Effects of water-nitrogen coupling on growth, development and yield of pumpkin

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Abstract. To investigate the reasonable water and nitrogen regulation system of drip-irrigated pumpkin in arid and semi-arid areas. A randomized block group design was adopted, and two irrigation levels were set: 55%～65%FC (FC is the amount of water held in the field), 65%～75%FC , and 75%～85%FC (W1, W2, and fully irrigated); and four nitrogen application levels of 100, 150, 200, and 250 kg/hm^2 (pure N) (N1, N2, N3, and N4). The results showed that water and N fertilization had significant ($p<0.05$) effects on pumpkin main vine length and stem thickness. Compared with CK treatment, the other treatments significantly reduced the vine length by 3.58% to 17.14%; compared with W2N3, the other treatments significantly reduced the stem thickness by 1.40% to 13.95%. Under the same level of nitrogen application, pumpkin vine length and stem thickness showed an increasing trend with the increase of irrigation volume, which was shown as fully irrigated>W2>W1. The interaction of irrigation, fertilization and water-nitrogen factors had highly significant effects on pumpkin yield ($p<0.01$), and W2N3 (nitrogen in water in the middle water) obtained a high yield of pumpkin doing (46,031.76 kg/ha^2), and it played a role in saving water and reducing nitrogen and increasing yield for the cultivation of pumpkin in the oasis of the west of the river. The effect of reducing nitrogen and increasing yield.

Keywords: pumpkin; water-nitrogen coupling; drip irrigation; growth characteristics; yield.

1. Introduction

Water resources and nitrogen are critical limiting factors in agricultural production, and the synergistic management of both has a profound impact on crop growth and development and yield formation [1]. According to statistics, agriculture accounts for more than 70% of global freshwater consumption, and resource wastage due to inefficient irrigation is particularly prominent [2]. Meanwhile, nitrogen, as a key nutrient element for plant growth, over-application not only reduces the utilization rate of nitrogen fertilizer, but also triggers environmental problems such as soil acidification and water eutrophication [3-5]. Therefore, how to achieve the efficient use of resources through the synergistic optimization of water and nitrogen has become an important direction of the current agroecological research.

Pumpkin is an annual trailing herbaceous plant with a long history of cultivation and a wide cultivation area. According to the latest FAO statistics, in 2023, China's pumpkin production reached 7.43×106t, ranking first in the world. In recent years, research on pumpkin has focused on variety improvement [6], stress tolerance physiology [7] and cultivation mode [8] optimization. However, systematic studies on water-nitrogen coupling to regulate its morphogenesis, physiological metabolism and yield formation are still insufficient.

In this context, this study took pumpkin as the object to explore the effects of different water and nitrogen ratios on pumpkin growth dynamics and yield composition, aiming to reveal the physiological and ecological mechanisms of water and nitrogen interactions in regulating the growth and development of pumpkin, and to seek for the optimal water and fertilizer management program for pumpkin cultivation in arid and semi-arid areas.

2. Material and methods

2.1 Overview of the test area

The average rainfall in the experimental area for many years was 183-285mm, while the annual evaporation was about 1680mm at the lowest and 2270m at the highest, the annual sunshine hours and total radiation were about 3000h and 139.910kcal/cm2, respectively, the frost-free period was 109-174d, and the wind speed was 2.6-4.1m/s. The soil has a bulk density of 1.4 g/cm3, the maximum water holding capacity of the field is 24%, and the water table is buried at a depth of more than 20m.

2.2 Experimental design

Test variety “Sweet” pumpkin .The experiment was conducted in a randomized block design. Three gradients of soil moisture were set up for the experiment, namely, fully irrigated (75%-85% FC, FC is the amount of water held in the field), moderate water deficit (W1, 55%-65% FC), and mild water deficit (W2, 65%-75% FC); nitrogen application (pure nitrogen) was set up for a total of four levels of 100, 150, 200, and 250 kg/hm2 (N1, N2, N3, and N4), and eight treatments and the control treatment CK (75%-85% FC, with a nitrogen application rate of 250 kg/hm2), as shown in Table 2-1. The protection row spacing was 1.2 m, and each treatment was set up with three replications, and the area of each plot was 18m2 (6m × 3m). Before sowing, urea, calcium superphosphate and potassium sulfate were spread on each plot as basal fertilizer; supplementary fertilizer was applied during the extension period and flowering and fruiting period, and the proportions of nitrogen fertilizer applied during the basal fertilizer, extension period and flowering and fruiting period were 30%, 20% and 50%, respectively, and the nitrogen fertilizer was urea (N: 46.4%). The pumpkin was planted in one film and one row, and the planting method was opposite climbing type with 40cm spacing.

Table.2-1 Experimental design

Treatments	Fertilizer (kg/hm2)	Seeding	Vine extension stage	Flowering and fruiting stage	Fruit expansion stage
W1N1	100	55%～65%	55%～65%	55%～65%	55%～65%
W2N1	100	65%～75%	65%～75%	65%～75%	65%～75%
W1N2	150	55%～65%	55%～65%	55%～65%	55%～65%
W2N2	150	65%～75%	65%～75%	65%～75%	65%～75%
W1N3	200	55%～65%	55%～65%	55%～65%	55%～65%
W2N3	200	65%～75%	65%～75%	65%～75%	65%～75%
W1N4	250	55%～65%	55%～65%	55%～65%	55%～65%
W2N4	250	65%～75%	65%～75%	65%～75%	65%～75%
CK	250	75%～85%	75%～85%	75%～85%	75%～85%

Note: The figures in the table are the upper and lower limits of soil moisture design.

2.3 Indicator measurements and methods

2.3.1 Growth indexes

Six pumpkins were randomly selected in each plot, and the length of the main vine was measured with a steel tape measure with an accuracy of 0.1cm, and the diameter at the stalk 1cm above the ground was measured with a digital vernier caliper with an accuracy of 0.001mm.

2.3.2 Yield

An electronic scale with an accuracy of 0.01 g was used for weighing and calculating the yield of each plot and the average yield of three replicates of each treatment was taken for analysis.

2.4 Data statistics and analysis

Microsoft Excel 2019 and SPSS26.0 were used for data calculation and analysis, Duncan method was used for multiple comparisons, and Origin software was used for plotting.

3. Results

3.1 Effects of water-nitrogen coupling on pumpkin growth indexes

3.1.1 Effect of water-nitrogen coupling on the length of pumpkin main vine

The effects of different water and nitrogen treatments on the main vine length of pumpkin are shown in Table 2-1. The single factors of irrigation and fertilization had highly significant ($p<0.01$) effects on the main vine length at the whole reproductive stage, and the effects of water and nitrogen interactions on the vine length of pumpkin varied at each reproductive stage. Overall, vine length was positively correlated with water irrigation and nitrogen fertilization factors. At the fruit expansion stage, the size of main vine length under nitrogen fertilizer factor was N4>N3>N2>N1; the size of main vine length under irrigation factor was fully irrigated>W2>W1; the main vine length reached the maximum under CK treatment, which was not significantly different from W2N4 treatment but significantly higher than the other treatments ($p<0.05$), and increased by 13.21% and 1.54% compared with W1N1 and W2N3, respectively. It can be seen that increasing the irrigation volume and nitrogen fertilizer is beneficial to promote the growth of pumpkin main vine length.

Table.3-1 Changes in the main vine length of pumpkin under different water and nitrogen treatments

Treatments	Seeding(cm)	Vine extension Stage(cm)	Flowering and fruiting stage(cm)	Fruit expansion Stage(cm)
W1N1	19.20±0.59e	200.61±5.32e	382.11±10.06e	492.65±9.55f
W2N1	19.66±0.46de	207.82±7.68de	425.23±8.16d	507.38±5.37e
W1N2	20.35±0.60de	216.83±6.64d	447.77±3.66c	516.51±5.04de
W2N2	20.33±0.56c	237.88±7.69c	455.39±2.34bc	526.40±5.29cd
W1N3	20.21±0.26d	239.24±4.40c	461.63±3.51ab	529.45±8.13c
W2N3	21.62±0.35bc	240.80±5.21c	471.12±6.14a	549.28±5.31b
W1N4	21.15±0.43c	251.87±7.18b	453.85±11.2bc	535.68±6.18c
W2N4	22.34±0.34b	266.77±6.40a	462.57±10.69ab	557.72±7.13ab
CK	23.17±0.54a	275.55±7.69a	470.59±9.27a	561.50±4.83a
W	**	**	**	**
N	**	**	**	**
WxN	*	*	**	ns

Note: ** denotes p<0.01,** denotes p<0.05, the same as below.

3.1.2 Effect of water-nitrogen coupling on pumpkin stem thickness

The effects of water-nitrogen coupling on pumpkin stem thickness are shown in Table 2-2. The results showed that the effects of irrigation volume and nitrogen fertilizer on pumpkin stem thickness were highly significant (p<0.01), and the effects of water-nitrogen interaction on pumpkin stem thickness were different, with a significant effect in the seedling stage (p<0.05) and a highly significant effect in the rest of the periods (p<0.01).

In terms of the whole life span, stem thickness increased rapidly from the seedling stage to the elongation stage, stabilized at the flowering and fruiting stage, and reached a maximum at the fruit expansion stage; the whole life span showed a trend of increasing stem thickness with irrigation and nitrogen level. By the time of maturity, stem thickness under W2N3 treatment reached the maximum (22.8 mm), which increased by 16.21% compared with W1N1 (19.62 mm) treatment, and was not significantly different from CK treatment, but significantly higher than other treatments (p>0.05). The stem thickness under the fertilizer factor was N4>N3>N2>N1; and the stem thickness under the influence of irrigation factor was CK>W2>W1. In conclusion, increasing the nitrogen and irrigation levels were beneficial to the development of pumpkin stem thickness.

Table.3-2 Changes in the main vine length of pumpkin under different water and nitrogen treatmentsb

Treatments	Seeding(cm)	Vine extension Stage(cm)	Flowering and fruiting stage(cm)	Fruit expansion Stage(cm)
W1N1	11.03±0.21f	16.62±0.15f	18.67±0.22e	19.62±0.18f
W2N1	11.45±0.20e	17.97±0.24e	20.18±0.29d	20.93±0.24e
W1N2	12.36±0.09d	17.61±0.18e	19.80±0.26d	20.44±0.24d
W2N2	13.24±0.26c	19.13±0.23c	20.93±0.24bc	21.76±0.26bc
W1N3	13.32±0.19c	18.72±0.33d	20.63±0.28c	21.48±0.25c
W2N3	13.66±0.09b	19.49±0.22bc	21.23±0.07ab	22.8±0.22a
W1N4	13.41±0.15bc	19.17±0.30c	20.91±0.32bc	21.62±0.16bc
W2N4	13.73±0.20b	19.85±0.20b	21.11±0.19b	21.90±0.20b
CK	14.14±0.14a	20.47±0.12a	21.54±0.10a	22.48±0.14a
W	**	**	**	**
N	**	**	**	**
WxN	*	**	**	**

3.2 Effect of water-nitrogen coupling on pumpkin yield

The effect of water and nitrogen regulation on pumpkin yield is shown in Figure 3-1, and the results of ANOVA showed that the interaction of irrigation, fertilization and water and nitrogen had highly significant effects on pumpkin yield (p<0.01). Pumpkin yield showed a slow increasing trend with the increase in irrigation, and at the same level of irrigation, it showed an increasing and then decreasing trend with the increase in the level of nitrogen application, which reached a maximum under the W2N3 treatment (46031.76 kg/ha2), significantly higher than the other treatments, and increased by 4.14% compared to the CK (44200.24 kg/ha2), and increased by 4.14% compared to the W1N1 (34698.61 kg/ha2) increased by 32.66% as compared to W1N1 (34698.61 kg/ha2). At W2 level, yield gradually increased with increase in N application and decreased when N level reached N4. Yield was ranked in order of irrigation factor: adequate irrigation > W2 > W1 and in order of fertilization factor: N3 > N4 > N2 > N1.

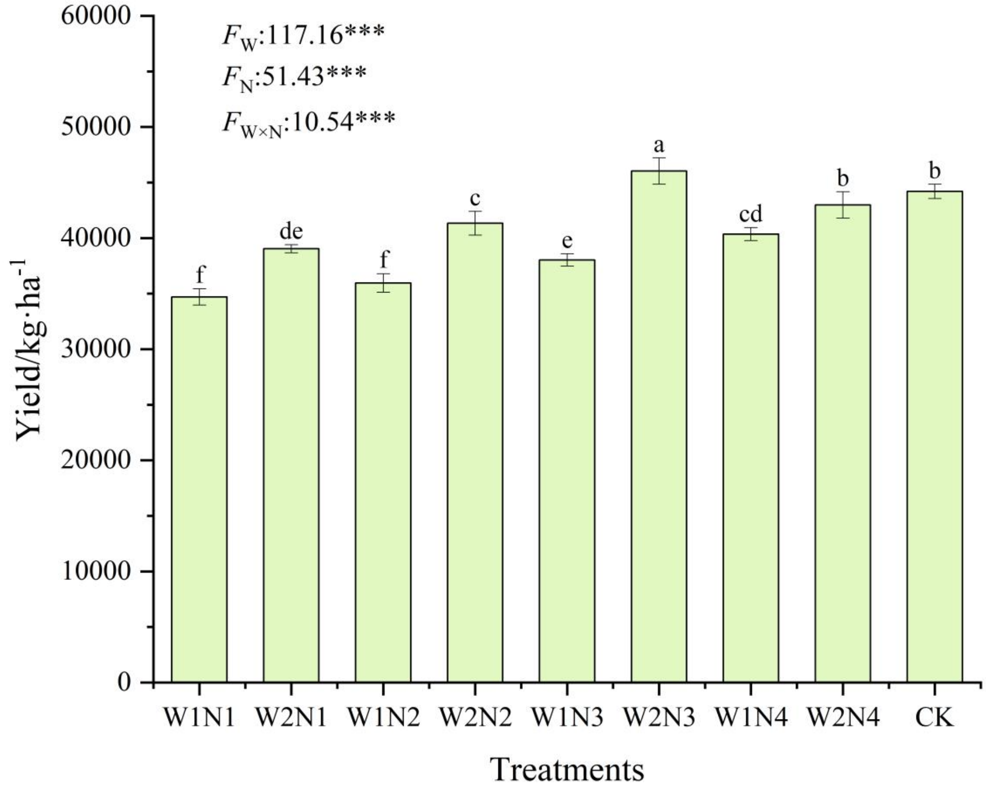

Fig. 3-1 Effects of different water and nitrogen treatments on yield of pumpkin

4. Discussion

In irrigated agriculture in dry areas, rational water and nitrogen regulation is an effective way to improve crop growth and development. The results of this study showed that increasing nitrogen fertilizer and irrigation quota could significantly promote the growth of pumpkin plants within a certain range, which was consistent with the results of Cheng et al [9]. At the same level of N application, pumpkin main vine length showed a significant increase ($p<0.05$) with the increase of irrigation water at the seedling stage. At the same level of N application, pumpkin stem thickness showed that fully irrigated > W2 > W1. At the fruit expansion stage, the main vine length reached the maximum in the high water and high N (CK) treatment, the stem thickness reached the maximum in the medium water and high N (W2N3) treatment, and both the vine length and the stem thickness in the low water and low N (W1N1) treatment were the smallest. The high water and high nitrogen treatments caused pumpkin vine length and branch and leaf futility, forcing pumpkin to convert nutrients to vine length and branch and leaf, as well as having an inhibitory effect on the growth of stem thickness. Yang et al. [10] in watermelon found that under the same fertilization level, increasing the irrigation volume is beneficial to the growth of main vine length in watermelon, but too high irrigation volume will inhibit the reduction of stem thickness.

Water and fertilizer regulation is a key field technology for coordinating nutritive and reproductive growth and achieving increased crop yields. This study showed that pumpkin yield was positively correlated with irrigation level, which first increased and then decreased with fertilization level; the effect of irrigation was greater than fertilization, and appropriate irrigation and fertilization could increase pumpkin yield, which was consistent with the results of the previous study [11], and elevating irrigation at high fertilizer levels did not have a significant effect on pumpkin yield, water-nitrogen coupling at higher nitrogen fertilizer levels can have a negative effect and inhibit yield formation, Li et al. [13] and others found that appropriate water and nitrogen regulation can compensate for the reduction in yield caused by the lack of both, but too much of both can lead to a reduction in crop yield, which is consistent with the results of this study.

5. Conclusions

Moisture and nitrogen fertilizer significantly ($p<0.05$) affected both main vine length and stem thickness of pumpkin. Compared with CK treatment, the other treatments significantly reduced the vine length by 3.58% to 17.14%; compared with W2N3, the other treatments significantly reduced the stem thickness by 1.40% to 13.95%. Under the same level of nitrogen application, pumpkin vine length and stem thickness showed an increasing trend with the increase of irrigation, which was manifested as fully irrigated>W2>W1.

The interaction of irrigation, fertilization and water and nitrogen factors all had highly significant effects on pumpkin yield ($p<0.01$), W2N3 (nitrogen in medium water) gained pumpkin do high yield (46031.76 kg/ha2), and it had the effect of water saving, nitrogen reduction and yield increase on pumpkin cultivation in Hexi Oasis.

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References

[1] Janni M, Maestri E, Gullì M, et al. Plant responses to climate change, how global warming may impact on food security: a critical review [J]. Frontiers in Plant Science, 2024, 141297569-1297569.

[2] Suyala Q, Li Z, Zhang Z, et al. Developing a Hyperspectral Remote Sensing-Based Algorithm to Diagnose Potato Moisture for Water-Saving Irrigation[J]. Horticulturae, 2024, 10(8):811-811.

[3] S. B V, Rebecca Z, Paramu M. The Effects of Different Tillage Techniques and N Fertilizer Rates on Nitrogen and Phosphorus in Dry Land Agriculture [J]. Agronomy, 2022, 12(10): 2389-2389.

[4] Ma Y, Wang JH, Wang C, et al. Effects of water and fertilizer regulation on yield, quality, and water and nitrogen use efficiency of alfalfa [J]. Water Resources Planning and Design, 2023, (07): 88-95.

[5] Yan SJ, Fang YL, Zhang ZJ, et al. Research progress on the impact of nitrogen fertilizer application on crop growth and development [J]. Agricultural Technology and Equipment, 2022, (04): 45-47.

[6] Dong J. Optimization of in vitro regeneration system and preliminary exploration of genetic transformation of oilseed American pumpkin [D]. Inner Mongolia Agricultural University, 2024. DOI: 10.27229/d.cnki.gnmnu.2024.000747.

[7] Xu K. Physiological response of oilseed American pumpkin to powdery mildew stress and identification of VQ gene family related to disease resistance [D]. Inner Mongolia Agricultural University, 2022. DOI: 10.27229/d.cnki.gnmnu.2022.001165.

[8] Liu X. Key technologies for high-yield cultivation of pumpkin in plastic greenhouses [D]. Northwest A&F University, 2016.

[9] Cheng LF. Effects of fertilization methods and nitrogen, phosphorus, and potassium application rates on growth, yield, and quality of honey pumpkin [D]. Hunan Agricultural University, 2020.

[10] Yang XZ. Study on the coupling effect of water and fertilizer on greenhouse watermelon under drip irrigation [D]. Northwest A&F University, 2014.

[11] Budak E, Güneş A. The effects of potassium applied at different doses and times on the yield and nutrient content of pumpkin seed(Cucurbita pepo L.)[J]. Gesunde Pflanz, 2023, 75(6):2879- 2887.

[12] Wuchao L, Lei L, Wei W, et al. Research on the coupling effect of water and nitrogen and the efficient utilization of water and fertilizer in wheat [J]. Acta Agriculturae Boreali-Sinica, 2018, 33(05): 232-233.