

## Progress of Coupled Water and Fertilizer Research in Winter Wheat and Summer Corn

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### Abstract

Winter wheat-summer corn is a major food crop in China, and securing its production is of great significance to China's food security. China's water shortage, and water and fertilizer utilization rate is low, so it is very necessary to carry out water-fertilizer coupling experiments, to investigate the efficient water-fertilizer coupling program and the impact of different irrigation volume of fertilizer application on crop growth. This paper discusses and summarizes the effects of water-fertilizer coupling on the growth, yield and quality of winter wheat-summer maize, and puts forward the prospects for future research.

### Keywords

Water-fertilizer coupling; Winter wheat; Summer corn; Quality; Yield.

## 1. INTRODUCTION

The total amount of water resources in China is abundant, but the per capita water resources are only one-third of the world average, and the distribution of water resources in China is uneven. There are large differences between regions, the contradiction between supply and demand is prominent, and the serious shortage of water resources has become One of the factors restricting China's economic development. Among the water consumption of various industries, agricultural water is the largest water user in my country. In 2018, agricultural water consumption accounted for 61.4% of the country's total water consumption. Therefore, improving agricultural water efficiency and reducing agricultural water consumption are the current priorities.

Water and fertilizer are two important factors affecting the growth of crops, but it is not necessary to blindly increase the amount of irrigation and fertilizer to obtain high yields. Excessive irrigation water will affect the respiration of plants, which is not conducive to the absorption of nutrients, and will reduce photosynthetic efficiency, resulting in lower yields; and flood irrigation will not only destroy the soil aggregate structure, cause soil compaction, but also cause soil salinization. Excessive fertilization will affect the soil and atmospheric environment, resulting in decreased soil fertility, leaching and polluting groundwater, reducing crop quality, and harming human health through the food chain; and excessive use of nitrogen fertilizers will also cause the volatilization of greenhouse gases and destroy the ozone layer [1].

## 2. DEFINITION AND DEVELOPMENT OF WATER AND FERTILIZER COUPLING

The coupling effect of water and fertilizer refers to the comprehensive consideration of soil and water in the agricultural ecosystem, and the integration of soil and water to act on plant growth. Different combinations of water and fertilizer can produce three different effects on plants, namely synergistic effect, Superimposed effect and antagonistic effect [2].

## 2.1. Synergy

The two factors of water and fertilizer interact and promote each other so that their influence is greater than the sum of their respective effects.

## 2.2. Stacking Effect

The coupling effect of the two factors of water and fertilizer is equal to the sum of their respective influencing effects, that is, the influencing factors are independent and not related to each other.

## 2.3. Antagonism

The effects of the two factors of water and fertilizer are mutually restricted, and one of the factors will offset the positive influence of the other factor and produce a negative effect.

## 2.4. Development of Water and Fertilizer Coupling

The research on the coupling of water and fertilizer began when people began to explore the relationship between fertilizer and water. As early as 1911, Montgomery and others began to study the influence of soil fertility on water consumption of corn. They found that corn water consumption in high-fertility soils Increased application of organic fertilizers has a tendency to increase crop water use efficiency. In 1953, C.G.Panten and R.W.Leamer noticed high soil water potential in their research, and applying more fertilizers can obtain higher crop yields [3]; 1977 Campbell CA [4] explored the effects of nitrogen fertilizer and water on the dry matter accumulation rate and plant nitrogen content of spring wheat [4]. Different water and fertilizer conditions have different effects on crop growth and yield. Li Shiqing [5] explored the effects of different water and fertilizers on corn yield and fertilizer efficiency, and found that the combination of water and fertilizer can improve the distribution of nutrients in crops and the composition of grains and stems. Is conducive to the formation of yield. Zhao Bingzi [6] also found that different water and fertilizer conditions will affect the absorption of N, P, and K of crops. Different soil moisture will affect the absorption of nutrients. This is because the transport of nutrients in the soil to the plant body mainly depends on mass flow and diffusion. Transpiration provides the driving force for it, so that nutrients move to the root zone with the soil water. And different soil moisture will change the tortuous degree of the diffusion path in the soil[7][8]. Therefore, it is very important to study the impact of water and fertilizer coupling on crops and to propose a scientific and reasonable water and fertilizer program, so that water and nutrients can work together and play an important role in improving yield and water and fertilizer use efficiency.

# 3. THE EFFECT OF WATER AND FERTILIZER COUPLING ON WINTER WHEAT

## 3.1. The Effect of Water and Fertilizer Coupling on Winter Wheat Growth, Yield and Water Use Efficiency

Winter wheat planting areas are mainly distributed in northern China. The growth period is about 240 days and needs to pass the wintering period. The water consumption during the whole growth period is about 450mm, and the average water use efficiency is 15.91kg/(hm<sup>2</sup>\*mm)[9], and the water demand is large. Part of it is satisfied by irrigation. Predecessors have conducted research on the irrigation of winter wheat. For example, Zhang Xingjuan[10] found that two irrigations during the jointing and flowering periods under limited water conditions can achieve high yields and higher water use efficiency; Huang Caixia [11] think that the best irrigation scheme is to irrigate 75mm at the jointing, heading and filling stages. Nitrogen nutrition has an important effect on winter wheat population development, photosynthetic material assimilation and transportation, and root-shoot ratio. Under water

deficit conditions, with the increase of nitrogen application rate, the root-shoot ratio decreases, and more photosynthetic compounds are transported to the above-ground part. Economic yield and water use efficiency have an increasing trend; but under full irrigation, with the increase of nitrogen application, yield and water use efficiency first increase and then decrease, and there is an obvious threshold of nitrogen application [12]. Phosphorus is also an important factor restricting the growth of winter wheat. In the winter wheat water-phosphorus coupling experiment, with the increase of irrigation and phosphorus application, the water potential and water content of flag leaves increase, which prolongs the photosynthetic function period of flag leaves and delays the flag. Leaf senescence [13], proper water and phosphorus combination can promote the absorption of N and P by winter wheat, and can also increase the transport speed of nutrient elements in the plant body, while excessive phosphorus application under low water conditions will inhibit the plant Absorption of N and P [14]. Water-potassium coupling has a significant response to promoting dry matter accumulation and increasing dry matter transport to grains. For example, Wang Lijin's research concluded that proper potassium application can increase leaf chlorophyll content and dry matter accumulation speed to promote dry matter transport to grains, and Irrigation twice in the jointing stage and flowering stage, combined with the application of K<sub>2</sub>O 225 kg/hm<sup>2</sup>, can achieve high yield and water saving effects [15].

### **3.2. The Effect of Water and Fertilizer Coupling on Winter Wheat Quality**

In addition to the variety and climate, the quality of winter wheat is also affected by different water and fertilizer management modes. For example, Li Sha's study found that with the increase of irrigation water under the same nitrogen level, the crude protein content of grains decreases and the starch content increases; With the increase of nitrogen application rate, the crude protein content of grains increased and the starch content decreased [16]. This shows that water and fertilizer interact, and nitrogen fertilizer can only work with the cooperation of water. A reasonable water and nitrogen model can not only increase yield but also improve quality, and Zhai Bingnian [17] found that the jointing stage is water and nitrogen. During the sensitive period of efficient utilization, topdressing nitrogen during this period can increase the content of free amino acids and protein in the grain. The quality of winter wheat is also affected by different types of nitrogen fertilizer. The yield and quality of winter wheat with single application of inorganic nitrogen fertilizer are better than those with organic nitrogen fertilizer, which is due to insufficient nitrogen supply capacity of organic fertilizer [17]. Potassium fertilizer also has an important effect on the quality of winter wheat. Reasonable application of potassium fertilizer has a significant improvement in the precipitation value, dough stability time, wet gluten content, protein content and protein yield of wheat [19]. This is because potassium can increase the photosynthesis of flag leaves. Speed and sucrose phosphate synthase (SPS) activity, increase the accumulation of soluble protein in flag leaves before and after anthesis.

## **4. THE EFFECT OF WATER AND FERTILIZER COUPLING ON CORN**

### **4.1. The Effect of Water and Fertilizer Coupling on Corn Growth, Yield and Water Use Efficiency**

Corn is the second largest food crop in my country, with multiple uses such as food, feed, and industrial raw materials, and it occupies an important position in agricultural production [20]. The growth period of summer corn is about 100 days, the water consumption during the whole growth period is about 350mm, and the average water use efficiency is 23.36 kg/(hm<sup>2</sup>\*mm)[9]. The rainfall during the growth period is relatively abundant, so reasonable arrangements for irrigation and fertilization are particularly important. There have been some studies on the coupling of water and fertilizer in maize. For example, Guo Bingyu[21] found that the dry matter accumulation and nitrogen uptake rate of maize increased with the increase of nitrogen

application. Increasing irrigation water and nitrogen application can both increase maize. The interaction between yield, irrigation water volume and nitrogen application rate is significant, and the main effect is nitrogen application rate. Zhang Zhongxue [22] established a regression model for the four factors of irrigation water, nitrogen fertilizer, phosphate fertilizer and potassium fertilizer to analyze the influence of each factor and its coupling effect on the photosynthetic rate of maize. The test results showed that the influence of each factor on the photosynthetic rate ranges from large to The small differences are: irrigation amount, nitrogen fertilizer, potassium fertilizer, and phosphate fertilizer. With the increase of various factors, the photosynthetic rate shows a trend of first increasing and then decreasing; among the coupling effects of various factors, the coupling effect of water nitrogen, phosphorus potassium, and water potassium is significant. The coupling effect of other factors is not significant. Water-nitrogen coupling and phosphorus-potassium coupling have negative interactions on maize photosynthetic rate, and water-potassium coupling has positive interactions.

#### 4.2. The Effect of Water and Fertilizer Coupling on Corn Quality

Improving corn quality is of great significance to feed and processing [23], and water and fertilizer regulation has an important impact on corn quality. With the increase of nitrogen application rate, corn grain yield and nutritional quality indicators such as crude protein, crude starch and crude fat also increase [24]. A reasonable water and nitrogen application mode can obtain higher yield and quality. Yang Li [25] The water-nitrogen coupling experiment of corn in Henan area showed that water-nitrogen coupling can regulate the activity of sucrose phosphate synthase (SPS). SPS plays an important role in regulating leaf sucrose synthesis, and it controls the synthesis and synthesis of sucrose in leaves. Decomposition, so maintaining the activity of SPS has an important impact on improving corn quality. Under the same irrigation treatment, nitrogen application will significantly increase the activity of SPS. Under the same nitrogen application treatment, with the increase of irrigation water, the activity of SPS also increases. The experiment showed that the nitrogen application rate is 240 kg/hm<sup>2</sup>, and the higher irrigation water amount can maintain the higher activity of SPS, accelerate the formation of sucrose and protein in the leaves, and improve the quality of corn. Different regions have different optimal water and fertilizer schemes. For example, Feng Peng et al. [25] conducted a water-fertilizer coupling experiment in Inner Mongolia and found that the yield of corn and the content of lactic acid were high and the nutritional quality was high when 207mm of irrigation and 225kg/hm<sup>2</sup> nitrogen fertilizer was applied simultaneously is an ideal combination of water and fertilizer.

### 5. PERSPECTIVES

With the domestic emphasis on agricultural development, more and more attention has been paid to the relationship and interaction between water and fertilizer. In recent years, the application of water and fertilizer integration has become more and more widespread. "Integration of water and fertilizer", as the name implies, is to turn water and fertilizer into a whole and act together on farmland. The fertilizer is dissolved in the water and transported to the roots of the crop through the pipe. The flow rate of the emitter can be adjusted by changing the pipe pressure. The advantage of this is that the fertilizer can be fully dissolved in the water to uniformly and accurately act on the plant roots, avoid soil compaction, maintain the soil aggregate structure, facilitate the respiration of the plant roots and save water resources. In this way, the unified combination of water and fertilizer can be realized, and the same management of farmland water and nutrients can be realized, and "water-promoting fertilizer, fertilizer-adjusting water, water-fertilizer coupling" can comprehensively improve water and fertilizer utilization efficiency, and avoid water waste and leaching loss of fertilizer.

Winter wheat and summer corn are the main food crops in China. Improving their water and fertilizer management technology is of great significance to saving water resources. In the future, remote sensing technology and artificial intelligence can be combined to build a complete water and fertilizer observation management system, and combined with large sprinkler irrigation machines, no one Machine technology realizes modern precision water and fertilizer agricultural management. The climate and rainfall in different regions are different. Crop growth models can be established according to local climate factors and uploaded to the cloud to provide local farmers and technicians with real-time optimal water and fertilizer implementation management plans, effectively improving the water and fertilizer use efficiency of winter wheat and summer corn, Yield and quality, alleviate China's water shortage and low fertilizer utilization problems.

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