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A Study of Regulated Deficit Irrigation on Farmland Soil Environment, Yield and Water Productivity of Potato

Xiaofan Pan [1,2,3], Hengjia Zhang [1,*] and Haiyan Li [3]

[1] College of Agriculture and Biology, Liaocheng University, Liaocheng, Shandong, 252059, China
[2] Yimin Irrigation Experimental Station, Hongshui River Management Office, Zhangye, Gansu, 734500, China
[3] College of Water Conservancy and Hydropower Engineering, Gansu Agricultural University, Lanzhou, Gansu, 730070, China
* Correspondence: Hengjia Zhang, College of Agriculture and Biology, Liaocheng University, Liaocheng, Shandong, 252059, China

Abstract: This paper examines the impact of regulated deficit irrigation on the soil moisture and temperature environment of farmland, as well as its effects on the physiological characteristics, yield, and water productivity of potatoes at various growth stages. The aim is to determine the optimal control period and the appropriate degree of deficit irrigation for potatoes. In conclusion, while water stress may decrease photosynthetic rate, transpiration rate, stomatal conductance, and overall water consumption, it can also improve the soil's hydrothermal conditions. Mild regulated deficit irrigation during the seedling and tuber formation stages does not negatively affect potato yield. In fact, it can enhance both water productivity and irrigation water productivity.

Keywords: potato; regulated deficit irrigation; physiological characteristics; water productivity

1. Introduction

Potatoes are not only highly productive but also rich in nutritional value, serving both as food and feed. By 2013, the potato cultivation area in Gansu Province reached 695,000 hectares, with an output of approximately 13 million tones. The potato industry in the Hexi Corridor has shown consistent growth, with the development of detoxification breeding seeds, base planting, and large-scale processing forming a robust industrial structure. However, in 2015, China's per capita annual potato consumption was only 41.2 kg, much lower than that of Europe and the United States, reflecting a limited and narrow consumption structure. The region's potato production, characterized by large tubers, high starch content, and excellent overall qualities, is among the best in Gansu Province for producing high-quality potatoes. With the modernization of agriculture, rural land has been collectively planned, leading to the formation of an integrated farming model that combines modern planting and harvesting techniques. However, the low utilization of irrigation water resources results in high annual water consumption for potato cultivation.

In recent years, the development of water-saving irrigation technology has been significant, with drip irrigation gaining popularity in agricultural production in Wuwei City [1]. Alongside drip irrigation, the use of ridge and furrow membrane covers, which effectively capture rainwater and reduce soil moisture evaporation, has become a key local farming method. This technique offers dual benefits of water replenishment and evapo-

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ration suppression, making it an important water-saving strategy. Regulated deficit irrigation (RDI) technology has emerged as a crucial measure in efficient water-saving irrigation, enabling high yields despite limited water resources and enhancing the overall productivity of dry agriculture [2,3]. Soil moisture, a direct water source for crops, plays a critical role in crop growth and development, ultimately influencing yields and quality. Moreover, soil water content can indirectly affect crop distribution and influence microclimate changes within the system [4]. Research on RDI began with water-intensive crops like fruit trees and vegetables, and has since been extended to potatoes [5,6]. Studies have shown that timely and moderate RDI improves water use efficiency, crop yield, and quality, leading to its widespread adoption in potato farming.

2. Influence of RDI on the Farmland Microenvironment Effect of Potato

2.1. Mprovement of Soil Moisture Environment

The relationship between crop water requirements and soil moisture in field conditions is not yet fully understood, leading to inefficient water use. Additionally, the absence of clear, systematic indicators for farm management has resulted in substantial water waste. However, using plastic film mulching combined with regulated deficit irrigation (RDI), which integrates film coverage, evaporation control, and even irrigation, enhances the crop's water environment. This method synchronizes the crop's water demand with the available supply during its growth stages, helping mitigate reductions in yield and quality caused by water deficits and minimizing the negative effects of excessive water during periods of anaerobic growth. Thus, plastic film mulching with RDI ensures sufficient water during the reproductive phase of the crop while maintaining a controlled water deficit during the anaerobic phase. Furthermore, the film reduces evaporation, which helps conserve soil moisture, supporting robust crop growth. It has been noted that RDI technology can effectively regulate soil moisture, optimizing it for potato growth, promoting better plant development, boosting yields, and improving water use efficiency [7].

2.2. Improvement of Soil Temperature

As a warm-season crop, maintaining optimal soil temperature is essential for enhancing potato yield. Surface runoff on farmland is mainly caused by continuous rainfall, storms, or irrigation. When water input exceeds the soil's infiltration capacity, surface runoff occurs. This runoff not only causes erosion of the surface soil but also significantly affects soil temperature. The use of plastic film mulching combined with drip irrigation can prevent surface runoff, effectively stabilizing soil temperature, especially after fertilization, and reducing issues like temperature fluctuations. Studies on regulated deficit irrigation (RDI) in Gansu Province have shown that soil temperature under RDI was higher compared to full irrigation during the same growth period. Temperature variations were more significant at soil depths of 5, 10, and 15 cm, with smaller fluctuations in deeper soil layers. These findings suggest that RDI not only ensures sufficient water for potatoes but also increases soil temperature. Furthermore, while full irrigation helps stabilize soil temperature through increased moisture, excessive water can lower soil temperatures, with a decrease of 1-1.5°C at a 15 cm depth [8,9].

3. Effects of RDI on Potato Yield

The ultimate goal of regulated deficit irrigation (RDI) is to enhance crop yield. Many studies have been conducted on the impact of RDI on crop yield. A study showed that mild RDI at the seedling stage resulted in a slight reduction of 5.05% in potato yield. Full irrigation at other growth stages led to a similar decrease in yield compared to normal irrigation, with no significant difference, but water use efficiency and irrigation water use efficiency improved by 15.29% and 23.92%, respectively [10]. Another review showed that water stress during different fertility periods of potato led to yield reduction. A moderate water deficit during the starch accumulation period had less impact on yield formation,

while a moderate water deficit during the stem expansion period resulted in a significant yield reduction of 28,633.33 kg/hm², which was 18.93% lower than that of the control with full water supply throughout the entire growth period [11]. Water stress effects on yield varied during different growth periods. An experiment in the Hexi Oasis irrigation area on deficit regulation for potatoes under plastic film mulching drip irrigation revealed that water deficit at the seedling stage had no significant effect on potato yield, which reached 33,027.22 kg/hm². However, water deficit at the tuber formation, tuber expansion, and starch accumulation stages significantly reduced the yield [12]. A further study found that potato yield decreased with deficit adjustment during the entire growth period or specific growth stages, and the reduction rate increased with the degree of water deficit [13]. It can be seen that RDI at different growth stages of potatoes has varying effects on yield, where mild water deficit at the seedling stage has little effect on yield, while water deficit during the starch accumulation stage significantly affects yield.

4. Effects of RDI on Potato Yield

Water productivity serves as an important indicator for evaluating water absorption and utilization throughout the crop growth process. Its value reflects the efficiency of water resource utilization in a given region and indirectly assesses the effectiveness of irrigation practices in saving water. As a result, improving water productivity is crucial for the stable and sustainable development of dryland agriculture. During the early stages of agricultural irrigation development in China, the primary goal was to increase crop production. However, with the acceleration of agricultural modernization, the dual importance of both production increase and water conservation has become increasingly apparent. Hence, improving water use efficiency has emerged as a focal point in water-saving irrigation practices. Studies have shown that different regulated deficit irrigation (RDI) periods have varying effects on water productivity. For instance, compared to full irrigation, moderate water treatment during the tuber formation stage of potatoes resulted in no significant yield reduction but an increase in water productivity by 22.07%. Similarly, moderate RDI during the starch accumulation stage showed minimal impact on yield, though it did not significantly enhance water productivity. Other research also found that RDI during the block formation stage of potatoes slightly reduced yield by 7.16%, but it significantly improved water productivity by 7.53% and irrigation water productivity by 13.18%. These findings suggest that deficit irrigation during the block formation period of potatoes may be optimal for oasis agriculture in arid and semi-arid regions like the Hexi Corridor. In conclusion, while reasonable RDI can improve water use efficiency in potato cultivation, improper regulation can lead to adverse effects such as reduced yield. Therefore, irrigation management should be adjusted based on soil water content and crop water consumption patterns during different growth phases.

5. Conclusion

With the continuous development of irrigation technology, there has been a significant shift in focus towards more efficient water conservation methods that consider the physiological needs of crops. Traditionally, irrigation practices have been focused on meeting the overall water requirements of crops, without paying close attention to their varying water needs at different growth stages. However, recent research has demonstrated that different crops have specific water requirements that fluctuate depending on their developmental stages. For example, crops may need more water during flowering and fruit development stages, while requiring less during the early growth stages. Therefore, understanding these dynamic water consumption patterns is crucial for optimizing irrigation strategies.

By combining advanced irrigation techniques, such as film mulching, with knowledge of crop water needs during different growth phases, farmers can apply a more

targeted approach to water management. This can include applying moderate water deficits during periods of low water demand, such as during vegetative growth, while ensuring sufficient water supply during critical stages, such as flowering or tuber formation. This approach not only helps conserve water but also ensures crops receive the necessary moisture for optimal growth, reducing water wastage. Ultimately, this integrated strategy improves water use efficiency, leading to higher crop yields with reduced water input and promoting sustainable agricultural practices in regions facing water scarcity.

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