Study on the Effects of Different Fertilization Times on Crop Yield and Soil Fertility Changes

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Abstract. The level of soil fertility plays a decisive role in the growth and development of crops and agricultural production. Reasonable fertilization time is of great significance for maintaining and improving soil fertility, increasing crop yield, and economic benefits. Rice is one of the main grain crops in China, and its yield and quality are influenced by natural environment, variety, water content, and fertility. Among them, fertility has the greatest impact on the yield and quality of rice. Within the scope of Design of experiments, rice yield is directly related to fertilizer application time. With the increase of fertilizer application time, rice yield increases significantly, and fertilizers and nutrient promoters play a good ecological and economic benefit. Although Biopesticide do not have a large yield increase effect, they can play the same effect as chemical pesticides. The amount of fertilizer used is the main factor in increasing crop yield, and the long-term application of nutrient promoters can also become an important factor in increasing yield. Different fertilization treatments also have different effects on the soil nutrient content of vegetable fields, and fertilization can significantly increase the soil nutrient content. This article takes rice as an example to study the effects of different fertilization times on rice yield and soil fertility changes.

Keywords: Changes in crop yield and soil fertility at different fertilization times

1. Introduction

Soil fertility is an essential attribute of soil, manifested as the ability of plants to grow and supply, coordinate nutrient conditions, and environmental conditions [1]. The level of soil fertility is related to the high, stable, and sustainable production of crops. Soil fertility is not fixed and unchanging. The material composition of the soil, natural environmental conditions, and human cultivation management affect the level of soil fertility. Unreasonable soil management leads to the degradation of soil fertility [2]. Currently, with the rapid development of China's economy and the continuous improvement of people's living standards, there is a higher demand for the quality of agricultural products. To improve the yield and quality of rice and ensure the sustainable development of the ecological environment, scientific and reasonable fertilization is necessary [3].

Rice is widely planted in China, and with the efforts of researchers, the yield of rice in China is also constantly increasing. Fertilization plays a crucial role in improving rice yield. Mastering scientific fertilization techniques can effectively improve rice yield and increase farmers' income [4]. The application of chemical fertilizers has played a huge role in improving crop yield. However, in recent years, in order to pursue high crop yield, there has been a continuous increase in the amount of chemical fertilizer input in farmland. A series of problems such as soil hardening, reduction of available nutrients and organic matter content, Soil acidification, reduction of fertilizer utilization rate, increased greenhouse gas emissions, and reduction of soil enzyme activity will be caused by long-term large-scale application of chemical fertilizers, thus affecting soil quality and crop yield [5]. How to apply fertilizer reasonably, improve crop yield, and enhance soil fertility has been a long-standing concern. Only through good and sustainable soil management, reducing soil degradation, and improving soil fertility can we meet the needs of sustainable development in human society. Since the 1990s, China has been continuously investing high amounts of fertilizers and nutrients, promoting a steady increase in crop yield and ensuring China's sustained and stable food supply; At the same time, the continuous application of chemical fertilizers has promoted the accumulation of soil nutrients, and the fertility of Soil organic matter, total nitrogen, available phosphorus and available potassium has been improved [6]. Rice is a fertilizer loving plant, and relying solely on the nutrient supply of the land is difficult to meet the nutrients required for rice growth. Therefore, it is necessary to apply corresponding fertilizers according to the characteristics of different growth stages of rice, especially the nitrogen, phosphorus, potassium and other fertilizers necessary for rice growth.

At the same time, attention should be paid to the methods, periods, and techniques of fertilization.

Improving soil fertility is an important measure to improve crop yield, and the addition of organic materials such as Manure and straw returning is an effective means to improve soil fertility [7]. This study focused on the differences of the effects of different fertilization time on rice yield and soil fertility, and discussed the effects of increasing Manure and returning straw to the field on crop yield and soil carbon and nitrogen storage intensity, so as to provide scientific basis for improving crop yield and better soil fertility.

2. Materials and Methods

2.1 Experimental Design

The fertilizer positioning experiment began in 2018, with the test soil being red soil, and the main rice varieties tested were single season rice varieties. There are four treatments in the experiment: (1) nitrogen phosphorus potassium (NPK); (2) NPKM+22.5 t · hm^{-2} Manure; (3) N, P, K+33.75t · hm^{-2} Manure (NPKM+); (4) Nitrogen, phosphorus, potassium, and straw returning to the field (NPKS). Each community is separated by a cement ridge, with a buried depth of 0.5 meters underground, a height of 0.2 meters above the surface, and a width of 0.2 meters. Each district group has a single row and single irrigation. Before transplanting rice, manual plowing and irrigation should be carried out. Select 3 experimental areas with uniform and consistent crop growth in each processing community, 3 m^2 (2.0 m×1.5m) as an experimental micro area, there are a total of 12 micro areas. A 30 cm buffer area is set around the micro area, and it is strictly prohibited to enter the micro area for experimental operations before crop harvesting. In the treatment, N, P, and K respectively represent the application of N 150 kg· hm^{-2}, P_2O_5 75 kg · hm^{-2}, and K_2O 45 kg · hm^{-2} per crop season; M is Manure (water content 28%); M+is excess Manure (water content 28%, dosage 1.5 times of M); S is wheat straw, of which Manure is pig manure, with N content of 1.5% (dry basis), and wheat straw with N content of 0.49% (dry basis). The fertilization amount of each treatment is shown in Table 1.

Table 1 Fertilization amount for each treatment

Handle	N	P_2O_5	K_2O	Organic fertilizer	Wheat straw
NPK	160	85	50	0	0
NPKM	160	85	50	22000	0
NPKM+	160	85	50	33800	0
NPKS	160	85	50	0	2180

2.2 Measurement Items and Methods

Soil nutrient content: When rice is harvested, soil samples are collected using the five point sampling method to collect 0-20 cm of topsoil. After the collected topsoil is mixed evenly, the roots, stones, etc. in the sample are picked out and processed using the quartering method. Finally, about 1 kg of sample is left, and each treatment is repeated 3 times. Soil SOC was determined by Potassium dichromate external heating capacity method; The soil TN was determined using the concentrated H_2SO_4 digestion semi micro Kjeldahl method and a fully automatic Kjeldahl nitrogen analyzer (KDY-9830, Beijing).

The calculation formula for soil C and N storage capacity is as follows:

$$S = C \times B \times H \times 10^{-1} (1)$$

In the formula, S represents the soil SOC and TN storage capacity (Mg · hm^{-2}); C represents the soil SOC and TN content (g · kg^{-1}); B represents soil bulk density (g · cm^{-3}); H represents the depth of the soil layer (cm).

Calculate the nitrogen fertilizer partial productivity during rice harvest in October 2018 and 2022, respectively, using the following formula:

Partial factor productivity of nitrogen (PFP N, kg · kg^{-1})=yield in the nitrogen application area/nitrogen application rate, referring to the crop yield produced by the unit of nitrogen fertilizer input.

3. Results and Discussion

3.1 Results

As shown in Figure 1 and Figure 2, increasing the application of Manure (NPKM, NPKM+) and returning straw to the field (NPKS) can improve the rice yield, and the extension of fertilization time will strengthen the yield increase effect. After one year of fertilization, the rice yield under NPKM treatment was the highest, reaching 3695kg · hm^{-2}, an increase of 16.4% compared to NPK treatment, followed by NPKM+and NPKS treatments, which increased by 16.2% and 4.6% respectively compared to NPK treatment. There was no significant difference between NPKM and NPKS treatments ($P>0.05$). Different fertilization measures have a significant impact on the marginal yield of rice. With the extension of fertilization years, the rice yield of NPKM+treatment was the highest, reaching 5287 kg · hm^{-2}, an increase of 50.1% compared to NPK treatment, followed by NPKM and NPKS treatment. The rice yield was 4835 and 4279 kg · hm^{-2}, respectively, an increase of 37% and 21% compared to NPK treatment, and there was a significant difference between NPKM+and NPKS treatment ($P<0.05$). The decomposition and release of phosphorus and potassium in Manure lead to the surplus of phosphorus and potassium in the soil, thus reducing the marginal production of phosphorus and potassium. Therefore, when applying Manure, the content of phosphorus and potassium in Manure should be comprehensively considered.

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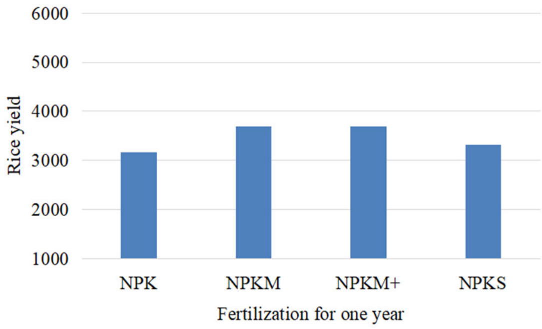

Figure 1 Annual rice yield after fertilization

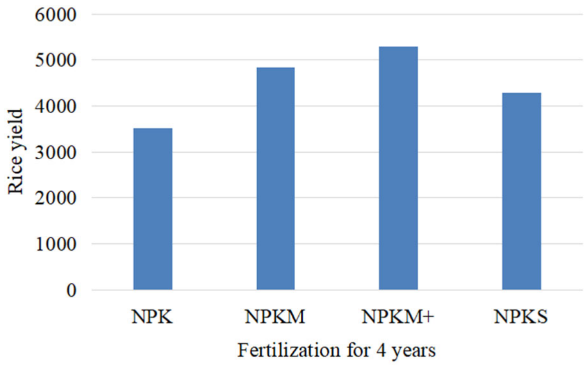

Figure 2 Rice yield after four years of fertilization

With the extension of fertilization years and the deepening of soil profile, the SOC storage capacity of each treatment at different years shows a trend of gradually increasing and then decreasing. Long term application of Manure and straw returning can increase the surface and deep soil carbon pool, and the effect of increasing Manure on SOC is stronger than straw returning. For areas with abundant alkaline nitrogen content, the alkaline nitrogen in the soil is sufficient to meet the nutrient needs of plants, coupled with the decomposition and release of organic nutrients, resulting in a rapid increase in the available nutrient content of organic and inorganic treatments. However, pure fertilizer treatment lacks continuous input of organic nutrients, and rice growth continuously absorbs nitrogen from the soil, resulting in a gradual decrease in the alkaline nitrogen content in the soil. With the extension of fertilization years, the soil cumulative carbon and nitrogen pool of each fertilization treatment showed an increasing trend, and the increase of soil cumulative carbon storage by applying Manure was more obvious than that of straw returning, while the increase of soil cumulative nitrogen storage was lower than that of straw returning.

3.2 Discussion

In this experiment, long-term addition of exogenous organic materials such as Manure and straw returning could significantly increase rice yield ($P<0.05$). Long term application of exogenous organic materials such as Organic fertilizer and straw returning has a positive effect on crop yield. On the one hand, Manure and straw returning increase soil organic carbon content and nutrient cycle, thereby improving crop yield; On the other hand, the application of organic materials improves nutrient utilization efficiency, increases the inherent nutrient supply capacity of the soil, improves soil health, alleviates fluctuations in crop yield caused by adverse environmental factors, and thereby enhances crop growth vitality [8]. Under the conditions of organic inorganic fertilizer combination, attention should not only be paid to nitrogen fertilizer, but also to the balanced application of phosphorus and potassium fertilizer, in order to maximize economic benefits. Manure and straw returning have been advocated and practiced to improve soil fertility and increase soil carbon and nitrogen storage capacity. The addition of exogenous organic materials, including pig manure and straw, can not only directly input carbon into the soil, but also indirectly input carbon into the soil through higher plant biomass such as crop residues, litter, and roots [9]. Long term fertilization has an obvious effect on soil fertility, and the fertilization mode of combining organic fertilizer with inorganic fertilizer has the most obvious effect on soil fertility, but the balanced application of nitrogen, phosphorus and potassium should be taken into account when applying Manure.

Long term application of Manure can significantly improve soil fertility and increase the content of available nutrients in soil. According to the level of soil fertility, targeted adjustment of fertilization measures can better tap into the potential of land production and increase rice yield. The soil with low basic soil fertility has a low content of available nutrients, and Manure cannot meet the needs of crop growth in a short time. However, the application of pure chemical fertilizer alone can meet the needs of nutrients for rice in a timely manner, significantly improving rice yield. For the soil with high basic soil fertility, the content of available nutrients is high, and a large amount of inorganic fertilizer is applied, resulting in a surplus of soil nutrients, causing serious loss of nutrients in the soil, while the combination of organic and inorganic fertilizers ensures the continuous supply of nutrients in the soil, Thus, the rice yield can be high and stable. The level of soil fertility should be considered when applying Manure. For soil with low fertility, increase the proportion of inorganic fertilizer on the basis of increasing the amount of fertilizer; For soils with higher fertility, the opposite is true, thereby achieving high and stable rice yield [10].

4. Conclusions

According to this experiment, long-term fertilization can increase crop yield. The interaction between fertilization type, soil depth, and fertilization years significantly affects soil carbon, nitrogen pool, and carbon nitrogen ratio. Long term application of Manure promoted the improvement of soil comprehensive fertility, while non fertilization or partial application of chemical fertilizer led to the reduction of soil comprehensive fertility. Long term application of Manure and straw returning can improve crop yield and soil fertility, and with the extension of fertilization years, the lifting effect will increase. The traditional "big fertilizer" model of farmers, with excessive fertilizer application, can easily cause problems such as soil compaction and non-point source pollution. Especially, single application of fertilizer significantly affects soil nutrient improvement and nutrient environment balance, which is a very unreasonable fertilization method for agricultural production. Organic matter fertilization can increase the content of Soil organic matter, total nitrogen, total phosphorus and alkali hydrolyzed nitrogen, phosphorus and potassium, reduce soil bulk density and pH, increase the activity of soil phosphorus and potassium, and increase the retention rate of soil carbon and nitrogen. The comprehensive fertility index of soil can objectively reflect the level of soil productivity. Long term application of Manure can maintain high fertility of yellow soil and high crop yield. Reasonable balanced application of chemical fertilizer or combined application of Manure can maintain high crop yield and stability and sustainability of yield. According to the demand patterns of different nutrients for crops and the scarcity of soil nutrients, applying fertilizers in a timely and appropriate manner according to local conditions is beneficial for ensuring crop yield and quality, reducing costs, increasing soil fertility, promoting soil health, and ultimately achieving sustainable agricultural development.

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