The Effects of Water and Nitrogen Regulation on the Growth and Yield of Sweet Pepper

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Abstract. To explore the effects of water and nitrogen regulation on the growth and yield of sweet peppers under subsurface drip irrigation, a crop water and nitrogen regulation experiment was conducted using the "Aisheng Qiamen" sweet pepper as the research object at the Yimin Irrigation Experiment Station in Minle County, Zhangye City, Gansu Province. A total of 9 water and nitrogen treatments and 1 fully irrigated treatment (CK) were set up at each growth stage. The results indicated that different water and nitrogen treatments had significant effects on the plant height, stem diameter and yield of sweet peppers. Under the same irrigation level, the plant height, stem diameter and yield of sweet peppers showed a trend of increasing first and then decreasing with the increase of nitrogen application rate. Among them, the plant height and yield reached the maximum under the W1N2 treatment, and the yield was the best under the W2N2 treatment. Therefore, moderate water and nitrogen regulation is conducive to the increase of plant height, stem diameter and yield of sweet pepper under drip irrigation.

Keywords: Bell pepper; Water and nitrogen regulation; Plant height; Stem thick; yield.

1. Introduction

Capsicum frutescens L. is an annual herb in the Solanaceae family. It is rich in a variety of vitamins and minerals, has excellent taste, rich nutrition and significant medicinal value, and is deeply loved by consumers of all ages. It is widely planted and is one of China's important export vegetables [1-2].

Sweet pepper is a shallow root crop, which is very sensitive to water change, and the lack of water supply will affect the fruit development and yield. Excessive irrigation can lead to plant growth and root diseases [3]. Nitrogen is the key nutrient element affecting the growth of sweet pepper, and it is the fourth main element besides carbon, hydrogen and oxygen. Proper nitrogen supply is conducive to enhancing the vitality of plant roots and ensuring the normal growth and development of crops. However, excessive nitrogen supply will inhibit plant vegetative growth and cause soil environmental pollution [4]. Therefore, the key to good crop growth and development and high and stable yield depends on appropriate water and nitrogen regulation.

2. Materials and methods

2.1 Overview of the study area

The experiment was conducted from May to September 2024 at Yimin Irrigation Experimental Station (100°43′E, 38°39′N) in Sanbao Town, Min le County, Zhang ye City, Gansu Province, with an average altitude of about 1970m. The annual average temperature is 7.6℃, the annual average precipitation is 183-285mm, and the annual average evaporation is about 1638mm. The soil type is light loam, with medium fertility, groundwater depth greater than 20m, and no salinization effect.

2.2 Experimental design and method

A two-factor randomized block design was used in this study. The experimental variety "Aisheng Jiamen" sweet pepper was selected, and the planting mode combined ridging and mulching with drip irrigation under the film was adopted. A total of 10 water and nitrogen control levels were set, and the experimental design was shown in Table 1. Each processing is set up for 3 repetitions, for a total of 30 cells. Two rows in one zone and two rows in one row were adopted, ridge width 70 cm, ridge height 25 cm, ridge spacing 30 cm, single plant planting, planting row spacing 40 cm, plant spacing 40 cm.

Tab.1-1 Experimental design

Treatments	Seeding stage	Blossom and fruit stage	Full fruit stage	Later fruit stage	Nitrogen rate (kg·ha-1)
CK	75-85%	75-85%	75-85%	75-85%	0
W1N1	75-85%	75-85%	75-85%	75-85%	300
W2N1	65-75%	65-75%	65-75%	65-75%	300
W3N1	55-65%	55-65%	55-65%	55-65%	300
W1N2	75-85%	75-85%	75-85%	75-85%	225
W2N2	65-75%	65-75%	65-75%	65-75%	225
W3N2	55-65%	55-65%	55-65%	55-65%	225
W1N3	75-85%	75-85%	75-85%	75-85%	150
W2N3	65-75%	65-75%	65-75%	65-75%	150
W3N3	55-65%	55-65%	55-65%	55-65%	150

Note: The figures in the table indicate the upper and lower limits of designed irrigation volume (percentage of field capacity).

2.3 Determination indexes and methods

2.3.1 Plant height

A steel tape measure with an accuracy of 1 mm is used for measurement.

2.3.2 Stem thickness

CJW888 digital display vernier caliper with accuracy of 0.01mm was used for measurement.

2.3.3 Output

The electronic balance with accuracy of 0.01g was used to weigh the bell pepper harvested from each crop, and the total production of bell pepper in each plot was calculated.

2.4 Data Analysis

Excel 2019 software was used for data sorting, IBM SPSS 26.0 software was used for significance analysis, and Origin 2021 software was used for plotting.

3. Results

3.1 Effects of water and nitrogen regulation on growth dynamics of sweet pepper

3.1.1 Plant height

Table 2-1 reflects the effects of each water and nitrogen regulation treatment on different growth stages of sweet pepper. The plant height of sweet pepper showed a trend of continuous increase

with the advancement of growth period. Under the same nitrogen application level, the plant height of sweet pepper decreased with the decrease of irrigation water. Plant growth was slow at seedling stage, and the difference between treatments was small. With the progress of growth stage, the difference between different water and nitrogen treatments was more significant during flowering and fruit setting period, until the plant height reached the maximum at aftermath stage. During the whole growth period, the plant height of sweet pepper ranged from 13.73 to 61.17cm. In each growth period, the peak value of W1N2 treatment was 16.84-61.17 cm, which was significantly increased by 14.87%-24.51% compared with CK treatment ($P<0.05$).

Table 2-1 Plant height changes of sweet pepper under different water and nitrogen treatments

Treatments	Seeding stage （cm）	Blossom and fruit stage（cm）	Full fruit stage （cm）	Later fruit stage （cm）
CK	14.66±0.23d	30.19±0.78de	40.21±1.19de	49.13±2.21ef
W1N1	15.85±0.23bc	31.26±0.32c	42.34±0.78c	54.29±2.21bc
W1N2	16.84±0.28a	35.85±0.53a	48.46±1.25a	61.17±1.77a
W1N3	16.47±0.17a	34.47±0.13b	45.09±0.84b	57.69±1.58ab
W2N1	15.56±0.24c	30.36±0.48de	42.2±1.01c	53.24±1.66cd
W2N2	16.42±0.49ab	35.42±0.16a	47.57±0.91a	59.36±2.33a
W2N3	16.26±0.11ab	34.11±0.5b	43.76±1.15bc	55.68±1.32bc
W3N1	13.73±0.64e	28.2±0.6f	36.58±0.76f	45.72±1.86f
W3N2	15.29±0.22c	30.71±0.3cd	40.35±1.23d	50.63±2.11de
W3N3	14.34±0.36d	29.77±0.6e	38.44±1.32e	47.04±2.28f

3.1.2 Stem thickness

As can be seen from Table 3-2, in terms of the whole growth period, the plant height of each treatment of sweet pepper showed a rising trend. The growth was slow at seedling stage, and the stem diameter was between 3.93-5.72mm. Flowering and fruiting stage and full fruiting stage increased rapidly, and the average growth rate was 0.19-0.28mm/d and 0.07-0.12mm/d, respectively. Stem diameter continued to increase and reached the maximum in consequence stage, and the average growth rate of each growth stage was as follows: flowering and fruiting stage > full fruit stage > consequence stage > seedling stage. The stem diameter of W1N2 was the highest in the whole growth period (5.72-19.4mm), which was significantly increased by 16.7%-30% compared with CK ($P<0.05$).

Table 2-2 Changes in stem diameter of bell pepper under different water and nitrogen treatments

Treatments	Seeding stage （mm）	Blossom and fruit stage（mm）	Full fruit stage （mm）	Later fruit stage （mm）
CK	4.4±0.15de	9.73±0.5e	13.35±0.42de	15.26±0.39d
W1N1	4.72±0.09c	11.21±0.21cd	13.96±0.39cd	16.06±0.41c
W1N2	5.72±0.24a	12.26±0.31a	15.38±0.55a	19.4±0.69a
W1N3	5.13±0.08b	11.94±0.12ab	14.58±0.46abc	16.58±0.47c
W2N1	4.57±0.2cd	10.89±0.38d	13.22±0.45de	15.17±0.3d
W2N2	5.39±0.19b	12.25±0.16a	14.91±0.52ab	18.14±0.32b
W2N3	4.74±0.14c	11.67±0.36bc	14.28±0.38bc	16.84±0.26c
W3N1	3.93±0.11f	8.73±0.28f	10.76±0.55f	13.45±0.62f

W3N2	4.24±0.09e	9.56±0.21e	12.6±0.5e	14.76±0.48de
W3N3	4.16±0.19ef	9.07±0.11f	12.46±0.61e	14.15±0.18ef

3.2 Influence of water and nitrogen regulation on yield of sweet pepper

Crop yield is mainly determined by internal genetic factors and external environment, and water and nitrogen fertilizer are the two most important factors to regulate crop yield [5]. As shown in Figure 2-1, irrigation, nitrogen application, and water-nitrogen interaction all had extremely significant effects on the total yield of sweet pepper ($P<0.01$). The maximum yield of W2N2 treatment was 45454.17kg • ha-1, which was significantly increased by 33.26%, 29.7% and 54.08% compared with CK, W1N1 and W3N3 treatments ($P<0.05$).W3N3 treatment showed the minimum yield (29499.60 kg • ha-1), which was 15.54% lower than CK treatment, and the difference was significant. It can be seen from the figure that under the same irrigation level, the total yield of sweet pepper increased first and then decreased with the increase of nitrogen application. With the same amount of nitrogen applied, the total yield of sweet pepper increased first and then decreased with the increase of irrigation level.

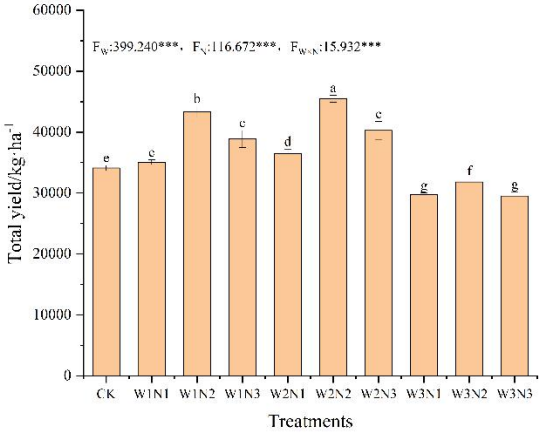

Figure 2-1 Effects of different water and nitrogen treatments on total production of sweet pepper

4. Discussion

The growth and development of bell pepper are closely related to its yield and quality. It was found that different water and nitrogen coupling modes had different effects on plant height and stem diameter of sweet pepper.When the amount of nitrogen applied was the same, the plant height and stem diameter of sweet pepper showed an increasing trend with the increase of irrigation level. During the whole growth period, medium nitrogen treatment (W1N2) obtained the maximum plant height and stem diameter under full irrigation. The growth rate of plant height and stem diameter was the highest in flowering and fruiting stage, followed by full fruiting stage. The reason is that the flowering and fruit-setting stage is the key period for the transformation of vegetative growth into reproductive growth of sweet pepper, while the full fruit stage is mainly fruit-bearing growth, and nutrient distribution is also in progress [6]. The above results are consistent with the research results of Ma et al. [7]. Under different treatments, plant height and stem thickness of sweet sorghum showed a trend of rapid growth in the early stage and a slow increase in the later stage, and then tended to be stable. Pan et al. [8] found that under the same nitrogen application level, cotton plant height and stem diameter increased with the increase of irrigation amount. Under the same irrigation level, plant height and stem diameter had a certain increase trend with the increase of nitrogen application, but this promoting effect would be weakened when increasing to a certain level. This indicates that both low and high nitrogen are not conducive to crop growth, and plant root growth is inhibited and stems are thin and short at low nitrogen level. However, high nitrogen

will cause nitrogen accumulation in soil, inhibit the growth of crop cells and tissues, and thus make crop growth poor.

It was found that the yield of sweet pepper reached the maximum value under the middle water nitrogen treatment, which increased by 4.91-54.08% compared with other treatments. This is consistent with the results of Zhu et al. [9] 's study on tomato, which showed that both crop yield and number of fruit per plant reached the peak under the treatment of medium water and nitrogen, and both low water and low nitrogen and high water and high nitrogen would inhibit the increase of yield. The research results of Zhang [10] also show that excessive water and nitrogen consumption will not only result in reduced production, but also lead to waste of water and fertilizer resources. This is because too little or too much nitrogen fertilizer can inhibit the synthesis of growth hormone in crops, which leads to the reduction of cell division and affects the expansion of fruit development. However, insufficient or excessive water supply will cause water competition between fruits and leaves, resulting in falling flowers, fruit cracking and other phenomena, resulting in decreased yield [11]. Moderate drought stress and nitrogen deficit are conducive to the absorption of soil water and nutrients by crops, giving full play to the coupling potential of water and nitrogen, promoting plant leaf growth and SPAD accumulation, coordinating the distribution of photosynthetic products, avoiding the extravagant consumption of water and nutrients, and increasing yield [12].

5. Conclusion

Different water and nitrogen coupling modes had different effects on plant height and stem diameter of sweet pepper, both of which reached the peak value under W1N2 treatment, significantly increasing by 14.87% to 24.51% and 16.7% to 30% compared with CK treatment ($P<0.05$).

Irrigation and nitrogen application had significant effects on the total yield of sweet pepper ($P<0.05$). The maximum yield of W2N2 treatment was 45454.17kg • ha-1, which was significantly increased by 33.26%, 29.7% and 54.08% compared with CK, W1N1 and W3N3 treatments ($P<0.05$).It can save water, reduce nitrogen, increase and stabilize the yield of sweet pepper cultivation in Hexi oasis.

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