Effect of water and nitrogen regulation on the appearance quality of marigolds

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Abstract. This study was carried out at the Yimin Irrigation Experimental Station in Minle County, aiming to investigate the effects of water and nitrogen regulation on the appearance and nutritional quality of pigmented marigolds under drought conditions. The experiment was conducted by drip irrigation under membrane, with 10 treatments (including the control group CK), divided into four fertility stages, namely, seedling stage, bud stage, early flowering stage and full flowering stage through randomized block group design, with three gradients of soil moisture (moderate water deficit W1, mild water deficit W2, and full irrigation W3), and four levels of nitrogen application (low nitrogen N1, medium nitrogen N2, high nitrogen N3, and the local nitrogen level CK), to analyze the effects of different treatments on the appearance and nutritional quality of the main inflorescence of marigolds. The effects of different treatments on the OD of main inflorescence and lutein content of marigold were analyzed. The results showed that the effect of irrigation water amount on lutein content of marigold was highly significant ($P<0.01$), the effect of nitrogen application was significant ($P<0.05$), while the interaction effect of water and nitrogen was not significant ($P>0.05$). In terms of appearance quality, the W2N2 treatment (mild water deficit and moderate nitrogen application) had the largest main inflorescence OD, which increased by 4.21% compared to the control, while in terms of nutritional quality, the W2N2 treatment had the highest lutein content (20.88 mg·g-1), which increased by 0.21% compared to the control. The combination of moderate water deficit and moderate nitrogen application significantly improved the appearance and nutritional quality of marigold.

Keywords: water and nitrogen regulation; marigold; quality; lutein.

1. Introduction

China's Hexi Corridor region has more severe natural conditions, desertification is a serious problem, while agriculture and industry over-exploitation of groundwater has exacerbated the contradiction between man and land. The region is an important commercial grain production area and cash crop production area in the west of China, but in recent years, the Qilian Mountain snow line is rising, the precipitation is low and the population is increasing, which leads to water resource tension and gradual degradation of the ecological environment[1]. In this study, through the water-nitrogen coupling technology of drip irrigation under the membrane, combined with field experiments and data analysis, we investigated the effects of water-nitrogen regulation on the appearance quality and nutritional quality of marigolds, revealed the optimal water-nitrogen combination, and provided theoretical basis and technical support for the sustainable development of the color pigmented marigold industry in the Hexi oasis. Marigold (Tagetes erecta L.) has multiple values as an important ornamental plant and cash crop. Its ornamental value is reflected in the variety of varieties, rich flower color and long flowering period, which can provide abundant choices for urban gardening, potted greenery and fresh cut flower market[2]. At the same time, the economic value of marigold is also very significant. In recent years, with the growth of the market demand for natural pigments, the economic value of marigold, as an important source of natural

pigments such as lutein, has been increasing[3]. In addition, the pollen of marigold can be used as a poultry feed additive to improve the color of egg yolks and poultry skin, and its extracts are widely used in the field of medicine and health care[4]. In agricultural production, water and nitrogen regulation is crucial for crop growth and yield. Studies have shown that rational water-nitrogen coupling can significantly improve the photosynthetic efficiency and yield of crops[5]. For example, in maize cultivation, the coupling of medium irrigation level and medium nitrogen application level can significantly enhance photosynthetic parameters and yield[6]. For marigold, the rational application of nitrogen fertilizer also has an important impact on its growth and yield. It was found that different nitrogen fertilizer treatments had significant effects on the biological traits and yield of marigold, and the appropriate level of nitrogen fertilizer could promote the growth and pigment accumulation of marigold[7].

2. Materials and Methods

2.1 Design of test scheme

2.1.1 Overview of the pilot area

The experiment was carried out at the Yimin Irrigation Experimental Station in Minle County, which is located at 100° 43′ E longitude, 38° 39′ N latitude, and 1970 meters above sea level. The region has a dry climate and insufficient water sources, which belongs to the typical continental desert grassland climate. Under such natural conditions, the promotion and application of water-saving irrigation technology is particularly important[8]. After screening, the more suitable marigold variety for local cultivation is pigmented marigold. This variety has strong resistance, can adapt to the arid environment, and has its own “immune system”, which is highly resistant to epidemics and viral diseases. The leaves are odd-pinnate, the flowers are rounded and honeycomb-like, with a cross diameter of up to 11 centimeters, a single flower mass of more than 35 grams, and a bright orange-yellow flower color. The head is solitary, the involucre is cup-shaped with a toothed tip, the ligule is yellow or dark orange, and the flowering period is mainly concentrated from July to September.The drip irrigation material used in the experiment was PE hose, and the drip irrigation system was divided into main pipe, branch pipe and capillary pipe, of which the capillary pipe was inlaid patch type.

2.1.2. Experimental design

The experiment was designed in a randomized block group manner. There were 10 treatments (including the control treatment CK) with three replications. The experiment divided the fertility period of marigold into four fertility periods: seedling stage, bud stage, early flowering stage, and full flowering stage, and three gradients of soil moisture were set up, respectively, moderate water deficit W1 (soil water content of 55% to 65% of the water holding capacity of the field), mild water deficit W2 (soil water content of 65% to 75% of the water holding capacity of the field), full irrigation W3 (soil water content of 75% to 85% of the water holding capacity of the field), and full irrigation W3 (soil water content of 75% to 85% of the water holding capacity of the field). , full irrigation W3 (soil water content of 75% to 85% of the field water holding capacity); compound fertilizer and urea for the test nitrogen fertilizer fertilizer, this experiment nitrogen application set four levels, low nitrogen level N1 (120 kg/hm2), medium nitrogen level N2 (180 kg/hm2), high nitrogen level N3 (240 kg/hm2) and the local nitrogen application level CK (300 kg/hm2), the The specific experimental design scheme is shown in Table 1.

Table 1. Experimental design scheme

Treatments	Nitrogen rate (kg/hm2)	Seedling period	Squaring stage	Early flowering period	Prime bloom period
CK	300	75～85a	75～85	75～85	75～85

W1N1	120	65～75	75～85	75～85	75～85
W1N2	180	65～75	75～85	75～85	75～85
W1N3	240	65～75	75～85	75～85	75～85
W2N1	120	65～75	75～85	65～75	75～85
W2N2	180	65～75	75～85	65～75	75～85
W2N3	240	65～75	75～85	65～75	75～85
W3N1	120	65～75	75～85	55～65	75～85
W3N2	180	65～75	75～85	55～65	75～85
W3N3	240	65～75	75～85	55～65	75～85

Note: a Soil water content as % of field holding capacity (FC).

2.2 Measurement indicators and methods

2.2.1 Appearance quality

During the blooming period of marigold, select three marigold plants with similar growth, robust growth, no pests and diseases as samples, choose the petals on each plant to open the flowers completely, use the vernier caliper or straightedge as the measuring tool, place the ends of the vernier caliper on the outermost edge of the inflorescences, gently clamp it and read the value of the outer diameter, to ensure the accuracy and precision of the measurements. The measured OD data were recorded in a table, and the average OD of the three samples was calculated and statistically analyzed to assess the differences between treatments or varieties.

2.2.2 Nutritional quality

At the time of harvesting each crop, three pigmented marigold plants with similar growth were first randomly selected from each plot. After harvesting, the flowers were dried at a low temperature, usually set at 65 ° C, to maintain the stability of their nutrient content. The dried flowers need to be crushed to powder form and sieved through a 60-mesh sieve, and the lutein was extracted using a sonic-assisted organic extraction method. The powder was mixed with the organic extractant (usually ethanol) at a material-liquid ratio of 1:20. The acoustic frequency was set at 53 KHz, the extraction time was 40 min, and the temperature was kept at 30 ℃. After extraction, the samples were centrifuged, usually set at 5000 r·min-1, to separate the liquid and solid components. After centrifugation, the supernatant was taken for colorimetric analysis of the extracted lutein using a UV-visible spectrophotometer (e.g., T6 New Century model), and the transmittance was usually measured at 445 nm, which in turn gave the content of lutein in the crude extract of marigold (mg·g-1).

2.3 Data processing and analysis

Relevant data were pre-processed using Microsoft Excel 2016 software for regularization; in the middle and late stages, IBM SPSS Statistics 26 software was applied for between-group ANOVA, etc., and Origin 2021 software was used for plotting.

3. Results and analysis

3.1 Effect of water nitrogen regulation on appearance quality of marigolds

As shown in Table 1, under the same water supply conditions, the main inflorescence flower diameter of pigmented marigolds performed best at the N2 level (medium N application), which was significantly larger than the other N application levels. Specifically, the main inflorescence flower diameter was significantly higher at the N2 level compared to the N1 (low nitrogen application) and N3 (high nitrogen application) treatments at the three moisture supply levels of W1, W2 and W3, respectively. At the same level of nitrogen supply, the main inflorescence floral

diameter performed best at the W2 level (moderate water supply), where the main inflorescence OD of W1N2 was lower than that of W3N2 at the first versus the second crop level. This shows that a certain degree of water and nitrogen regulation has a significant effect on the main inflorescence flower diameter of pigmented marigold.

Table 1. Effect of water nitrogen regulation on the outer diameter of pigment marigold main inflorescences

Treatments	Outer diameter of the main inflorescence in the first crop（mm）	Outer diameter of the main inflorescence in the second crop（mm）	Outer diameter of the main inflorescence in the third crop（mm）
CK	107.54±3.99bc	109.08±2.53ab	96.62±1.92bcd
W1N1	98.36±1.68d	97.77±2.95d	88.01±3.64d
W2N1	98.43±5.91d	99.77±0.96d	91.93±9.59cd
W3N1	99.03±1.36d	98.95±4.91d	92.09±4.86cd
W1N2	107.90±2.09bc	107.48±3.93abc	102.56±6.21ab
W2N2	117.88±6.85a	112.69±6.79a	103.79±4.98ab
W3N2	109.53±3.61b	111.95±3.22a	109.99±2.93a
W1N3	104.02±2.43bcd	104.10±4.31bcd	96.97±2.77bcd
W2N3	102.00±3.19cd	100.53±2.31cd	96.36±3.75bcd
W3N3	101.13±3.58cd	104.55±4.99bcd	98.68±5.77bc
F significance test			
FW	**	**	**
FN	ns	ns	ns
FW×N	**	**	**

3.2 Effects of water and nitrogen regulation on the nutritional quality of marigolds

Lutein is an important carotenoid, widely found in pigmented marigold petals, with significant antioxidant and health care functions. Its molecular structure is more sensitive to environmental conditions, especially under high temperature and strong light conditions, less stable and easy to volatilize. Therefore, by regulating the water content and nitrogen content of the tillage soil, the microclimate of the field and the water condition in the plant can be changed, which in turn affects the content of lutein in pigmented marigold petals.

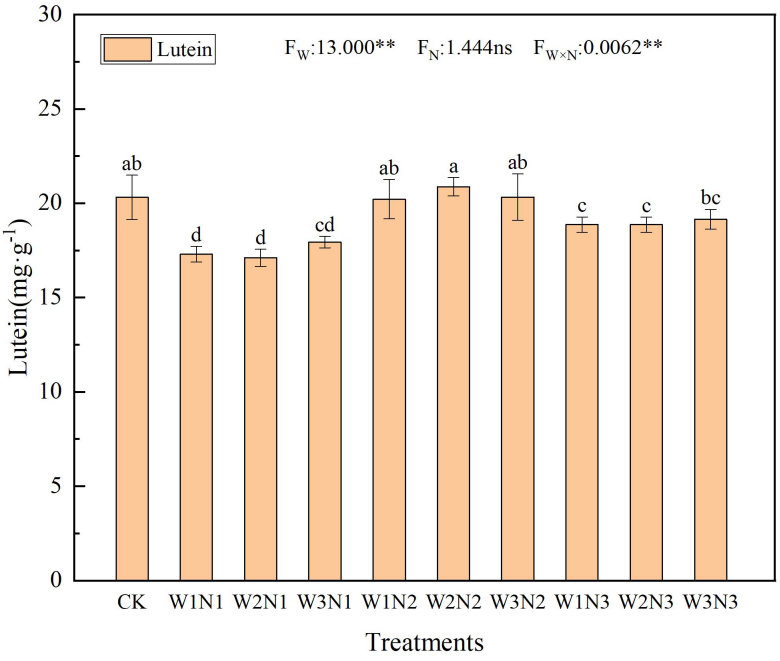

Fig. 1 Effect of water and nitrogen regulation on lutein

In this study, changes in lutein content in pigmented marigold were analyzed by different water and nitrogen regulation treatments. The results showed that the effect of irrigation water amount on lutein content in pigmented marigold reached highly significant level ($P<0.01$), while the effect of nitrogen application also reached significant level ($P<0.05$). However, the difference between the interaction effects of moisture and nitrogen on lutein content was not significant ($P>0.05$). Specifically, the W2N2 treatment (medium irrigation water and medium nitrogen application) had the highest lutein content of 20.88 mg·g-1, on the contrary, the W2N1 treatment (medium irrigation water and low nitrogen application) had the lowest content of 17.11 mg·g-1. Medium nitrogen application was able to provide lutein synthesis provide sufficient precursor substances for lutein synthesis, thus increasing the lutein content to some extent.

4. Discuss

In terms of appearance quality, the treatment with moderate level of nitrogen application (N2) significantly increased the main inflorescence outer diameter of marigold, especially under mild water deficit (W2) condition, where the W2N2 treatment showed the largest main inflorescence outer diameter. This indicated that the combination of moderate water deficit and moderate N application could optimize the growth conditions of marigold and promote the increase of flower diameter. This suggests that water-nitrogen regulation is not only applicable to marigold, but also has general applicability to other crops. In terms of nutritional quality, lutein content, an important nutrient index in marigold, was significantly affected by irrigation water and N application.The W2N2 treatment showed the highest lutein content of 20.88 mg·g-1, which was 2.68% higher than the control. This indicated that moderate water deficit and moderate nitrogen application could promote the synthesis and accumulation of lutein.

5. Conclusion

This study focused on the effects of water and nitrogen regulation on the yield, quality, water and nitrogen use efficiency and economic benefits of pigmented marigold under drought conditions,

and explored in depth from the perspectives of the degree of water stress, nitrogen fertilizer reduction, and water and nitrogen interactions effects. It was found that water and nitrogen had highly significant effects on the appearance quality (main inflorescence OD) of pigmented marigolds ($P<0.01$), while the effects of water-nitrogen interaction on the appearance quality of marigolds did not reach the significant level ($P>0.05$). Specifically, the effects of different nitrogen application levels on the outer diameter of main inflorescence of marigold varied significantly. Among them, the main inflorescence flower diameter at N2 level (medium nitrogen application) increased by 4.21% and 8.85% compared with N1 (low nitrogen application) and N3 (high nitrogen application) levels, respectively. This indicates that the appropriate nitrogen application can significantly improve the appearance quality of marigolds and increase the flower diameter, thus enhancing their ornamental value. However, excessive nitrogen application will not only delay the onset of flowering of marigold, but also limit its nitrogen utilization efficiency, reproductive growth, quality formation and flowering quality. Excessive input of nitrogen fertilizer will lead to imbalance in plant growth, affecting the flowering period and flower quality, and thus reducing its ornamental value and economic benefits. To summarize, reasonable regulation of water and nitrogen supply is of great significance to improve the appearance quality and economic benefits of marigold. In the actual planting process, excessive nitrogen application should be avoided, and water and nitrogen utilization efficiency should be optimized by combining with water management under drought conditions, so as to achieve high quality and high yield of marigold and sustainable development.

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