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Study on the Effects of Different Irrigation Strategies on the Yield and Quality of *Chrysanthemum morifolium*

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Abstract We studied the effects of different irrigation methods on the yield, quality, stress resistance and water use efficiency of *Chrysanthemum morifolium*. The results showed that water-saving irrigation and precision irrigation during the growth period could significantly improve the water use efficiency without affecting the yield. If sufficient irrigation is adopted, although the yield per mu is the highest, the water use efficiency is poor. We also noticed that the amount of effective components such as flavonoids and volatile oil would change with different irrigation methods. Among them, precision irrigation can make these medicinal ingredients accumulate more. Water saving irrigation also makes chrysanthemum more drought resistant and disease resistant, and powdery mildew and leaf spot disease occur less. The study also shows that efficient irrigation methods such as drip irrigation can further improve water use efficiency and provide a good help for planting in different regions. This study provides a theoretical basis and technical methods for the efficient planting of *Chrysanthemum morifolium*. By adjusting the irrigation strategy, it can not only save water resources, but also promote the development of chrysanthemum industry, and also help to promote the development direction of green agriculture.

Keywords *Chrysanthemum morifolium*; Irrigation strategies; Yield; Quality; Water use efficiency

1 Introduction

Chrysanthemum morifolium is a common ornamental plant. It is not only beautiful, but also has high economic and medicinal value. It can be used in traditional Chinese medicine and daily herbs, and is very popular in the flower market because of its beautiful flower shape (Sun et al., 2010; Yuan et al., 2020; Hao et al., 2022; Cai et al., 2024).

Irrigation is particularly important when growing chrysanthemum. In order to improve yield and quality, irrigation methods should be selected well. Many studies have discussed this issue, indicating that reasonable water use can help it grow better and blossom better (Amarin et al., 2021; Gurjar et al., 2023). Now water resources are becoming increasingly scarce, so we need to study more water-saving irrigation methods to ensure that *Chrysanthemum morifolium* can be continuously planted (Amarin et al., 2021). Irrigation methods will directly affect the growth and flower quality of *Chrysanthemum morifolium*. For example, drip irrigation and irrigation with treated wastewater, different methods will affect the number, size and overall quality of flowers. The results showed that more and better quality flowers could be planted by controlling the amount of drip irrigation; Wastewater irrigation can sometimes improve soil conditions and is also good for plants (Gurjar et al., 2023). In addition, the experiment of irrigation with saline water showed that *Chrysanthemum morifolium* could tolerate a certain amount of salt, but the change of salinity would affect its physiological state and appearance (Amarin et al., 2021).

Our study will test several different irrigation methods to see how they affect the yield and quality of *Chrysanthemum morifolium*. We want to find out which irrigation method can save water without degrading the quality of flowers, or even become better. At the same time, we will also see how the growth and reaction of *Chrysanthemum morifolium* will change when irrigated with saline water or wastewater. It is hoped that these results can provide some practical suggestions for growers, help them grow high-quality Chrysanthemum under the condition of water shortage, and realize a more water-saving and environmental friendly planting method.

2 Biological Characteristics and Water Requirements of *C. morifolium*

2.1 Growth and development characteristics of *C. morifolium*

At different growth stages of *Chrysanthemum morifolium*, the demand for water is different. At the beginning of sowing, enough water is needed so that the roots can grow well and the plants can grow normally (Buwalda and Kim, 1994; Taweesak et al., 2014). When the flower is about to bloom, the plant needs more water, because the flower buds need more water to support. Studies have pointed out that in order to grow high-quality and marketable flower branches, Hangzhou White Chrysanthemum needs about 0.96 to 1.07 cm of water every day. This shows that in the whole growth process, it is really critical to control irrigation. The time and method of irrigation will also affect the length of growth period and water use efficiency. If properly managed, the output and quality can be improved (Zhao et al., 2018).

2.2 Effects of water on quality

The active ingredients in *Chrysanthemum morifolium*, such as flavonoids and volatile oil, are affected by the amount of water. Only when enough water is available can these components be formed normally. These substances are the key to determine the medicinal value and market price of *Chrysanthemum morifolium* (Zhang et al., 2020). Karasudani et al. (2023) found that the content of effective components such as chlorogenic acid and Luteolin in *Chrysanthemum morifolium* will increase if organic fertilizer is combined with less chemical fertilizer, indicating that water and nutrients jointly affect the quality of *Chrysanthemum morifolium*. The antioxidant effect of *Chrysanthemum morifolium* extract was also affected by water content. If the water management is good, it is not only good for the flower, but also helpful to retain its health function (Xu et al., 2021).

2.3 importance of irrigation in *C. morifolium* cultivation

In order to plant chrysanthemum, precision irrigation is particularly critical. Too much or too little water will bring problems. Too much water, the soil is easy to accumulate water, and the root system is impermeable, which will affect the absorption of nutrients by the root, and finally make the yield and quality of flowers worse (Gurjar et al., 2023). If there is too little water, the plants will lack water, grow slowly, have fewer flowers and poor quality (Amarin et al., 2021). Now, some more advanced irrigation methods, such as using sensors to control wastewater irrigation, have been proved to improve soil conditions and make plants stronger and more stress resistant (Gurjar et al., 2023).

3 Design and Implementation of Different Irrigation Strategies

3.1 Climate and environmental conditions

Climate and environment will directly affect the irrigation effect of *Chrysanthemum morifolium*. The study found that different seasons, different planting methods, and different varieties will affect crop water consumption, as well as the yield and quality of flowers (Posse et al., 2019). The salinity of irrigation water is also a problem that can not be ignored. If the salt content is too high, *Chrysanthemum morifolium* may not grow high, the yield will decline, and the quality of flowers will become worse. However, some substrates, such as zeolite soil, can reduce the adverse effects of salt (Amarin et al., 2021; Yasemin et al., 2022).

3.2 Irrigation strategies design

We use full irrigation as the control group, which is to provide the plants with the most water so that they can grow freely and achieve the best flowering effect. It is usually irrigated when the soil moisture drops to a certain extent to keep the soil moisture (Gurjar et al., 2023). The goal of water-saving irrigation is to save water without reducing the yield and quality. Technology such as drip irrigation has proved very effective, and can control the daily water consumption between 0.96 and 1.07 cm. Drip irrigation is particularly useful where water is scarce. For example, studies have installed drip irrigation equipment on each pot of *Chrysanthemum morifolium* in the field to supply water in a fixed amount (Figure 1) (Posse et al., 2019). Intermittent irrigation is watering at intervals, not every day. This method helps to improve water utilization. It can better regulate the water content of soil, which is helpful for plant growth and flower quality (Lin et al., 2011). Moreover, this method can also be combined with the treated wastewater, which not only supplements nutrition, but also does not increase the content of heavy metals too much (Gurjar et al., 2023). Precision irrigation is to adjust the amount of irrigation

according to the growth stage of plants. For example, more watering at the early stage and less watering at the time of flowering can save water and make the flowers bloom better (Li et al., 2014). However, this method requires close monitoring of soil moisture and plant status in order to adjust the irrigation plan in time.

Figure 1 Chrysanthemums cultivated in pots, under open field conditions, placed on ceramic bricks (Adopted from Posse et al., 2019)

3.3 Key monitoring indicators

To evaluate the irrigation effect, we need to look at several key data. The first is the soil moisture, which can tell us whether the plants are full of water and prevent too much watering (Lin et al., 2011). The growth of plants, such as height, crown width and branch number, can reflect the health of plants (Pansuriya and Kumari, 2024). The quantity and quality of flowers are directly affected by irrigation. If the irrigation method is selected well, the flowers will bloom more and better (Li et al., 2014). Finally, the content of active ingredients, such as flavonoids and chlorogenic acid, is an important standard for judging the quality of *Chrysanthemum morifolium* and is directly related to its medicinal value (Li et al., 2014; Xu et al., 2021).

4 Effects of Different Irrigation Strategies on the Yield of *C. morifolium*

4.1 Yield analysis

The yield of *Chrysanthemum morifolium* will be significantly affected by irrigation methods. The study found that the amount of water consumption will directly affect how many marketable flower stems can be harvested. In general, daily irrigation of 0.96 to 1.07 cm of water can make Hangzhou White Chrysanthemum produce more high-quality flowers. This result is true in different varieties and planting methods. The frequency of irrigation and the amount of water per irrigation are also important. They will affect how fast plants grow and when they bloom. For example, when irrigated with treated wastewater under different soil drought levels, it is found that more water supply will lead to better growth performance and higher yield (Turan et al., 2015; Gurjar et al., 2023).

4.2 Relationship between water supply during critical growth periods and yield

In some key stages, such as when the flower bud is just beginning to form, enough water must be guaranteed. At this time, if there is no water supply, the flowers will be less and the size will be smaller, and finally the total output will be affected (Hassanein, 2015; Pansuriya and Kumari, 2024). Irrigation with saline water will reduce the quantity and quality of flowers, which shows that in these critical periods, it is necessary to ensure not only the availability of water, but also the quality of water (Amarin et al., 2021).

4.3 Balancing water-saving irrigation and efficient production

It is very important to save water and ensure the yield in Chrysanthemum planting. In 2024, pansuriya and Kumari used organic fertilizers such as "jeevamrut" and "panchagavya" in their research and found that they can help crops grow well and reduce water consumption. Another way is to use sensors to control the irrigation system. It

can decide when to water and how much according to the real-time data of soil moisture. This not only saves water, but also ensures that the yield of flowers will not be reduced (Gurjar et al., 2023).

5 Effects of Different Irrigation Strategies on the Quality of *C. morifolium*

5.1 Sensory quality

The sensory performance of Hangbai Chrysanthemum, such as its color, shape, and neatness, is significantly influenced by irrigation methods. For example, irrigating with water with high salt content can make flowers smaller and their colors less vibrant, which can affect the overall viewing effect (Amarin et al., 2021). To maintain consistency in the shape and size of flowers, the water tension in the soil needs to be well controlled (De Farias and Saad, 2011). If the soil is too dry, the stems and inflorescences may become shorter and smaller, but in most cases, the quality of the flowers can still meet the sales standards.

5.2 Active component accumulation

The irrigation method can also affect the amount of active ingredients in Hangbai Chrysanthemum, such as flavonoids, volatile oils, and total phenols. Gurjar et al. (2023) found that irrigating with wastewater can increase the organic matter and trace elements in the soil, which can help increase the content of medicinal ingredients in plants. If the water used for irrigation has a high salt content, it may affect the normal physiological activities of plants and lead to a decrease in the active ingredients (Amarin et al., 2021). Choosing a good water source and controlling irrigation methods are crucial for enhancing the medicinal value of Hangbai Chrysanthemum.

5.3 Flower drying characteristics

Different irrigation methods can also affect the moisture content and drying speed of Hangzhou white chrysanthemum flowers. Scientific management of irrigation during the planting process can not only promote good flower growth, but also stabilize the quality of dried flowers. If the soil is too dry, both the fresh and dry weight of flowers will decrease, and the drying performance will also deteriorate. Saline irrigation can reduce the relative moisture content of flowers, which may affect their performance during the drying process and ultimately affect the quality of dried flowers (Amarin et al., 2021).

6 Effects of Different Irrigation Strategies on the Stress Resistance of *C. morifolium*

6.1 Drought resistance

Under water-saving irrigation conditions, Hangbai Chrysanthemum exhibits stronger drought resistance. A study has found that spraying Robinin and Chitosan can make Hangbai Chrysanthemum more drought tolerant. These treatments can increase the moisture content of the leaves and improve the efficiency of photosynthesis. The chlorophyll content will also increase accordingly, and important substances such as carbohydrates, proline, potassium, and calcium in the plant body will also increase, helping the plant regulate water (Elansary et al., 2020). These treatments can also increase the activity of some antioxidant enzymes, such as superoxide dismutase (SOD), peroxidase (POD), and ascorbate peroxidase (APX), further enhancing drought resistance. The use of exogenous melatonin (MT) is also effective. It can enhance the level of photosynthesis during drought, allowing plants to maintain a high water content, while also improving the activity of antioxidant enzymes and osmotic regulation ability, enhancing drought resistance (Luo et al., 2023). Through these methods, more drought tolerant varieties can also be screened for future planting (Sun et al., 2013).

6.2 Disease resistance

Different irrigation methods can also affect the disease resistance of Hangzhou white chrysanthemum, especially against common diseases such as powdery mildew and leaf spot. Appropriate irrigation can alleviate the pressure on plants, make them more vibrant, and thus help reduce the risk of diseases (Elansary et al., 2020; Luo et al., 2023). Although there is not much research on the impact of irrigation on disease incidence, existing studies suggest that optimizing irrigation to make plants grow healthier, such as enhancing antioxidant capacity and improving nutritional status, may lower their chances of disease.

6.3 Environmental adaptability

In areas with unstable climate conditions, the effectiveness of irrigation strategies is crucial for the successful

planting of Hangzhou white chrysanthemums. A study has found that the combination of stress resistant substances such as Robinia pseudoacacia extract, chitosan, and melatonin can greatly enhance the environmental adaptability of *Chrysanthemum morifolium*. These treatments can regulate the physiological responses and gene expression of plants, allowing them to maintain a good state in the face of stress such as drought and salinity (Elansary et al., 2020; Luo et al., 2023) (Figure 2). Using special substrates such as zeolite soil to replace ordinary soil can also enhance the salt resistance of plants, indicating that the selection of planting substrates is also important (Amarin et al., 2021). Some people have also experimented with different shading rates and watering intervals, and found that adjusting the light and watering frequency appropriately can reduce the pressure on plants, allowing Hangzhou white chrysanthemums to maintain normal photosynthesis and transpiration even in water tight environments (Sahithi et al., 2020; Bdewi and Kadhim, 2024a; 2024b).

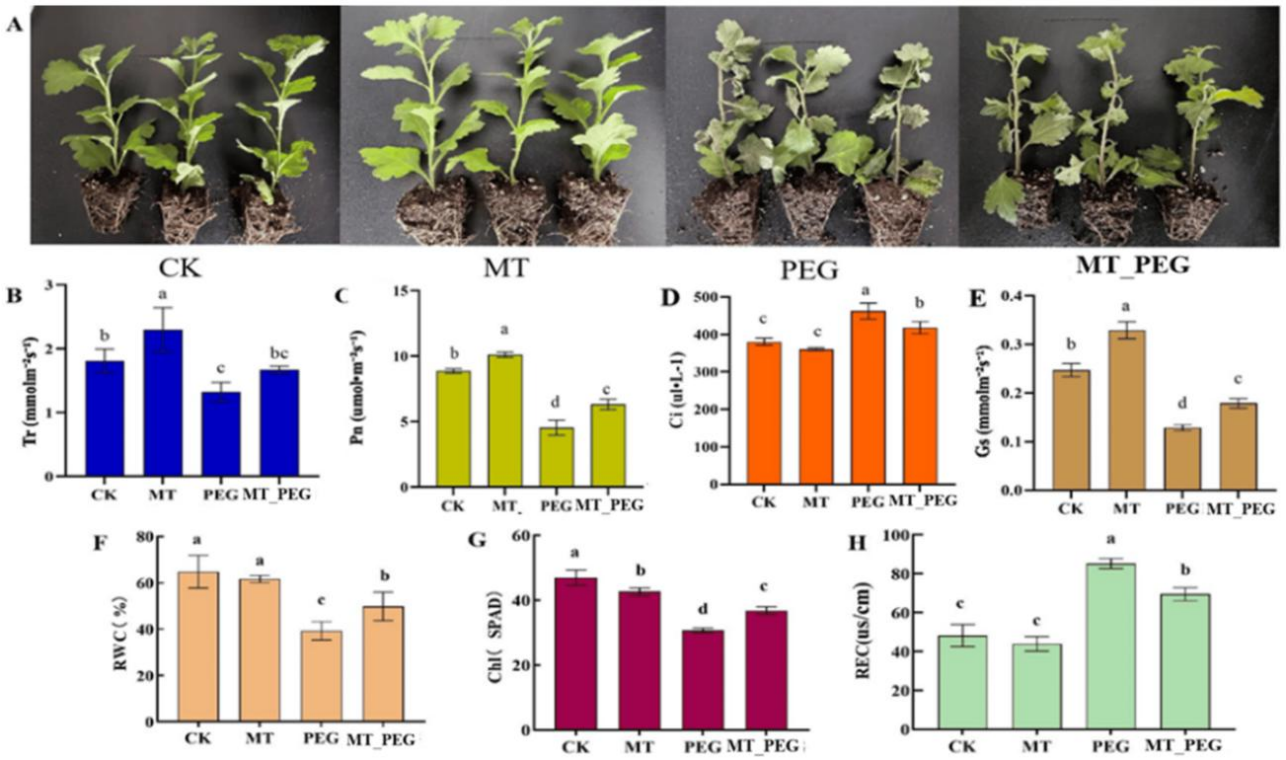

Figure 2 Effects of melatonin on chrysanthemum seedlings and their chlorophyll content and photosynthetic capacity under drought stress (Adopted from Luo et al., 2023)

Image Caption: (A)Phenotypes after 12 days of drought stress treatment. (B) Tr (Transpiration rate). (C) Pn (Net photosynthetic rate). (D) Ci (Intercellular carbon dioxide concentration); (E) Gs (Stomatal conductance). (F) RWC (Relative Water Content). (G) Chl (Chlorophyll content). (H) REC (Relative conductivity). CK, control; MT, exogenous melatonin treatment; PEG, drought stress; MT_PEG, drought stress with exogenous melatonin treatment (Adopted from Luo et al., 2023)

Luo et al. (2023) also found that drought stress can lead to a decrease in photosynthesis in Hangzhou white chrysanthemum seedlings, a decrease in leaf water content and chlorophyll, and an increase in cell membrane conductivity, indicating that the cells have been damaged. However, if exogenous melatonin (MT-PEG) is used under drought conditions, these negative effects can be significantly alleviated. The transpiration rate, photosynthetic capacity, and water retention of the plant have all been improved. This indicates that melatonin can regulate photosynthesis and antioxidant systems, enabling Hangzhou white chrysanthemums to better withstand drought, providing new ideas for planting management under water deficient conditions.

7 Water Use Efficiency and Irrigation Strategy Optimization

7.1 Irrigation methods and water use efficiency

Different irrigation methods can have a significant impact on the water use efficiency (WUE) of Hangzhou white chrysanthemum. For example, drip irrigation can directly deliver water to the roots of plants, so that water is used more accurately, not wasted, and can also improve the quantity and quality of cut flowers (Jawaharlal et al., 2017).

Research has shown that regardless of the variety or management method, the most suitable daily water consumption to achieve qualified flower stem yield is 0.96 to 1.07 centimeters. Gurjar et al. (2023) attempted to use sensor controlled wastewater irrigation systems in their research. This method can improve soil nutrients and structure, indirectly enhancing water use efficiency.

7.2 Coordination of irrigation levels and water utilization

Properly controlling the irrigation amount can achieve both no water waste and guaranteed yield. For example, some people use organic fertilizer combined with some chemical fertilizers to grow Hangzhou white chrysanthemums, and the effect is very good. Research has found that reducing the use of chemical fertilizers by 28% and replacing them with organic fertilizers not only results in more flowers growing, but also enhances the nutrients and antioxidant capacity inside, indicating that both water and fertilizers are used more effectively (Xu et al., 2021). Another method is to choose a suitable planting substrate, such as zeolite rock. In areas with high salt content and water scarcity, using this substrate combined with regulated irrigation can keep plants healthy without affecting yield (Wahome and Shongwe, 2014; Amarin et al., 2021).

7.3 Water use efficiency and economic benefits

A reasonable irrigation plan can also help farmers save costs and increase income. For example, the "water fertilizer integration" technology combines irrigation and fertilization. This method not only allows Hangbai Chrysanthemum to grow better, but also increases its yield. Vimal et al. (2022) confirmed through research that using 100 kilograms of fertilizer per hectare, combined with appropriate planting density, is an ideal practice for producing high-quality cut flowers and can also bring good economic benefits (Vimal et al.. 2022). Using organic liquid fertilizers like Jeevamrut and Panchagavya can not only make plants grow more vigorously, but also save fertilizer costs and increase income (Pansuriya and Kumari, 2024).

8 Challenges and Future Directions

8.1 Challenges of climate change on irrigation strategies

Climate change has brought many troubles to the irrigation management of Hangzhou white chrysanthemums, especially extreme weather conditions such as drought and high temperatures that can affect their normal growth and make their water needs more complex. Rising temperatures and decreasing water often lead to an increase in soil salinity. This salinization can cause plants to become shorter, resulting in a decrease in the yield of fresh and dried flowers, and the quality of flowers may also deteriorate. Studies have shown that excessive salt content can affect the flowering and growth performance of *Chrysanthemum morifolium* (Amarin et al., 2021). Different planting methods and varieties can also lead to significant differences in water usage across different regions, and seasonal water changes make irrigation plans difficult to arrange. This has become a more challenging issue in the face of increasingly evident climate change.

8.2 Integration of technology and precision management

Irrigation nowadays no longer relies solely on manual experience. Integrating modern technologies such as smart sensors and big data can make irrigation more precise and water-saving (Wang et al., 2024). Sensor controlled wastewater irrigation systems have been proven to be useful. It can improve the nutritional status of the soil without exceeding the limit of heavy metals. This indicates that this method has the potential for sustainable development (Gurjar et al., 2023). These technologies can also help us monitor the status of soil and plants in real time, adjust irrigation plans in a timely manner, and provide water as needed. This not only allows Hangbai Chrysanthemum to grow better, but also improves the quality and quantity of flowers.

8.3 Regional adaptability studies

The soil and climate vary in different regions, so irrigation plans need to be designed according to specific circumstances in order to ensure good cultivation of Hangzhou white chrysanthemums. Amarin et al. (2021) found through their research that selecting appropriate planting substrates (such as zeolite rock) can help plants better cope with salinization issues, indicating that substrate selection is also important in irrigation management. Organic liquid fertilizers like Jeevamrut and Panchagavya have shown good application effects in different regions, not only improving soil quality but also increasing yield. This indicates that these organic inputs can be

adjusted according to local conditions to further optimize irrigation efficiency (Pansuriya and Kumari, 2024).

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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