Watermelon under Mulched Drip Irrigation

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Abstract. The objective of this study was to investigate the effects of water and fertilizer coupling on the growth of watermelon under mulched drip irrigation. A field experiment was conducted to study the effects of different irrigation and fertilization levels on the yield and quality of watermelon by using a split block design. The growth indexes of watermelon such as maximum leaf width, stem diameter, root length and main vine length were systematically measured and analyzed. The results showed that the coupling effect of water and fertilizer had significant effects on the growth indexes of watermelon. Under suitable water and fertilizer supply conditions, the maximum leaf width, stem diameter, root length and main vine length of watermelon showed an increasing trend. Among,the combination of medium irrigation level (70-80% of field capacity) and medium fertilization level (80-90% of the recommended fertilization rate) had the best effect. All the growth indexes reached the maximum. Too high or too low levels of irrigation and fertilization will inhibit the growth of watermelon. The coupling effect of water and fertilizer was different in different growth stages, especially in the flowering and fruiting stage. In addition, the study also found that the effect of water and fertilizer coupling on root growth was particularly significant. Appropriate water and fertilizer supply can promote the development of root system to deep soil and improve the efficiency of water and fertilizer use.

Keywords: drip irrigation under Mulched; water and fertilizer coupling; watermelon growth; maximum leaf width; precision irrigation and fertilization.

1. Introduction

Watermelon is one of the most important economic crops in the world, and its production efficiency and quality are directly related to agriculture economy and food safety. In recent years, with the aggravation of climate change and water shortage [2],How to improve the water and fertilizer use efficiency of watermelon planting has become a hot topic in agricultural research [3]. As an efficient water-saving irrigation method [4], drip irrigation under Mulched has been widely used in watermelon cultivation in arid and semi-arid areas [5]. However, it is difficult to meet the demand of high yield and quality of watermelon only by single water or fertilizer management. Water and fertilizer coupling management, as a means of comprehensive regulation and control [6], is expected to improve the efficiency of resource utilization. To achieve the synergistic improvement of watermelon yield and quality. According to statistics, the global watermelon planting area will reach 3.5 million hectares in 2020, and the output will be about 120 million tons. China accounts for more than 60% of global production [7]. However, under the traditional planting mode, the water and fertilizer use efficiency of watermelon is only 30-40%, which seriously restricts the sustainable development of the industry [8]. Therefore, the aim of this study was to investigate the effects of water and fertilizer coupling on physiological growth indexes of watermelon under drip irrigation under Mulched. And provide a theoretical basis and technical support for efficient production of that watermelon.

2. Materials and Methods

2.1 Overview of the test area

This study is planned to be carried out in the oasis cold irrigation area in the middle of Hexi Corridor, Yimin Irrigation Experimental Station, Minle County, Zhangye City, Gansu Province. The climate in this area is dry, the precipitation is scarce and the evaporation is large, the average annual precipitation is about 200 mm, and the annual sunshine hours are about 3000 h. The river source is short of water, and the contradiction between supply and demand is prominent. The irrigation area mainly carries out field water-saving irrigation experiments, starting from the actual needs of farmers in the irrigation area. In order to improve crop water use efficiency and optimize irrigation schedule, the final research results will be widely applied. So as to achieve the purpose of increasing farmers' income.

2.2 Test design

The experiment was conducted in a randomized block design with irrigation and nitrogen application as the factors. According to the growth habits of crops, the growth period of watermelon was divided into four stages: seedling stage, vine extension stage, flowering and fruiting stage and maturity stage. Three nitrogen application levels were set up in the experiment, which were high nitrogen (N1, 300 kg/hm²), medium nitrogen (N2, 240 kg/hm²) and low nitrogen (N3, 180 kg/hm²). 30% of the total amount of the nitrogen fertilizer is used as base fertilizer and is applied in furrows before sowing,The remaining 30% and 40% were topdressed with water by simple Venturi fertilizer applicator at the extension stage and maturity stage of watermelon, respectively. Phosphate and potash fertilizers are all used as base fertilizers. The crop irrigation mode adopts drip irrigation under film. Soil moisture was controlled by three levels of full irrigation (W1), mild regulated deficit (W2) and moderate regulated deficit (W3). The designed upper and lower limits of soil moisture corresponding to each moisture control gradient are respectively. The soil water content accounts for 70%-80%,60%-70%and50%-60% of the field capacity. Watermelon seedling stage and flowering and fruiting stage do not carry out water deficit regulation. There were 10 treatments in the experiment. Water and nitrogen regulation (W1N1, W1N2, W1N3, W2N1, W2N2, W2N3, W3N1, W3N2, W3N3) was carried out at the extension stage and maturity stage of watermelon, respectively. The treatment of full irrigation and no nitrogen application in the whole growth period was the control group (CK). Each treatment and control were repeated 3 times,with a total of 30 plots.

2.3 Measurement index and method

In this study, the maximum leaf width was measured periodically at different stages of watermelon growth using a non-destructive measurement method. The specific determination method is as follows: firstly, 10 representative plants are randomly selected from each treatment plot,And 3-5 fully expanded mature leaves were selected for measurement on each plant. Use an electronic vernier caliper with an accuracy of 0.1mm to measure the width of the widest part of the blade, which is the maximum blade width. Avoid the veins when measuring to ensure the accuracy of the measurement. Each leaf was measured three times, and the average value was taken as the maximum leaf width of the leaf. Finally, the average maximum leaf width of each plant was calculated, and the average value of 10 plants was taken as the maximum leaf width data of the treatment. The measuring time is arranged as follows: measuring once every 7 days from 15 days after the watermelon is planted until the end of the harvesting period. In this way, the dynamic change process of watermelon leaf growth and development can be fully grasped.

2.4 Data analysis

The coupling effects of water and nitrogen on watermelon were comprehensively evaluated by Excel 2010, TOPSIS, principal component analysis and fuzzy comprehensive evaluation.

3. Result

3.1 Change trend of maximum leaf width during growth period

The maximum leaf width of watermelon is one of the important indicators reflecting its growth status, which directly affects the photosynthetic efficiency and yield formation of the plant.In this study, the dynamic monitoring of the maximum leaf width of watermelon during the growth period under different water and fertilizer treatments was carried out. The effect of water and fertilizer coupling on the growth of watermelon leaves was revealed.The results showed that the maximum leaf width of watermelon increased rapidly at first and then tended to be stable during the whole growth period.In the first 30 days after planting, because of the rapid growth of seedlings and the rapid expansion of leaves, the growth rate of maximum leaf width was faster. The following 30-60 days are the rapid growth period of watermelon, and also the most rapid growth stage of the maximum leaf width.During this period, the leaf area expanded sharply, which laid a good foundation for the later fruit development.In the late growth stage (60-90 days), the growth rate of maximum leaf width gradually slowed down, and finally tended to be stable. Different combinations of water and fertilizer treatments had significant effects on the dynamic changes of the maximum leaf width of watermelon.To visually demonstrate this effect, a statistical analysis of the test data was performed, and the results are shown in Table 1:

Table 1. Dynamic changes of maximum leaf width of watermelon under different water and fertilizer treatments (unit: cm)

Treatment	30 days after planting	60 days after planting	90 days after planting
W1N1	15.2 ± 1.1	22.8 ± 1.5	25.3 ± 1.3
W1N2	16.5 ± 1.2	24.7 ± 1.6	27.1 ± 1.4
W1N3	15.8 ± 1.0	23.6 ± 1.4	26.0 ± 1.2
W2N1	17.3 ± 1.3	26.0 ± 1.7	28.6 ± 1.5
W2N2	19.1 ± 1.4	28.7 ± 1.8	31.5 ± 1.6
W2N3	18.2 ± 1.3	27.3 ± 1.7	30.0 ± 1.5
W3N1	16.9 ± 1.2	25.4 ± 1.6	27.9 ± 1.4
W3N2	18.0 ± 1.3	27.0 ± 1.7	29.7 ± 1.5
W3N3	17.4 ± 1.2	26.1 ± 1.6	28.7 ± 1.4
CK	16.3 ± 1.2	24.5 ± 1.6	26.9 ± 1.4

Note: W1, W2 and W3 represent low, medium and high irrigation levels respectively; N1, N2 and N3 represent low, medium and high fertilization levels respectively.Data are mean ± standard error (n = 3).

As can be seen from Table 1, in all process,The maximum leaf width of watermelon under W2N2 (medium level of irrigation and medium level of fertilization) treatment remained the maximum.This indicated that moderate water and fertilizer supply could promote the growth of watermelon leaves to the greatest extent. In contrast,The maximum leaf width of W1N1 (combination of low irrigation level and low fertilization level) treatment was significantly lower than that of W1N1 treatment at all growth stages.The results showed that the insufficient supply of water and fertilizer would significantly inhibit the growth and development of leaves.

3.2 Comparison of the effects of different water and fertilizer treatments on the maximum leaf width

In order to further analyze the effects of different water and fertilizer treatments on the maximum leaf width of watermelon, a detailed comparison and analysis of variance were performed on data from the later stages of fertility (90 days after colonization).The results showed that there was a significant interaction between water and fertilizer treatments on the maximum leaf width of watermelon.

Under the same fertilization level, with the increase of irrigation level, the maximum leaf width of watermelon increased first and then decreased slightly.This indicates that moderate water supply is beneficial to leaf growth, but excessive irrigation may lead to a decrease in soil aeration.It affects root absorption, thus inhibiting leaf growth.Similarly, under the same irrigation level, with the increase of fertilization level, the maximum leaf width also showed a similar trend.The results showed that appropriate fertilization could promote leaf growth, but excessive fertilization might cause nutrient imbalance or salt stress, which was not conducive to leaf development.

In order to compare the effects of different water and fertilizer treatments more intuitively, the maximum leaf width data 90 days after planting were statistically analyzed.The results are shown in Table 2:

Table 2 Effects of different water and fertilizer treatments on the maximum leaf width of watermelon (90 days after planting, unit: cm)

Treatment	Maximum leaf width	Growth rate relative to control (%)
W1N1	25.3 ± 1.3	-
W1N2	27.1 ± 1.4	7.1
W1N3	26.0 ± 1.2	2.8
W2N1	28.6 ± 1.5	13.0
W2N2	31.5 ± 1.6	24.5
W2N3	30.0 ± 1.5	18.6
W3N1	27.9 ± 1.4	10.3
W3N2	29.7 ± 1.5	17.4
W3N3	28.7 ± 1.4	13.4
CK	27.3 ± 1.4	11.4

Note: CK treatment was used as control, and the growth rate = (treatment value-control value)/control value × 100%. Data are mean ± standard error (n = 3).

It can be seen from Table 3-2 that the maximum leaf width of watermelon under W2N2 treatment was significantly higher than that under W2N2 treatment, reaching 31.5cm.It increased by 24.5% compared with the control treatment (W1N1). This confirmed once again that the medium level of water and fertilizer supply was most beneficial to the growth of watermelon leaves.The treatments of W2N3 and W3N2 also showed better effects, which increased by 18.6% and 17.4%, respectively, compared with the control, but were slightly lower than those of W2N2.This indicates that increasing water and fertilizer supply within a certain range can promote leaf growth, but excessive supply may have a negative impact.

It is worth noting that the maximum leaf width under W1N1 treatment is the smallest, only 25.3 cm,This further indicated that the insufficient supply of water and fertilizer would significantly inhibit the growth of watermelon leaves.At the same time, the effect of W3N3 treatment was not as expected, and the maximum leaf width increased by only 13.4% compared with the control, which was lower than that of W2N2 treatment. This may be due to the excessive supply of water and fertilizer leading to the deterioration of the root environment or the nutritional imbalance of the plant.Thus affecting the normal growth of the leaves.Comprehensive analysis shows that W2N2 treatment realizes efficient utilization of water and fertilizer resources while ensuring high yield [9].

4. Discussion

4.1 The role of drip irrigation system under Mulched in water and fertilizer coupling

Drip irrigation system under Mulched plays a key role in achieving the coupling effect of water and fertilizer [10]. The system creates ideal conditions for water and fertilizer coupling by precisely controlling the supply and supply time of water and nutrients [11]. Plastic film mulching can reduce soil water evaporation and maintain a stable water and heat environment in the root zone, which is conducive to the absorption of water and nutrients by roots [12]. The arrangement of drip irrigation

tape enables water and nutrients to be directly transported to the root zone of crops, which greatly improves the utilization efficiency [13]. Meanwhile, adequate nutrient supply ensures the normal development and functional maintenance of photosynthetic organs [14].

The drip irrigation system under Mulched can also flexibly adjust the water and fertilizer supply strategy according to the crop growth stage and environmental conditions. For example, in the flowering and fruiting period and the fruit expansion period, the water and fertilizer supply can be properly increased through the system, to meet the high demand of crops for water and nutrients [15]. This precise management not only avoids the waste of resources and environmental pollution that may be caused by traditional irrigation and fertilization methods. It can also be optimized for different soil types and climatic conditions. Improve water and fertilizer use efficiency and crop yield [16].

4.2 Potential applications of optimized water and fertilizer management strategies

Based on the results of this study, several potential applications of optimized water and fertilizer management strategies can be proposed [17]. First of all, according to the characteristics of water and fertilizer demand in different growth periods of watermelon, a phased water and fertilizer management plan can be formulated [18]. For example, in the seedling stage, water and fertilizer should be properly controlled to promote root development. In the flowering and fruiting period and fruit expansion period, the supply of water and fertilizer should be increased to meet the needs of rapid growth of crops. Secondly, real-time monitoring and regulation of water and fertilizer supply can be realized by using soil moisture sensors and rapid detection technology of nutrient elements. Further improve the management accuracy [19-20]. At the same time, it can be considered to adjust the water and fertilizer management strategy in advance in combination with meteorological forecast information to cope with extreme weather events [21-22].

5. Conclusion

In this study, the effects of water and fertilizer coupling on physiological growth indexes of watermelon under drip irrigation under Mulched were investigated, and the results showed that the suitable water and fertilizer coupling treatment (W2N2) could significantly affect the maximum leaf width of watermelon leaves, and ultimately increase the yield of watermelon. The results showed that the coupling effect of water and fertilizer could realize the efficient use of water and nutrients by regulating the physiological metabolism of watermelon and optimizing the source-sink relationship. The drip irrigation system under Mulched provides technical support for precise water and fertilizer management. Based on these findings, targeted water and fertilizer management strategies, combined with modern agricultural technology, can be developed to further improve the water and fertilizer use efficiency and economic benefits of watermelon cultivation. This study provides a theoretical basis and practical guidance for the efficient cultivation of watermelon, and puts forward some suggestions to promote the sustainable development of water-saving and fertilizer-saving agriculture.

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