

Response of water and nitrogen coupling to zinnia growth in arid areas

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Abstract. In order to evaluate the effect of water and nitrogen coupling on the growth of zinnia in arid areas, this study took the tall zinnia of the "Pink Dreamland" series as the research object, and used the integrated technology of drip irrigation and water and fertilizer under film to fertilize and irrigate, and a total of 3 water regulation levels and 3 nitrogen application levels were set up, among which the water regulation levels were W_1 (75%~85% field water holding capacity FC), W_2 (65%~75%FC) and W_3 (55%~65%FC). The nitrogen fertilization levels were N_1 (90 kg·ha⁻¹), N_2 (150 kg·ha⁻¹) and N_3 (210 kg·ha⁻¹). Based on three different irrigation levels and nitrogen application, 9 water nitrogen control treatments and one control treatment (CK) based on full irrigation (W_3) and local nitrogen application (270 kg·ha⁻¹), with a total of 10 water nitrogen combination treatments. The results showed that the SLA, Ph, Sd, Pn and Tr of Zinnia zinnia first increased and then decreased under low nitrogen conditions and showed a wave-like undulating trend of first increasing and then decreasing under medium and high nitrogen conditions. Compared with the other treatments and CK, W_2 N_2 significantly increased the content of SLA, Ph, Sd, Pn, Tr and soluble protein by 9.41%~43.08%, 6.87%~14.98%, 9.53~17.42, 6.20%~57.27, 1.83%~16.37 and 9.85~21.11, respectively. Therefore, the above trends indicate that the appropriate water-nitrogen ratio can promote the photosynthesis of Zinnia, increase the accumulation of nutrients in Zinnia, and increase its resistance to drought environment.

Keywords: Arid regions; Zinnia; Growth indicators; Physiological characteristics; Resistance.

1. Introduction

Zinnia (*Zinnia elegans* Jacq.) is native to Mexico, is one of the heat-tolerant flower varieties in summer and autumn in the southern subtropical region, with large and bright flowers, rich flower colors, delicate flower shapes, early flowering, long flowering period, beautiful plant type, is a common flower bed, flower material, dwarf species can be potted, and high-stem varieties are suitable for cut flower production. Its status is second only to marigolds, and together with marigolds, petunias, and a bunch of red, it is known as the four great King Kongs of grass flowers. Zinnia prefers warmth, is not cold-tolerant, likes sunlight, is afraid of heat, is strong, drought-resistant, barren, and avoidable, with deep roots and hard stems that are not easy to lodge, and should grow in fertile deep soils, with a suitable temperature of 15-30°C during the growth period [2]. Zinnia is widely cultivated in China, mainly in Yunnan and Sichuan, and is often found on roadsides, courtyards, and hillside wastelands [3]. As an important ornamental plant, zinnia is widely used in landscaping and home gardening because of its rich flower color and long flowering period. In recent years, with the increasing attention to urban beautification and ecological environment, the cultivation area of Zinnia has been expanding [4]. However, water shortage and nutrient insufficiency in arid areas have led to poor plant growth and reduced flowering quality, which have limited the growth and ornamental quality of zinnia and seriously affected the ornamental and economic value of zinnia [5].

Water and nitrogen regulation are important cultivation and management measures. Water is involved in photosynthesis, nutrient transport and metabolism in plants, while nitrogen is the

constituent element of important biomolecules [6]. Rational moisture and nitrogen in the physical environment can improve the growth rate and flowering quality of plants, which is of great significance for optimizing cultivation management and enhancing the ornamental value and ecological benefits of zinnia [7]. Under drought conditions, it is even more important to manage water and nitrogen reasonably and effectively, which can not only improve water use efficiency but also enhance the resistance of plants [8]. As the mineral element with the highest demand from plants, the availability of nitrogen is significantly affected by water supply [9]. Therefore, the influence of reasonable physical environment regulation on the growth of Zinnia in arid areas is of great significance for optimizing its cultivation management and improving its ornamental value. as shown in Figure 1.



Fig. 1 Growth dynamics of zinnia in each period

2. Materials and methods

2.1 Overview of the study areas

The experiment was carried out in Yimin Irrigation Experimental Station, Minle County, Zhangye City. The coordinates are 100 43 ' E and 38 39 ' N, an elevation is about 2000 m. This area is in the west of the Yellow River, in the middle of the Qilian Mountains and Heli Mountains. Dry climate, drastic cold and hot climate, dry water shortage. The annual total rainfall is 183~285mm and the annual sunshine hours are greater than or equal to 3,000 h. The soil is light loam, The maximum FC is 23.47%~24.53%, the soil capacity is 1.4 t / m³, low groundwater level (more than 20 m), no salinization effect.

2.2 Experimental design

After screening, the most suitable varieties for local planting are the pink Dream Zinnia series. This variety is one of the most popular mainstream varieties of zinnia, and its advantages are large flowers, flower diameter of about 10 cm, double-petaled flowers, high temperature resistance, and bright flower color. The suitable temperature for growth is 20 °C to 35 °C, the flowering is early, and the flowering is 50 to 55 days after sowing. It is an excellent variety suitable for summer cultivation and is very popular with consumers. In this experiment, the split-zone design was adopted, and two factors were set up for water and nitrogen regulation, in which the nitrogen application level was used as the main area, the irrigation level was used as the secondary area, and the other environmental factors remained unchanged. The experimental design scheme is shown in Table 1:

Table 1. Experimental Design

| Treatment | Irrigation method | Irrigation amount(%) | N (kg/hm ²) | P ₂ O ₅ (kg/hm ²) | K ₂ O (kg/hm ²) | N base and top-dressing ratio |
|-----------|-----------------------------|----------------------|-------------------------|---|--|-------------------------------|
| W1N1 | Sub-surface drip irrigation | 55-65 | 90 | 100 | 150 | 4: 6 |
| W2N1 | | 65-75 | 90 | | | 4: 6 |
| W3N1 | | 75-85 | 90 | | | 4: 6 |
| W1N2 | | 55-65 | 150 | | | 4: 6 |
| W2N2 | | 65-75 | 150 | | | 4: 6 |

| | | | | | | |
|------|--|-------|-----|--|--|------|
| W3N2 | | 75-85 | 150 | | | 4: 6 |
| CK | | 75-85 | 270 | | | 4: 6 |
| W1N3 | | 55-65 | 180 | | | 4: 6 |
| W2N3 | | 65-75 | 180 | | | 4: 6 |
| W3N3 | | 75-85 | 180 | | | 4: 6 |

2.3 Measurement indicators and methods

2.3.1 Growth traits

After sowing plant height (Ph), stem diameter (Sd) and leaf area per plant (LA) for 2 weeks. The first measurement of Ph and Sd was taken for the three zinnia plants selected for each plot with a steel tape measure and an electronic vernier caliper, and then at the end of each growth period. Leaf area was determined using the traditional fixed-point punching method.

2.3.2 Photosynthetic physiological indicators

The photosynthetic physiological indexes of zinnia were determined by LI-6400 type, portable photosynthetic analyzer (USA). Chlorophyll is determined using a portable chlorophyll meter. On cloudless and sunny days, three zinnia plants with the same growth and three true leaves of the same size in direct sunlight were selected at the appropriate time in each plot to take turns for zinnia net photosynthetic rate (Pn), stomatal conductance (Gs) and transpiration rate (Tr) throughout the day.

2.3.3 Determination of stress resistance index

The stress resistance index was determined by randomly selecting three zinnia plants with similar growth in each plot, harvesting fresh leaves, cutting them into a mortar and grinding them into pulp, and using the Coomassie Brilliant Blue G-250 method and spectrophotometer colorimetry to measure the soluble protein content of the plants.

2.3.4 Determination of soil temperature and moisture content

(1) Soil temperature

During the growth cycle of zinnia, a right-angle geothermometer was used, and the average soil temperature of the surface layer of two adjacent plants representing the growth potential of each plot was selected in each plot.

(2) Soil moisture content

The field water holding capacity of the tillage layer in the experimental field was measured by the indoor method, and the soil moisture content with a total depth of 100 mm was measured every 20 mm. After water absorption, the soil moisture content was obtained by drying method (Equation 2-1) in the soil sample in the ring knife.

3. Result

3.1 Effects of water and nitrogen regulation on physiological characteristics of zinnia in arid areas

In this experiment, the results of this experiment showed that the physiological characteristics of zinnia under each treatment were investigated at the Yimin Irrigation Experimental Station in Zhangye City, Gansu Province in 2024 (as shown in Table 2), and the results showed that SLA, Ph, and Sd showed significant differences in SLA, Ph, and Sd at the same nitrogen application level, only at the mild water deficit (W1), and the overall difference in other irrigation levels was not significant. Under the same irrigation level, SLA, Ph and Sd were significantly different under different nitrogen application levels. Among them, W₂N₂ significantly increased by 9.41%~43.08%, 6.87%~14.98%, 9.53~17.42 and 6.20%~57.2 in SLA, Ph, Sd, Pn and Tr, respectively. The results

showed that the supply of nitrogen determined the biomass of crops, and the stability of crop biomass and photosynthetic rate could be ensured through reasonable regulation of water and nitrogen, which had significant advantages over traditional water and fertilizer treatments. Therefore, under drought stress, reasonable physical environment regulation can promote root development, increase leaf area and biomass accumulation, and promote its normal growth.

Table 2. Effect of different water nitrogen regulation on the physiological characteristics of zinnia in arid areas

| Treatment | SLA/m ² | Ph/mm | Sd/mm | Pn/ $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ | Tr/ $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ |
|-----------|--------------------|----------|---------|---|---|
| W1N1 | 0.65d | 123.83d | 17.92cd | 11.90e | 12.89c |
| W2N1 | 0.66d | 126.60cd | 18.20bc | 12.96de | 13.19bc |
| W3N1 | 0.75bc | 127.78c | 18.65b | 13.44d | 13.42b |
| W1N2 | 0.73c | 128.6bc | 18.81b | 15.29c | 14.31ab |
| W2N2 | 0.93a | 142.38a | 21.37a | 20.60a | 15.00a |
| W3N2 | 0.80bc | 137.95ab | 19.27ab | 17.58b | 14.24ab |
| CK | 0.73c | 129.80bc | 18.52bc | 14.85cd | 13.74b |
| W1N3 | 0.71cd | 127.90c | 18.01c | 14.49cd | 13.84b |
| W2N3 | 0.85b | 133.23b | 19.51ab | 18.38ab | 14.73ab |
| W3N3 | 0.78bc | 132.68b | 18.76b | 17.02bc | 14.22ab |

3.2 Effects of water and nitrogen regulation on zinnia stress resistance in arid areas

Drought stress inhibits the growth of zinnia, while physical environment regulation of water and nitrogen can enhance the photosynthetic capacity of Zinnia, increase chlorophyll and photosynthetic rate, provide more energy for the plant, enhance root water absorption capacity, and reduce water loss [10]. As can be seen from Figure 2, different water and nitrogen management results in different soluble protein content in zinnia, among which the soluble protein content of W2N2 reaches a higher value of .46 mg/g, which is significantly increased by 9.85% ~ 21.11% compared with other treatments. The results show that an appropriate supply of water and nitrogen can promote the accumulation of soluble protein, soluble sugar and other osmotic adjustment substances, help cells maintain osmotic balance, and improve stress resistance. Therefore, through scientific management, zinnia can maintain high growth activity, productivity and best ornamental effect under drought conditions. Therefore, the water and nitrogen scheme play an active role in the development of ornamental flower industry in arid or semi-arid areas.

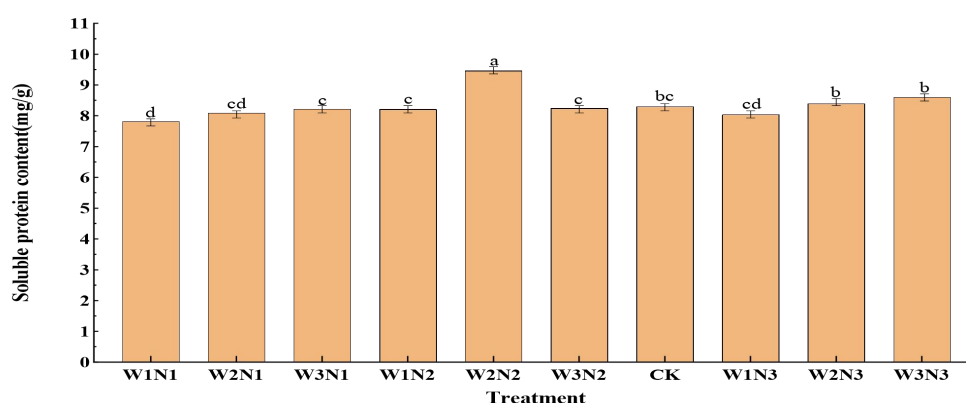


Fig. 2 Differences in soluble protein of zinnia by different water nitrogen treatments

3.3 Effects of water and nitrogen regulation on zinnia soil environment in arid regions

Under drought conditions, reasonable physical environment regulation can ensure the quantity and quality of zinnia flowering, as well as the content of medicinal components, and maintain its ornamental and medicinal value [11]. Appropriate water and nitrogen treatment can improve soil structure by increasing soil enzyme activity and microbial community diversity [12]. As can be seen

from Figure 3 below, the soil moisture content showed a gradual increasing trend with the increase of irrigation amount W1~W3. Under the same irrigation conditions, the soil moisture content of W1 showed a linear upward trend with the increase of nitrogen application rate, while the soil moisture content of W2 and W3 showed a wave-like floating trend of first increasing and then decreasing with the increase of nitrogen application rate. Under the same irrigation rate under the same irrigation rate in each treatment, there was no significant difference in soil temperature between W1 and W2 nitrogen application levels ($p, >0.05$), but the temperature difference between nitrogen application levels in W2 was significant ($p < 0.05$). It can be concluded that the irrigation amount has a great influence on the soil moisture content, and the nitrogen application rate plays a decisive role in the influence of soil temperature, and the irrigation amount plays an auxiliary role.

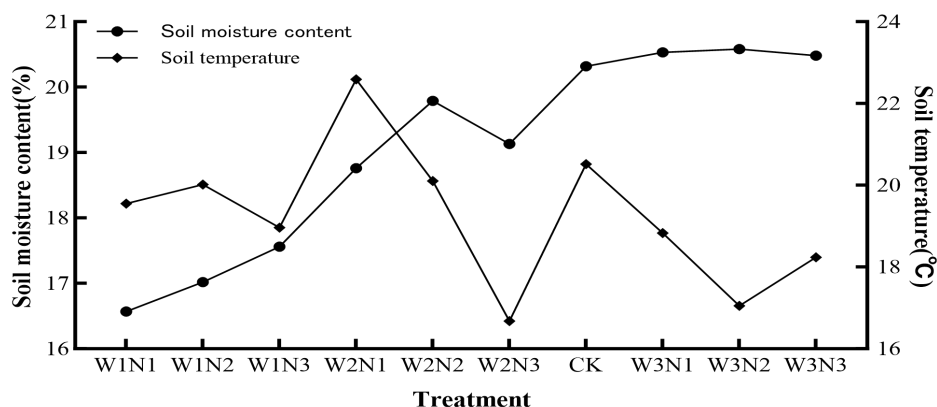


Fig. 3 Environmental differences of Zinnia soil from different water nitrogen treatments

4. Discuss

Water and nitrogen regulation are widely used in agricultural systems. For plant growth, especially during the growing season, large amounts of water and nitrogen input contribute to improved crop yield and quality [13]. In this study, when the same water amount, on the basis of the local habit of nitrogen fertilizer (CK) reasonably reduce the supply of nitrogen can promote the leaf photosynthesis and transpiration rate also increase the SLA, Ph, Sd, high nitrogen may reduce the leaf water potential, and decrease in the amount of moderate the leaf water potential also increased the stomatal conductance of zinnia leaves in the arid area, accelerate the accumulation of aboveground photosynthesis rate and biomass (Table 1). Previous studies have also shown [14, 16] that proper irrigation and nitrogen management practices can help crops achieve high and stable yields.

Controlling the amount of irrigation and applying nitrogen fertilizer at the appropriate level can significantly improve the soil moisture content and temperature changes (Figure 3), thereby optimizing the soil environment, so that the fibrous root system of zinnia can better absorb enough nutrients from the soil crevices, and increase the content of nutrients such as soluble protein content (Figure 2) to maintain the vegetative growth and reproductive growth of the plant. It has also been shown that proper water and nitrogen supply can increase the activity of antioxidant enzymes, thereby alleviating the damage to cells under drought stress [17].

5. Conclusion

In conclusion, potato is a typical cash crop, and appropriate water and nitrogen regulation can promote the yield and quality, soil structure and enzyme activity of potato in the production and management of potato crops. Furthermore, the significance of potato water and nitrogen regulation research lies in increasing the biomass and quality of agricultural crops, namely potatoes, through the rational application of water and nitrogen, while reducing the negative environmental impacts of

agriculture. Through rational application of irrigation technology, fertilization technology, shading technology and shading technology.

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References

- [1] Tian Da Cui, Li Yong. Interplanting of zinnia flowers under papaya forests in South China [J]. Bulletin of Forestry Science and Technology, 2023, (10): 92-3.
- [2] LI Wen Xia. China Agricultural Technology Extension,2019,35(04):52-53.
- [3] Bailu. Cultivation and Management Techniques for Zinnias [J]. Rural Science and Technology, 2011, (05): 54.
- [4] Zhu Hong Xia, Li Sai Nan, Su Wen Qing, et al. Effects of Exogenous Melatonin on Seed Germination and Physiological Characteristics of Zinnia Elegans Under Chromium Stress [J]. Shandong Agricultural Sciences, 2022, 54(09): 64-69.
- [5] The effect of exogenous salicylic acid on the growth of zinnia seedlings under low potassium stress [J]. Henan Agricultural Sciences, 2019, 48(11): 146-150.
- [6] LI S, CHEN H, JIANG S, et al. Selenium and Nitrogen Fertilizer Management Improves Potato Root Function, Photosynthesis, Yield and Selenium Enrichment [J]. Sustainability, 2023, 15(7).
- [7] Li Yihua, Ma Wen Xia, Lei Yuming, et al. Evaluation of the ornamental value of 27 types of flowers in Ganzhou District, Zhang Ye City [J]. Journal of Hexi University, 2019, 35(05): 1-8.
- [8] Wang Hui, Chen Yafei, Xu Jili, et al. Differences in Yield Stability and Dry Matter Accumulation and Allocation of Corn Varieties under Different Water and Nitrogen Conditions [J]. Agricultural Research in Arid Areas, 2024, 42(05): 71-84.
- [9] Wang Shaohua, Cao Wei Xing, Ding Yanfeng, et al. The effect of water-nitrogen interaction on nitrogen uptake and utilization in rice [J]. Chinese Journal of Agricultural Sciences, 2004, (04): 497-501.
- [10] Zhu Ju Hong, Liang Huan, Shi Xianfeng, et al. The effects of three types of plant growth regulators the growth of zinnia plants [J]. Heilongjiang Agricultural Sciences, 2022, (02): 44-7.
- [11] Liang Wenchao, Walking Side, Luo Siqian, et al. Effect of Nitrogen, Phosphorus and Potassium Compound Fertilizer on Physiological Characteristics of 'Longevity Crown' Begonia after Warming and Flowering [J]. Journal of Nanjing Forestry University (Natural Science Edition), 2022, 46(05): 81-8.
- [12] QING Q, ZHEN W, QUAN G, et al. Impact of drought on soil microbial biomass and extracellular enzyme activity [J]. Frontiers in Plant Science, 2023, 14: 1221288-.
- [13] Yang Ying Pan, Yin Juan, Zhu Yin He, et al. The effects of water and nitrogen regulation on potato yield and soil in the semi-arid area of central Ningxia [J]. Journal of Agricultural Machinery, 2024, 55(09): 38-370 458.
- [14] Yu-Xia, Li Hong-Jun. The effects of water and nitrogen coupling on the growth and yield of watermelon [J]. Agricultural Abstracts-Agricultural Engineering, 2024, 36(01): 41-45.
- [15] LI X, LI S, QIANG X, et al. Effects of Water and Nitrogen Regulation on Apple Tree Growth, Yield, Quality, and Their Water and Nitrogen Utilization Efficiency [J]. Plants, 2024, 13(17).
- [16] QIAO M, HONG C, JIAO Y, et al. Impacts of Drought on Photosynthesis in Major Food Crops and the Related Mechanisms of Plant Responses to Drought [J]. Plants, 2024, 13(13).

- [17] LI X, LI S, QIANG X, et al. Effects of Water and Nitrogen Regulation on Apple Tree Growth, Yield, Quality, and Their Water and Nitrogen Utilization Efficiency [J]. *Plants*, 2024, 13(17).