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Advances in Studies of Biological Nitrogen Saving Technology for Wheat

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Abstract This paper first described the current status of wheat nitrogen fertilizers utilization rate. Then, from balanced fertilizer application, applying slow/controlled release fertilizer, deep application of nitrogen fertilizers and graded application, controlled application amount, selection of application time according to soil properties, diagnosed application of fertilizer with instrument, addition of synergist, and precise fertilizer application, it summarized biological nitrogen saving methods and introduced prospects of future biological nitrogen saving technology.

Key words Wheat, Fertilizer utilization rate, Biological nitrogen saving method

1 Introduction

Nitrogen fertilizer plays an important role in the growth of wheat which is a major grain crop. In recent years, the excessive increase in chemical fertilizer utilization, the lag of fertilizer application and other related technologies and improper application of chemical fertilizers have led to a considerable decline in the utilization rate of chemical fertilizers, led to a series of problems such as waste of resources, increase in agricultural production costs, environmental and agricultural product pollution, as well as decline in the quality of agricultural products. However, under the pressure of limited cultivated land resources and large population, the sustainable development of agriculture in China will still need large amount of fertilizer for a long time. Nitrogen fertilizer occupies the most important position in the demand of crop nutrition. In China, at present, the utilization rate of nitrogen fertilizer is only 30% - 50%, lower than that of developed countries by 15 - 20 percentage points. Every year, some 9 to 15 million tons of chemical nitrogen is lost through leaching and volatilization, with a value of about 3 500 - 6 000 million yuan, causing huge waste of resources and serious damage to the environment. Therefore, it is of great significance to increase the utilization rate of fertilizers and give full play to the role of fertilizers for the sustainable development of China's agriculture.

At present, most studies are based on the results of field experiments. Due to the influence of various conditions such as soil, water and climate in field experiments, the experimental results of fertilizer utilization rate of different crops are quite different in different regions. Thus, it is necessary to summarize a large number of experimental results. Zhu Zhaoliang[1] summarized 782 field experiments in China and concluded that the utilization rate of nitrogen fertilizer in wheat, rice and maize ranged from 28% to 41%. Obviously, China's fertilizer utilization rate is low.

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2 Biological nitrogen saving methods

2.1 Balanced fertilizer application The balanced fertilization physicochemical integration technology is a scientific fertilizer application method based on nutrient balance theory, with the formula fertilizer as a carrier, combining the actual concept of technology with material object. The principle is based on the difference between the amount of nutrients needed to achieve the target yield and the amount of nutrients supplied to the soil as the basis for fertilizer application, so as to achieve the purpose of nutrient balance. In short, it solves the problem of "supplementing the nutrient that is needed at the amount that is needed" through applying the formula fertilizers[2]. The key point of balanced fertilization technology lies in the regulation of the types and proportion of different nutrient elements and the balance between the supply of fertilizer and the crop demand at different growth stages of the crop.

Generally, it is believed that the soil in China lacks nitrogen, but in case of lack phosphorus, nitrogen utilization will also be very low. Therefore, combined application of nitrogen and phosphorus, potassium and trace element fertilizers with nitrogen and organic fertilizers will have better effect. Nitrogen fertilizer has a great effect on wheat plant height, spike number and panicle size, grain weight, and the yield. Without application of nitrogen fertilizer, even if the same amount of phosphorus and potassium fertilizer is applied, the plant height was 8.91 cm shorter than those with application of nitrogen fertilizer, the number of spikes reduced 41%, the number of grains per spike reduced 14.4, and the basal spike degradation rate reached 19.7%. Although the 1 000-grain weight was increased, the theoretical yield and actual yield declined 48.2% and 46% respectively[3].

2.2 Slow/controlled release fertilizer One of the reasons for the low utilization rate of fertilizer is the imbalance between time and intensity of fertilizer releasing nutrients and crop demand. Slow / controlled release fertilizer is the use of various mechanisms to control the water solubility of conventional fertilizers, and to effectively slow down or control the release of fertilizer nutrients through modifying the fertilizer, making the release time and in-

tensity of fertilizer nutrients conform to the absorption rules of crop nutrients[4].

Coated controlled release fertilizer is the fertilizer that presets the fertilizer release mode in the crop growth season through coating, making the nutrient release rules synchronous with the absorption of crop nutrients, so as to increase the fertilizer utilization rate. It can slow down the release of the original nutrients to extend the effective absorption time of plants for nutrients. The characteristics of coated controlled release fertilizer are as follows. (i) High utilization rate of fertilizer. At present, due to air evaporation, underground infiltration and surface water flushing, the utilization rate of conventional fertilizers in China is low, the utilization rate of nitrogen fertilizer is in the range of 30% -50%, while the coated controlled release fertilizer can reach the utilization rate of 80% through avoiding the loss of fertilizer. (ii) Significant effect of yield increase. Through coating, it controls the release of nutrients, makes the supply of crop nutrients become steady and regular, and avoid the de-fertilization and sharp growth of crops.

The application amount of coated controlled release fertilizer should be determined according to the target crop yield, soil fertility level and nutrient content of fertilizer. At present, the fertilizer for large area of field crops is generally the mixed fertilizer of coated fertilizer and quick-acting fertilizer, and its application amount should take full account of the nutrient type, content and proportion of the coated fertilizer. The application of coated controlled release fertilizer should be carried out in accordance with planting and growth and development characteristics of different crops. For rice, wheat and other crops with dense and uniformly distributed roots, it is feasible to apply the special coated controlled release fertilizer at the recommended amount in time of sowing. The successful development of slow/controlled release fertilizers has greatly increased the utilization rate of fertilizers and made useful explorations in solving the problems of resource utilization, lowering agricultural production costs, improving agricultural product quality and reducing environmental pollution.

2.3 Deep and graded application of nitrogen fertilizer Deep application of nitrogen fertilizer is one of the most effective measures to increase the utilization efficiency of nitrogen fertilizer. The experimental results[5-6] indicated that the effect of deep application of ammonium bicarbonate or urea is about 2.7% - 11.6% higher than the surface application, and it can increase the nitrogen fertilizer utilization rate up to 7.2% -12.8%. Graded application at different stages can effectively reduce the loss caused by one-time fertilization and can increase the nitrogen fertilizer utilization rate.

2.4 Appropriate amount of nitrogen fertilizer Nitrogen fertilizer plays a greater and greater role in increasing the crop yield. According to statistical data, the grain yield of China increased significantly with the increase in the application amount of nitrogen fertilizer, but the grain yield per unit of fertilizer decreased significantly[7]. In the 1960s, 1 kg fertilizer could increase the grain yield 21.0 kg; in the 1970s, 1 kg fertilizer could only increase the grain yield 8.8 kg; in the 1980s to the middle of 1990s, 1 kg fertilizer could only increase the yield 6.3 kg, largely because of the low utilization rate[8]. At the low nitrogen application level, the yield increased gradually with the increase of the nitrogen application rate. When it exceeded a certain amount, the yield did not increase but decreased. What's more, with the increase in the nitrogen application amount, the amount of nitrogen fertilizer lost through various ways is also increasing, and the nitrogen utilization rate will also decline. Therefore, the application amount of nitrogen fertilizer should be controlled within the economic optimal nitrogen amount.

2.5 Application of nitrogen fertilizer in proper time and place Soil property and organic matter content have a great impact on the application of nitrogen fertilizer. It is generally believed that sandy soil features fast mineralization of organic matters and poor fertilizer holding, so it should be applied with less amount but many times; clay soil features slow mineralization, and the applied ammonia fertilizer is susceptible to adsorption of soil colloids and nitrogen loss due to denitrogenation. Loam soil has excellent performance of holding fertilizer, so the fertilizer application methods can be determined according to the growth of plants[9].

It is generally believed that under the conditions of high yield or super high yield, properly delaying the nitrogen application in spring can postpone the aging of flag leaves and roots, and increase the grain weight and increase the grain yield[10-11]. Under the conditions of super high yield, with the increase in the soil fertility level, the effect of topdressing nitrogen fertilizer on the number of spikes becomes extremely small.

Wang Mingyou[12] studied the effect of nitrogen topdressing period on the grain yield and quality, and found that from the perspective of high quality and high yield, topdressing in spring can be properly postponed to the jointing or flag leaf stage; because the topdressing period has different regulation effects on different gene varieties, it is required to pay attention to determine proper topdressing period according to the varieties and characteristics. Wu Ji *et al.* [13] carried out a study using pot experiment and results indicated that proper application of nitrogen fertilizer can significantly increase the grain yield of strong gluten wheat. Spraying nitrogen fertilizer on leaf surface at jointing stage could significantly increase the plant height, spike length, spike number, spike grain number and 1 000-grain weight of strong gluten wheat, thus promoting the realization of the highest yield of wheat. Appropriately increasing the proportion of nitrogen fertilizer application at middle and late stage is helpful to improve the quality of strong gluten wheat, and topdressing at jointing and heading stages has the optimal effect. Integrating the yield and quality effects, nitrogen application at the jointing stage is the best nitrogen fertilizer management method.

2.6 Diagnosed fertilizer application for crops The diagnosed fertilizer application method, developed in the 1990s, used Soil and Plant Analyzer Development (SPAD) to diagnose the

crop nutrients and provide recommendations for fertilizer application. It can detect the relative chlorophyll content of plant leaves without damage under the field condition. The working principle of SPAD is to determine the nitrogen nutrition status of crops by using the relationship between chlorophyll content in leaves and nitrogen content in leaves. The specific method is as follows: insert the plant leaves into the detection part of SPAD to read the chlorophyll value (leaf color value), and determine the leaf color value according to the relationship with the nitrogen content of the plant, so as to deduce the nitrogen content of the crop. This method simplifies many tedious processes compared with the traditional nitrogen fertilizer recommendation method. Under the field conditions, when using SPAD to diagnose the status of crop nitrogen nutrition, the results of different measurement periods and different measurement sites are different, therefore, the best determination period and the best determination site of crops should be properly selected, otherwise, it will affect the determination results[14]. SPAD is convenient, quick, nondestructive, and most importantly, it can reduce the amount of nitrogen fertilizer and increase the fertilizer utilization rate. At present, SPAD has been applied in crops such as rice[15] and wheat[16].

2.7 Adding synergist in nitrogen fertilizer Adding synergist in nitrogen fertilizer can inhibit soil nitrification, reduce microbial immobilization, and strengthen the fertilizer holding performance, then it can be applied by few times with large amount[9].

As one of the most widely used nitrogen fertilizers in China, urea accounts for more than half of China's chemical nitrogen fertilizers every year. However, after being applied to the soil, through the action of soil urease, the urea is easily hydrolyzed, leading to volatilization of NH_3, and bringing about tremendous economic losses and environmental pollution. Urease inhibitors can extend the diffusion time of urea at the fertilization point through delaying the hydrolysis of urea, so as to reduce the concentration of NH_4 and NH_3 in the soil solution and reduce the volatilization loss of NO_3.

Using lignin as the material for urea-controlled release, the results of wheat pot experiment showed that under the same nitrogen condition, compared with the pure urea treatment, adding lignin can accelerate the growth of plants, promote seed setting rate and the number of grains, so as to increase the yield; besides, it can greatly increase the utilization rate of nitrogen fertilizer, reduce the pollution to the ecological environment due to loss of nitrogen fertilizer, showing broad prospects of development of using lignin in the paper industry as a fertilizer controlled release material[17].

2.8 Precise and quantitative fertilizer application Slow release fertilizers release nutrients slowly, and their volatilization, leaching and other loss ways are also inhibited, the supply of nitrogen nutrients is little in the early period, but sufficient in the late period, which is close to the nutrient demand curve of crops, reaching the dynamic balance and accordingly greatly reducing the pollution[18]. Some experiments[19] show that SCU (slow/controlled release urea) can significantly increase the nitrogen utilization rate; it can increase the nitrogen physiological utilization rate by 7.1 percentage points compared with the ordinary urea, and increase the nitrogen fertilizer agronomic utilization rate by 5.8 percentage points. Thus, SCU fertilizer has better nitrogen saving and efficiency increasing effect. Nitrogen-saving high yield cultivation method should effectively improve the economic traits of rice, and optimize the various factors of yield structure. From analysis on effects of nitrogen-saving high yield cultivation method factors on the yield, it can be known that the key direction for nitrogen-saving high yield cultivation technology is the effective panicle per unit area[20].

3 Conclusions

At present, great advances have been made in the research on the theory and technology of biological nitrogen saving, but it still can not meet the demands of nitrogen-saving agriculture. There are still many problems to be solved urgently. It is recommended to develop and use quick-acting controlled nitrogen fertilizer centering on increasing the nitrogen utilization efficiency; study the ecological and physiological mechanisms of high-efficient utilization of crop nutrients; study the physiological and genetic mechanisms of differences in crop genotype nutrient efficiency, and improve the nutrition genetic traits using the biotechnology, screen and cultivate fine crops with high efficient utilization of nutrients, to realize the improvement of plant nutrient traits, and increase the crop nutrient utilization efficiency.

In summary, through comprehensive utilization of modern biological techniques and traditional techniques, it is recommended to use the physiological and genetic mechanisms of differences in the nutrient efficiency of wheat, to improve the nutrition genetic traits using the biotechnology, screen and cultivate fine crops with high efficient utilization of nutrients, to realize the improvement of plant nutrient traits, and increase the crop nutrient utilization efficiency. Besides, it is of great significance to develop highly efficient nitrogen fertilizers that meet the characteristics of nitrogen demand for crops, in order to ensure food security and protect the ecological environment according to wheat nitrogen demand signals and environmental information.

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exquisite couple packages, anniversary packages, birthday packages. They may provide special price for some dishes, for example, keeping high price of steak but reducing price of other dishes. (ii) Western-style fast food restaurant operators should develop a reasonable price system for products offering different types of products to college students with different motivations, and highlight the "value for money" pricing features. (iii) Western-style fast food restaurant operators should set up telephone booking, WeChat client ordering system, and promptly provide delivery service and meal reservation service. Through the microblogging platform and WeChat client, western-style fast food restaurants can issue the restaurant and product information. (iv) Western-style fast food restaurants can launch sponsorship activities and provide coupons.

5.2 Prospects Future research on the consumption motivation and consumption behavior of college students in western-style fast food restaurants can be carried out from the following aspects. (i) The study on factors influencing consumption behavior and satisfaction of college students in western-style fast food restaurants on campus. (ii) The study on the relationship between self concept and subconsciousness of college students and their consumption motivation in western-style fast food restaurants. In general, self-concept and subconsciousness of consumers will affect the consumption motivation, accordingly affecting the consumption behavior. (iii) The study on improvement of the model for the relationship between the consumption motivation and consumption behavior in western-style fast food restaurants. (iv) Comparative study on the consumption behavior of college students and general consumers in western-style fast food restaurants.

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