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The Effect of Water and Nitrogen Regulation on Potato Growth in Arid Regions

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Abstract: With the development of heavy industry around the world, the utilization of water and land resources is gradually increasing, and the problem of water demand and supply has become increasingly serious, therefore, the application of irrigation methods for water-saving and water-storage is inevitable. Due to the severe drought in Northwest China, the annual precipitation is less than 200mm, resulting in frequent sandstorms and serious soil desertification. To protect the environment in arid areas, it is imperative to adopt efficient water and nitrogen control technology. Deficit irrigation and nitrogen fertilizer management is a technology that involves the water and nitrogen requirements during potato growth, regulation methods, and the influence of environmental factors on the regulation effect. In terms of water and nitrogen requirements, potatoes have different needs for water and nitrogen at various growth stages. In the early stages of growth, potatoes have relatively low water requirements, but as the plant grows and tubers form and expand, the need for water gradually increases. During the growth process of plants, nitrogen is an essential basic element, and the supply of appropriate amounts of nitrogen fertilizer plays an important role in increasing the yield and improving the quality of potatoes. Water and nitrogen regulation is mainly achieved through irrigation and fertilization techniques. In terms of fertilization, nitrogen fertilizer is applied in a timely and appropriate manner according to the growth stage and needs of potatoes, while also being combined with other nutrients such as phosphorus and potassium to meet the growth needs of potatoes. In terms of environmental factors, the effect of water and nitrogen regulation on potatoes is also influenced by environmental conditions. Suitable temperature and light conditions are conducive to potato growth and tuber formation and expansion, while soil type affects the retention and supply capacity of water and nutrients. So, the proper use of this technology can bring about the peak of potato production.

Keywords: water nitrogen regulation; potato yield and quality; arid area; source library relationship

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1. Introduction

Potato (Solanum tuberosum L.) is an underground stem vegetable crop. Its root system grows from the tuber, with lateral roots emerging from the base of the seed potato. Plants that develop from seeds in the berries have both primary and lateral roots. Most of the potato roots are distributed 40 to 70 cm below the soil surface, although some can extend deeper, reaching over 1 meter. Each stage of growth requires a large and sufficient

supply of water and nitrogen to meet the plants' growth and development needs. In the early stages of growth, the potato's demand for water and nitrogen is relatively low. However, in the middle and late growth stages, this demand increases rapidly, especially during flowering and tuber development, when potatoes require more water and nitrogen to grow quickly, become strong, and reach harvest. Potatoes are an important crop, with global production exceeding 368.7 million tons, and two-thirds of the world's potatoes serve as a staple food. Potato production plays a significant role in supporting global food security.

The organs or sites of assimilate synthesis in crops are called sources, such as mature leaves. The site where assimilates accumulate is called the sink, and crop yields, represented by the harvested organ, are influenced by both the source and the extent to which assimilation accumulates in the sink. When the exchange is limited, the output is low, but when the exchange is large, the source capacity may still be insufficient to result in high output, as shown in Figure 1. Therefore, understanding the source-sink relationship in potatoes is crucial for ensuring national food security. Fertilizers play a vital role in potato growth [1]. As the saying goes, "too little water, too much fertilizer", these proverbs reflect the importance of water regulation in agriculture. Both water and fertilizer are significant factors affecting potato biomass and quality. Water is also essential for human life, and in today's world of water scarcity and excessive fertilizer use, agriculture faces significant challenges. With the rapid growth of the global population and extreme climate changes threatening food security, the availability of water has become a major limitation in crop production. Increased agricultural productivity is necessary to meet the needs of the growing population. Therefore, the efficient utilization of water and fertilizer in potato cultivation has become a key area of research [2].

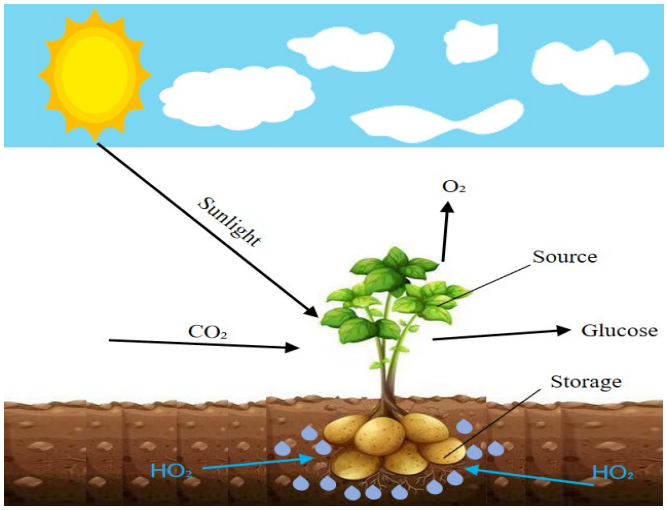

Figure 1. Source-Library Relationship of Potato.

2. Importance of Water-Based Nitrogen Regulation in Potato

According to incomplete statistics, by the mid-21st century, the demand for global resources will increase due to the growing population and rising consumption power, while the burden on agriculture will also become more severe [3]. This increased agricultural burden must be addressed without expanding the area of cultivated land or increasing resource inputs. Therefore, advancements in science and technology are necessary to enhance crop growth capacity, allowing for higher yields with less input [4].

2.1. Source-Reservoir Relationship of Potato under Water-Nitrogen Regulation

Generally speaking, understanding the determinants of individual plant biomass is crucial for improving plant yields. The organs or sites of assimilate synthesis in crops are

called sources, such as mature leaves, while the sites where assimilates accumulate are called sinks [5]. In general, the organ or part of the crop that synthesizes assimilates is called the source, such as a mature leaf. The location where assimilates accumulate is called the sink, which corresponds to the individual harvested organs of the plant. The main representative of the sink is the crop yield, which is primarily influenced by the assimilate production from the source and the degree of accumulation in the sink [6]. The source-sink relationship in crop yield is affected by both plant genetics and external environmental factors [7]. Among these, changes in environmental factors are the primary cause of yield variations. While many environmental factors can be artificially regulated in agricultural production, water and nitrogen management are particularly influential. Previous studies suggest that major changes in source-sink relationships can occur under drought conditions, as growth priorities shift, resulting in reduced photosynthetic rates, smaller grain size, lower grain quantity, and, consequently, yield fluctuations. Nitrogen is a key nutrient that impacts changes in plant biomass. Previous research concluded that the application of nitrogen fertilizer can improve the source-sink transformation efficiency by extending the duration of leaf area index (LAI), relative growth rate (RGR), and net assimilation rate (NAR), thereby increasing plant yield [8]. Additionally, nitrogen significantly affects crop yield [9]. Madani et al. showed that applying nitrogen fertilizer after flowering in winter wheat under drought conditions increased grain yield by reducing reservoir limitations rather than enhancing source intensity [10]. Therefore, studying the source-sink relationship of crops under different water and nitrogen conditions and its impact on yield is essential for maximizing yield and optimizing water and nitrogen use efficiency. In potato cultivation, water and nitrogen regulation can effectively improve stress resistance, promote plant growth, increase tuber yield, and enhance quality. Especially in water-scarce areas, this technology not only increases crop biomass and quality but also ensures improved water use efficiency while conserving water. In agricultural production management, it plays a crucial role.

2.2. Suitability of Water and Nitrogen Regulation in Potato

Potatoes have different water requirements at various growth stages, so managing soil water content appropriately is crucial for potato growth. Maintaining soil moisture within the optimal range for water retention in the field promotes the normal growth and yield formation of potatoes. Plant roots are the main organs responsible for water absorption, and understanding the distribution of roots across soil layers is the foundation for effective water management [11]. Potatoes are typically shallow-rooted crops, with their root systems primarily concentrated within the top 30 cm of soil. However, root depth can vary depending on soil texture, with some roots reaching depths of up to 1 meter. Therefore, irrigation methods such as drip irrigation and sprinkler irrigation, along with a reasonable irrigation plan based on the growth stage and soil moisture conditions, are essential to avoid both excessive irrigation and drought stress [12]. Through proper water management, the water use efficiency of potatoes can be improved, minimizing water resource waste.

Regarding nitrogen fertilizer application, nitrogen is a crucial nutrient for potato growth [13]. When fertilizing potatoes, the amount and timing of nitrogen application should be determined based on soil fertility, variety characteristics, and target yield. Nitrogen fertilizer should be applied in stages to meet the different needs at various growth stages of the potato. During tuber formation and expansion, the amount of nitrogen fertilizer should be increased to promote tuber growth and boost yield. Water and nitrogen have a synergistic effect on potato growth, so an optimal balance between water and nitrogen is important for promoting potato growth. Water and nitrogen regulation affects both the yield and quality of potatoes by influencing physiological and biochemical pro-

cesses as well as the soil environment. Further research into the physiological and biochemical mechanisms of water and nitrogen regulation will help develop more scientific water-nitrogen management strategies.

2.3. The Application of Water and Nitrogen Regulation and Its Impact on the Environment

Selection of Irrigation Methods: Appropriate irrigation methods should be chosen based on local hydrological and climatic conditions. Drip irrigation and sprinkler irrigation can improve the utilization of water and fertilizer, while reducing the loss of water and nutrients. For nitrogen fertilizers, high-efficiency, low-residue varieties, such as urea and ammonium nitrate, should be selected. Additionally, the application method and timing of nitrogen fertilizers must be carefully considered to prevent volatilization and loss.

Monitoring and Adjustment: During the management process, close attention should be paid to the physiological conditions of the plants at each growth stage, as well as to soil, water, and fertility conditions. Timely adjustments should be made as needed. The nutritional status, as well as the water and fertilizer demands of potatoes, can be assessed by observing indicators such as leaf color and growth rate, as shown in Figure 2.

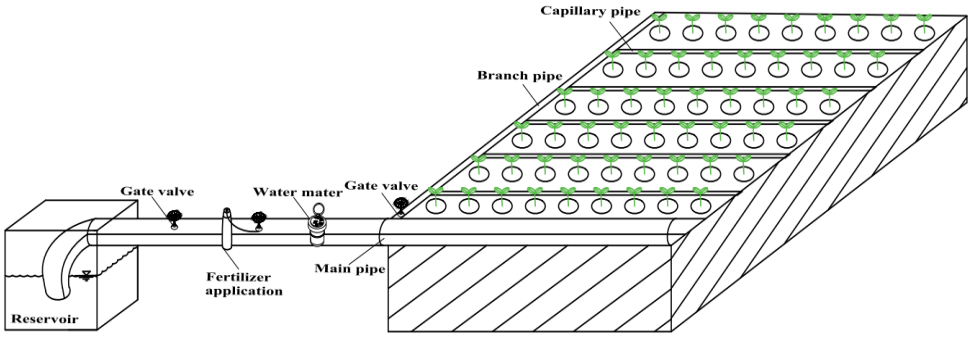

Figure 2. Application of Water and Nitrogen Regulation.

The application of these technologies varies globally, and their actual effects are influenced by a variety of factors. Water and nitrogen regulation technologies can enhance the photosynthetic rate, transpiration rate, chlorophyll content, and intercellular CO_2 concentration of plants, while effectively saving water and reducing nitrogen use. This provides plants with more energy and nutrients for growth and development, thereby improving the ability of the plant canopy to intercept sunlight for photosynthesis. As a result, the yield and quality of the plants are improved, benefiting both local food production and contributing to the prevention of wind erosion and sand fixation, thus forming a natural green barrier. The efficient technological system demonstrates significant potential for reducing water usage and increasing crop yields.

3. Effects of Water and Nitrogen Regulation on Biomass, Quality, Soil Environment and Water Use Efficiency of Potato

Through reasonable drip irrigation (DI), significant improvements can be achieved in potato yield and quality, soil structure and enzyme activity, as well as water and fertilizer conservation [14]. For example, under irrigation conditions, potato yield and the rate of marketable potatoes can reach high levels when irrigation is set at 180 mm and nitrogen application is 180 $kg \cdot ha^{-1}$. Additionally, water and nitrogen regulation can enhance the starch and vitamin C content of potato tubers.

3.1. Effect of Water and Nitrogen Regulation on Potato Yield and Quality

Water and nitrogen are the two main elements that regulate crop growth, and an appropriate supply of both is fundamental to maintaining consistently high yields in po-

tatoes. Nitrogen (N), one of the three essential nutrients required for crop growth, supports plant development throughout all growth stages. As a nitrogen-loving crop, potatoes respond positively to the proper application of nitrogen fertilizers, which can effectively promote growth and increase yield. Nitrogen is a vital component of proteins and other biological compounds, and it also plays a key role in critical physiological processes such as photosynthesis, respiration, and metabolism. The application of nitrogen fertilizer increases leaf nitrogen content, thereby enhancing chlorophyll content and the activity of photosynthesis-related enzymes, ultimately improving the photosynthetic rate of the plant [15]. An appropriate nitrogen supply can also promote potato plant growth and increase starch, protein, and vitamin C (VC) content in the tubers. Studies have shown that as irrigation and nitrogen application increase, potato biomass initially rises and then declines. Compared with traditional irrigation and fertilization methods, optimized water and nitrogen management can extend leaf lifespan and improve photosynthetic efficiency, thus maintaining a higher source capacity for the plant. This, in turn, facilitates the accumulation of dry matter in the entire plant and ultimately contributes to higher yields.

3.2. The Impact of Water and Nitrogen Regulation on Soil Environmental Structure

Studies have shown that appropriate water and nitrogen treatments can enhance soil enzyme activity, thereby improving the composition and structure of the soil. Controlling irrigation levels and nitrogen fertilizer application can significantly increase soil urease, catalase, and phosphatase activities, thus optimizing the soil environment [16,17]. In addition, suitable water-nitrogen management can reduce the soil microbial biomass carbon-to-nitrogen ratio, which contributes to improved soil quality and promotes crop growth. Variations in water and nitrogen conditions directly influence soil enzyme activity [18].

Research has also demonstrated that soil urease and alkaline phosphatase activities serve as important indicators for evaluating soil fertility, and their activity levels are affected by soil chemical properties and the activity of other soil enzymes. These findings further suggest that regulating water and nitrogen conditions to influence soil enzyme activity can indirectly improve soil fertility and promote crop development. Therefore, the rational regulation of water and nitrogen inputs can effectively improve soil structure and enzyme activity, ultimately enhancing soil quality and crop biomass. This provides a valuable theoretical foundation and practical guidance for agricultural production in China.

3.3. Effect of Water Nitrogen Regulation on Water Use Efficiency in Potato

The water use efficiency of potatoes is a key indicator for assessing the relationship between water consumption (including stage-specific and total water consumption) and yield [19]. Reasonable water and nitrogen management can optimize the water use process in potatoes, reducing ineffective evaporation and deep percolation.

Appropriate water stress can effectively regulate the closure of plant stomata, thereby decreasing non-productive evaporation, while roots in the moist zones absorb water to meet the minimum requirements for crop growth. This leads to improved water use efficiency [20].

Suitable levels of water and nitrogen fertilizer promote the growth and distribution of potato roots, enhance their water absorption capacity, and allow for more uniform root distribution. This enables potatoes to absorb water and nutrients from various soil depths, further improving water use efficiency.

However, beyond a certain level of fertilization or irrigation, water use efficiency tends to decrease with increasing amounts of water or nitrogen application.

4. 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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