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How to Use Chemical Fertilizer Scientifically to Raise Yield of Rice?

M. Zhong[1], D. He [1], J. Yang[2], and W. Ke[1]*

ABSTRACT

The negative impact of excessive fertilization on the sustainable development of agriculture has become the focus of universal attention. Thus, the aim is to maximize the yield of rice without imposing too much damage on the environment. This paper uses data regression analysis based on the statistical data (from 1990 to 2020) of a certain region to explore the impact of fertilizer application on rice yield, and adopts the sensitivity analysis to study the sensitivity of rice yield to the applied amount of chemical fertilizer. The results show that the average rice yield increased with increasing Nitrogen (N) and potassium (K) fertilizers application within the statistical data range; while the average rice yield decreased as Phosphorus (P) fertilizer application increased. Simultaneously, increasing the application of N and K fertilizers improved the average rice yield. Reducing the amount of P fertilizer and increasing the proportion of K fertilizer positively affected the average rice yield. The sensitivity analysis indicated that the average rice yield was most sensitive to K application amount. The sensitivity value maximized at a small amount of N fertilizer (11.25 kg hm^{-2}) and a large amount of P fertilizer (6 kg hm^{-2}). The findings reveal the interactive effect of multiple fertilizer application rates on grain yield and address the unclear mechanism of single fertilizer application on grain yield in the existing research. This paper provides a theoretical basis for scientific fertilizer use, agricultural quality, efficiency improvement, and sustainable development of agriculture.

Keywords: Application of chemical fertilizers, Sensitivity analysis, Sustainable development.

INTRODUCTION

Chemical fertilizers play a key role in increasing grain yield and promoting agricultural economic growth to some extent (Datta *et al*., 1983). According to the statistics of FAO (Food and Agriculture Organization of the United Nations), chemical fertilizers contribute to grain growth at a ratio from 40% to 60% on a global scale (Li Ma *et al*., 2014). This contribution rate in China is as high as 57% from 1978 to 2006 (Wang, 2008). In the last century, in order to meet the ever-increasing food demand with the growth of population, different countries and regions have adopted a series of agricultural support policies, including subsidies, to promote the application of chemical fertilizers. Besides, the favorable price ratio between grains and fertilizers has also greatly stimulated fertilizer inputs in Japan, South Korea, and other regions (Datta *et al*., 1983). The early food security concept that simply pursues high yields creates a modern agricultural production mode characterized by a high input of pesticides, fertilizers, and agricultural machinery (Mengyang *et al*.,

[1] School of Economics and Trade, Fujian Jiangxia University, Fuzhou 350108, China.
[2] School of Mechanical and Automotive Engineering, Fujian University of Technology, Fuzhou 350118, China.
* Corresponding author; e-mail: kewenlan1988@hotmail.com

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2019). The production mode has effectively promoted the agricultural economy and played an important role in alleviating the food crisis and increasing farmers' production and income.

However, the negative effects caused by the excessive application of chemical fertilizers have become increasingly prominent over time. Excessive chemical fertilizer inputs increase the production cost and reduce their utilization efficiency (Ju, 2009), leading to soil acidification and hardening (Morteza *et al*., 2011), degeneration of soil fertility, serious area-source pollution, and greenhouse gas emissions (Linquist *et al*. 2012； Kahrl *et al*., 2010). The mixed application of chemical fertilizers and pesticides pollutes soil and water (Noel, 1997), causing the loss of biodiversity (Asai *et al*., 2010) and the imbalance of the agricultural ecosystem (Raheem *et al*., 2020). Meanwhile, soil and water pollution affect food security and human health (Raheem *et al*., 2020; L. Ma., *et al.*， 2012). Many scientists have paid attention to scientific fertilizer application and conducted a lot of research to address the decreasing efficiency of chemical-fertilizer application. Early research interest in nitrogen fertilizer's utilization efficiency in developing countries was closely related to the rising price of nitrogen fertilizer. Datta (1983) studied the Nitrogen fertilizer's utilization efficiency (N_e) of rice planting in tropical developing countries. He believed that improving N_e ensured high production and cost-saving for small farmers in these regions. Therefore, he focused on N fertilizer management at different growth stages of rice. The compound fertilizer management mode, including biological N fixation, green manure, straw return, and organic fertilizer, were vital to improving N_e.

Different from early studies on economic considerations, more and more current researchers link N_e with environmental impact. Qiao *et al.* (2012) conducted an experiment on N fertilizer application during rice planting in Taihu Lake, Jiangsu Province, China, to improve N_e and reduce environmental pollution. The results showed that reducing N application in the short term would be feasible to maintain yields, while the long-term N application needs further verification. Li ma *et al.* (2014) used stochastic frontier analysis and the Tobit model to investigate fertilizer application efficiency in the Taihu Lake area. They found that the amount of chemical fertilizer could decrease by 75% under the existing technical conditions and rice yield level. Meanwhile, they identified the key factors affecting the efficiency of chemical fertilizer application. Zhang *et al.* (2018) evaluated the rational application of N fertilizer suitable for the environment by investigating the application of N in 1,531 counties in China from a macro perspective. The investigation showed that about 45% of rice fields applied N excessively and the N_e was lower than that at the highest yield level and under optimal environmental conditions (Zhang *et al.*, 2018).

A great deal of evidence showed that rice planting suffers from low utilization efficiency of chemical fertilizers. Many scholars have strived to reduce fertilizer input and improve efficiency. However, Min Zhang *et al.* (2018) believed that farmers did not easily make a decision to reduce chemical fertilizer application due to concerns about risking of agricultural-harvest loss. Therefore, field experiments and micro-area experiments were combined to verify whether increasing organic N fertilizer can reduce its application. More and more experiments proved that the practice could improve the N_e fertilizer and reduce environmental pollution Min Zhang *et al.* (2018). It is worth noting that the greenhouse gas emissions caused by excessively applying chemical fertilizers have aroused more and more research interest in the sustainable development of agriculture due to the extreme climate change in recent years (Arun Kumar Rath *et al*., 1999; Fredrich Kahrl *et al*., 2010； Z. Jiang *et al.*， 2019; Zhang *et al*., 2016； Yiming *et al*.,2016).

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Numerous theoretical and practical studies show that fertilizer reduction and efficiency improvement are extremely urgent and imperative. Wu *et al.* (2021) found that promoting agricultural scale operation has become an important way to reduce the excessive application of chemical fertilizers under the dual pressure of increasing yields and reducing labor supply. Huifeng (2020) argued that straw returning improved N_e and increased yields in the rice-wheat rotation. Haefele *et al.* (2014) examined the spatial heterogeneity of fertilizer management in paddy fields in Nepal and found that grain yields were improved by differentiating fertilization strategies in different geographical locations. Considering the wide distribution of pozzolanic paddy soil in Asia, Anda *et al.* (2015) advocated implementing various fertilizer reduction strategies according to different soil properties [24].

Besides, van Wesenbeeck *et al.* (2021) empirically analyzed the policy efficiency of reducing N fertilizer on the premise of sufficient food supply and farmers' income increased from a policy perspective. They held that proper policy combination reduced N and P fertilizers by, respectively, above 50 and 70% without affecting the food supply.

To sum up, the overuse of chemical fertilizers has attracted wide attention of researchers. Many scientists have focused on the application efficiency and application-reducing path of fertilizers in different countries and regions under various production conditions, such as natural climatic conditions, soil traits, and water sources, based on multiple perspectives (Haefele *et al.*, 2014 ; Pampolino *et al.*, 2007; Ener *et al.*, 2017). Great progress has been made in exploring the quantitative law of scientific fertilizer application and rice yields. Research on fertilizer application efficiency is no longer limited to the growth of grain quantity but increasingly focuses on the cost of fertilizer application, water and land pollution, and greenhouse-gas emissions. More consideration is given to placing agricultural production within a larger agricultural ecosystem.

Current studies have mainly focused on the application amount of a single type of fertilizer. There is unclear evidence on the interaction mechanism between the mixed use of multiple fertilizers and grain yield. Therefore, this paper uses data regression analysis to explore the interaction mechanism between fertilizer application and rice output based on the statistical data of rice yield and fertilizer use in a region from 1990 to 2020. Further, the sensitivity analysis method is employed to investigate the sensitivity of rice yield per hectare to the chemical fertilizer applied amount.

MATERIALS AND METHODS

Study Sites

The study area is located in the eastern region of Asia, mostly in the mid-latitude area between 3°51'N and 53°33'N. It is an important rice production area in the world, with approximately 29.921 million hectares of rice. The region can be divided into three categories according to geographical location, climate characteristics, and planting habits:

(1) The northeast region has a temperate monsoon climate, with an average annual temperature between 2.9-8.7°C and annual precipitation between 350-700 mm (Dan Z, *et al*., 2018). This region mainly produces single-season rice.

(2) The east-central region is characterized by a subtropical monsoon climate, with annual average temperatures ranging from 14.8 to 17.3°C and annual precipitation ranging from 950 to 1,500 mm (Dan *et al*., 2018). The cultivation method of this region is rice-upland (wheat/rap/vegetable) rotation.

(3) The southeastern region is dominated by a subtropical monsoon climate, with an average annual temperature ranging from 2.9 to 8.7°C and annual precipitation ranging from1, 200 to 2,000 mm (Dan *et al*.,

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2018). This region grows double-cropping rice.

The whole study area has applied large-scale chemical fertilizer, increasing from 265 kg hm^{-2} in 2000 to 357 kg hm^{-2} in 2013 (Shuqin *et al*., 2018). There was a slight decrease in 2017, with an average fertilizer application rate of 328.5 kg hm^{-2} (Wu *et al*. 2021).

Data Sources

To explore the relationship between fertilizer application and rice yield, this research adopted rice yields as output variable Y and nitrogen, phosphorus, and potassium fertilizers as input variables, with other factors (such as cultivated varieties and climate changes) remaining unchanged The three chemical fertilizers were all converted scalar and expressed by A (Nitrogen), B (Phosphorus), and C (Potassium), respectively.

Data were sourced from the official statistical yearbook of a certain region from 1990 to 2022(National Bureau of Statistics of the People's Republic of China, 2023). Considering the changes in cultivated land area over the years, the total inputs were divided by the cultivated land area of the corresponding year and converted into the average value (Table 1).

According to Table 1, the input of nitrogen fertilizer generally increased from 1990 to 2003, with a maximum value of 20.400 kg hm^{-2} in 2003, followed by a slow decline to 13.515 kg hm^{-2} in 2020. The use of phosphorus fertilizer increased continuously from 1990 to 2004, growing from 2.820 kg hm^{-2} in 1990 and reaching a peak of 6.780 kg hm^{-2} in 2003. Following that, there were a decline to 6.090 kg hm^{-2} in 2004 and a fluctuation around 5.925 kg in 2015, maintaining a relatively stable state. Finally, it dropped significantly from 5.850 kg hm^{-2} of 2016 to 4.815 kg hm^{-2} of 2020.

Similarly, the dynamic change of potassium fertilizer displays a U-shape. Application of K fertilizer increased from 0.900 kg hm^{-2} in 1990 to 4.515 kg hm^{-2} in 2015 and decreased continuously from 2016 to 3.990 kg hm^{-2} in 2020. Application of the three chemical fertilizers declined significantly in 2016 due to the increasing awareness of the carrying capacity of resources and the environment caused by the overuse of chemical fertilizers. The double-reduction policy of pesticides and fertilizers was widely implemented in 2015 to promote the scientific use of fertilizers and improve agricultural quality and production (Ministry of Rural Agriculture of the People's Republic of China, 2022).

The average rice yield per hectare has maintained a continuous upward trend from 5726.16 kg hm^{-2} in 1990 to 7029.15 kg hm^{-2} in 2020 (except for fluctuations in some years due to force-majeure factors such as natural disasters and extreme climate change). It has increased by 1,317.99 kg or 1.230 times in the past 30 years.

RESULTS AND DISCUSSION

Data Processing and Analysis

Model Reliability Analysis

The quadratic regression model was used to fit the data to obtain the mathematical model of the relationship between rice yields and chemical fertilizer application (Equation 1).

$$y = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \sum_{j=1}^{k} \beta_{jj} x_j^2 + \sum_{j=1}^{k} \beta_{ij} x_i x_j + \varepsilon \quad (1)$$

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Table 1. Chemical fertilizer application rate and rice yields from 1990 to 2020 (kg hm^{-2}).

No.	Years	A (Nitrogen)	B (Phosphorus)	C (Potassium)	Y (Yields)
1	1990	9.990	2.820	0.900	5726.160
2	1991	10.665	3.150	1.095	5640.075
3	1992	11.370	3.345	1.275	5803.050
4	1993	13.275	4.155	1.530	5847.795
5	1994	13.785	4.395	1.725	5831.100
6	1995	14.265	4.455	1.890	6024.915
7	1996	14.505	4.455	1.950	6211.995
8	1997	14.355	4.560	2.130	6319.215
9	1998	15.285	4.665	2.370	6366.060
10	1999	14.850	4.755	2.490	6344.985
11	2000	16.050	5.130	2.790	6271.605
12	2001	17.385	5.670	3.210	6163.410
13	2002	18.090	5.970	3.540	6188.925
14	2003	20.400	6.780	4.155	6060.810
15	2004	18.390	6.090	3.870	6310.650
16	2005	17.865	5.955	3.915	6260.265
17	2006	18.015	6.120	4.065	6279.630
18	2007	18.240	6.135	4.245	6432.855
19	2008	17.820	6.030	4.215	6562.515
20	2009	17.505	5.985	4.245	6585.435
21	2010	17.325	5.925	4.320	6553.140
22	2011	17.250	5.940	4.380	6687.330
23	2012	17.220	5.955	4.440	6776.805
24	2013	16.920	5.865	4.440	6717.360
25	2014	16.860	5.955	4.515	6813.255
26	2015	16.620	5.925	4.515	6891.240
27	2016	16.290	5.850	4.485	6865.605
28	2017	15.675	5.625	4.365	6917.100
29	2018	15.105	5.325	4.320	7026.735
30	2019	14.595	5.160	4.245	7059.000
31	2020	13.515	4.815	3.990	7044.150

Where, rice yields y is the output variable (response value); β_0 the intercept coefficient; β_j the primary linear coefficient; β_{jj} the quadratic linear coefficient; β_{ij} the primary coupling relation; x_j the parameter of fertilizer application amount; k the number of factors; and ε the correlation error.

Regression analysis was carried out based on the data in Table 1, according to which, there is a significant difference in the order of magnitude between the input variables of N, P, and K and the output variable of rice yield. To reduce the impact of significant data differences between group variables on statistical properties, variables were converted before data processing. As the traditional land measurement unit of East Asia, "mu" was adopted to convert the data at a ratio of 1:15 (1 hectare= 15 "mu"). After conversion, the data differences between group variables were reduced to facilitate regression analysis, and the results are listed in Table 2.

The P value of Equation (1) was less than 0.0001 (Table 2), indicating that the model had high accuracy and reliability. The adjusted R^2 and predicted R^2 were 0.9658 and 0.9601, respectively, and their values were close to 1. The difference between them was 0.0057, less than 0.2, indicating a high accuracy of the model. The model can be used to predict rice yields. R^2 of the rice

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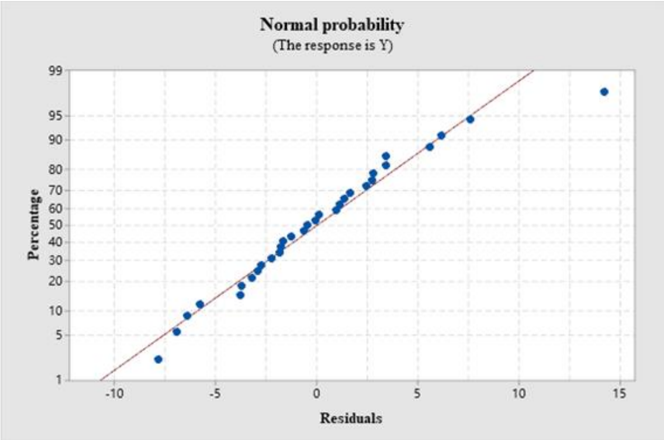

Figure 1. Normal probability of the average yield.

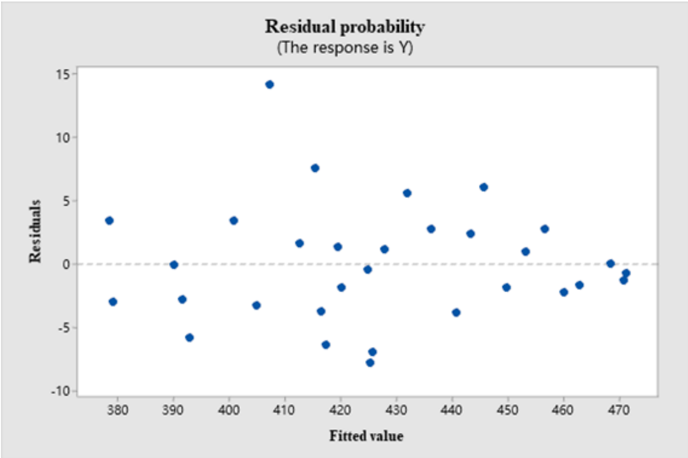

Figure 2. Residual probability of the average yield.

Table 2. Variance analysis of the average rice yield.

Sources	df	Adj SS	Adj MS	F-value	P-value
Regression	5	21697.40	4339.48	170.52	<0.0001
A (Nitrogen)	1	460.30	460.27	18.09	<0.0001
B (Phosphorus)	1	435.60	435.62	17.12	<0.0001
C (Potassium)	1	3590.30	3590.25	141.08	<0.0001
(Nitrogen)×(Potassium)	1	546.80	546.76	21.49	<0.0001
(Phosphorus)×(Potassium)	1	316.60	316.60	12.44	0.002
Error	25	636.20	25.45		
Total	30	22333.60			
R^2	0.9715		Adjusted R^2	0.9658	
S	5.0446		Predicted R^2	0.9601	

yield model was 0.9715, close to 1, showing a good correlation.

According to the P value, the application amounts of N, P, and K fertilizers correlated to rice yields at a significance level. The interaction items of N-fertilizer and K-fertilizer application rate significantly affected rice yields. Equation (2) provided the mathematical relation model between each parameter and rice yields.

$$y = 182.9 + 795 \times A - 1998 \times B + 1661 \times C - 3360 \times A \times C + 6753 \times B \times C \quad (2)$$

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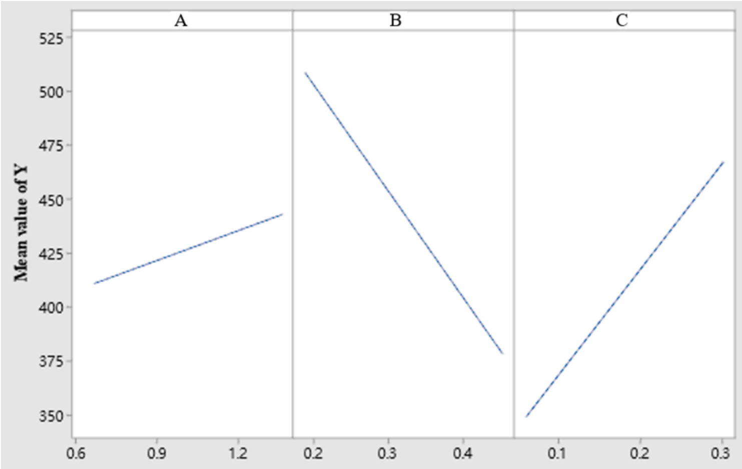

Figure 3. Main effect of the average yield. Y (Yields), A (Nitrogen), B (Phosphorus), and C (Potassium).

Figures 1 and 2 display the normal probability diagram and residual distribution diagram. Based on Figure 1, the observed values were distributed on both sides of the straight line without abnormal points, indicating that the model fitted well and had high prediction accuracy and reliability. Figure 2 demonstrated that all observed values were randomly distributed within the residual range, establishing the feasibility of the model. The symmetrical distribution of the error suggested that the data were random.

Main Effect Analysis

The main effect diagram of the model was obtained from fitted value output to test the difference between the horizontal means of one or more factors (Figure 3). According to the main effect analysis, the average rice yield increased with increasing application of N-fertilizer or K-fertilizer and decreased with increasing P fertilizer application. The main analysis results are as follows:

(1) The average rice yield increased with the increased N application, which accords with the action mechanism of N fertilizer on crops. Generally, applying N might facilitate reducing ineffective tillers, improving the effective ear-bearing tiller rate and stress resistance of rice. Consequently, this lowers the incidence of diseases and insect pests and greatly increases rice yields.

(2) Rice yields decreased with the increased P application, indicating that the P-fertilizer in the statistical range had exceeded the amount needed for normal crop growth. The negative effects of excessive P fertilizer application on rice yields include: (i) The nutrient imbalance of rice crops, leading to poor rice growth in the field; (ii) Too strong respiration of rice and too high consumption of dry matter, causing early maturity, small grains per spike of rice, and a declined yield; (iii) Silicon solidification in soil, generating silicon deficiency in rice and resulting in slender stems, lodging, or poor disease resistance of rice.

(3) Rice yields increased with the increased K fertilizer application rate, suggesting that the K applied within the statistical range positively promotes the average rice yield. Potassium, as an activator of enzymes, can greatly enhance the photosynthesis of rice, which is beneficial to the synthesis, transportation, and accumulation of carbohydrates. As a result, rice improves stress resistance and root-absorption capacity. Besides, enhanced photosynthesis contributes to N absorption and protein synthesis, greatly increasing rice yields. However, applying K fertilizer needs to be limited to a range because the overuse

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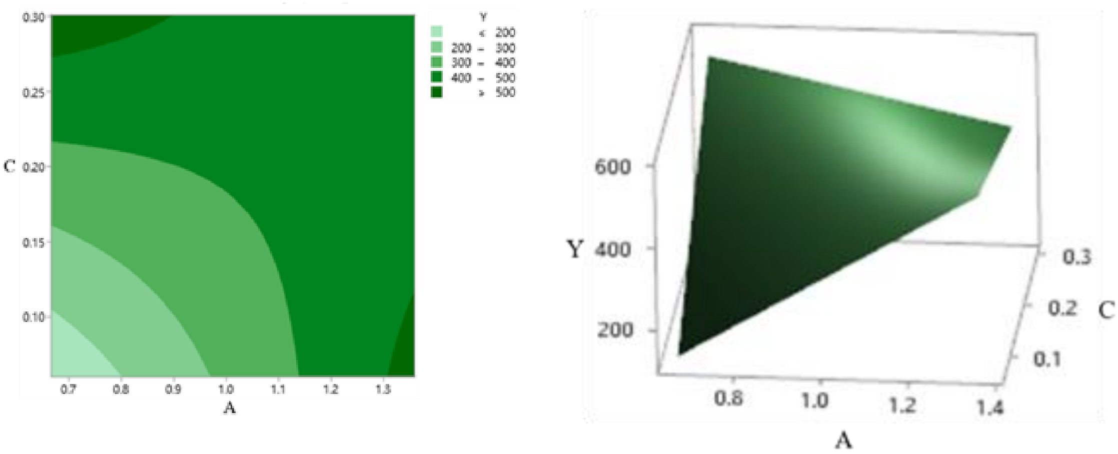

(a) Contour plot of application rate of N and K fertilizers and average yield.

(b) Surface diagram of application rate of N and K fertilizers and average yield.

Figure 4. Interaction of application amounts of nitrogen and potassium fertilizers on average yield. Y (Yields), A (Nitrogen) and C (Potassium).

of K fertilizer causes soil pollution, resource waste, and rice root rot, and affects the survival rate of rice.

Interaction Analysis

N, P, and K, as essential elements, play individual roles in rice production and development. Besides, their mixtures also produce chemical reactions to exert an interaction function on rice production and development. The variance analysis in Table 2 indicated an interaction between N and K fertilizers.

Figure 4 (a) provided the interaction between the application of N and K fertilizers on rice yields. The average rice yield increased with increasing N and K application. The interaction of N and K on rice yields was positively correlated. Besides, the increased use of N and K improved the average rice yield within the statistical data range (Figure 4 (b)).

Similarly, the variance analysis suggested that P and K also had an interaction. The average rice yield increased with the decreased use of P and increased application of K (Figure 5-a). The mixed application of P and K fertilizers requires an appropriate proportion, with a decrease in P and an increase in K.

The average rice yield can be improved by appropriately reducing N application and increasing K application (Figure 5 (b)). This is possibly because applying K promotes the absorption of N by rice roots.

Based on Figure 5 (b), when K application was large (4.5 kg hm^{-2}), increasing the P fertilizer did not significantly affect yield reduction. However, as the K fertilizer was used in a small amount of 1.5 kg hm^{-2}, increasing P application greatly decreased yields. Accordingly, rice yields had different sensitivity to different application rates of fertilizers.

Sensitivity Analysis

Sensitivity analysis explains the influence of factors on key indices through changing the values of related variables one by one. Mathematically, the sensitivity of the design objective function to design variables is the partial derivative of the function to its variables. Positive sensitivity means that the output increases due to changes in design parameters, while negative sensitivity is the opposite. Data in Table 1 were divided into

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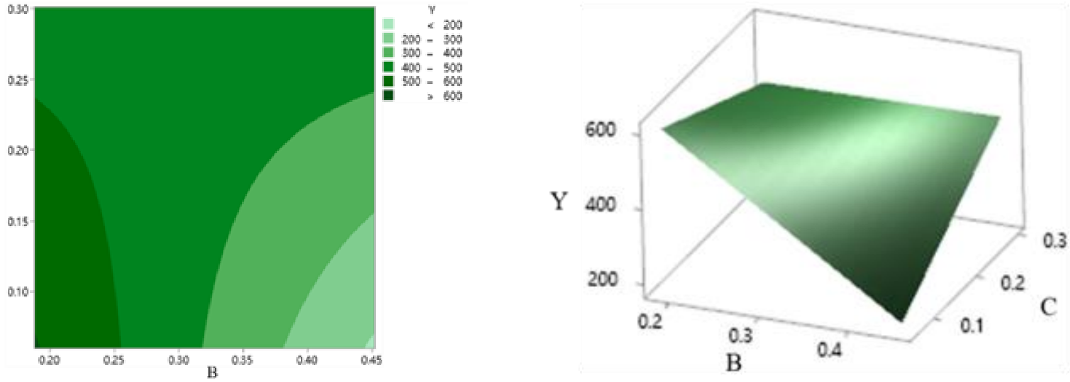

(a) Contour plot of application rate of P and K fertilizers and the average yield.

(b) Surface diagram of application rate of P and K fertilizers and the average yield.

Figure 5. Interaction of application amounts of phosphorus and potassium fertilizers on the average rice yield. Y (Yields), B (Phosphorus), and C (Potassium).

three intervals to analyze the sensitivity of rice yields to changes in applying chemical fertilizers (Table 3). The sensitivity analysis was conducted by taking the median of each interval to study the sensitivity of the average yield to the chemical fertilizer application in a certain interval. Table 4 provides the specific interval division of fertilizer application.

The sensitivity equation of output to parameters can be obtained according to interval division in Table 3 and Equation (2). Equations (3) to (5) show the sensitivity of average yield for different fertilizers.

$$\frac{\partial y}{\partial A} = 795 - 3360 \times C \quad (3)$$

$$\frac{\partial y}{\partial B} = -1998 + 6753 \times C \quad (4)$$

$$\frac{\partial y}{\partial C} = 1661 - 3360 \times A + 6753 \times B \quad (5)$$

Based on Figure 6, the average yield was most sensitive to K fertilizer. The sensitivity of the average rice yield to N fertilizer decreased with the increased use of K fertilizer (Figure 6-a). This sensitivity maximized at lower content of K fertilizer (0.75 kg hm^{-2}). The average rice yield was negatively sensitive to P fertilizer (Figure 6-b). The negative sensitivity value decreased with increasing K application and became highest at small content of potassium-fertilizer. (0.75 kg hm^{-2}).

The average rice yield became negatively sensitive to K fertilizer with the increasing use of N (Figure 6-c). The sensitivity value to K became gradually higher with the increased application of P. This sensitivity value maximized under addition of small N (11.25 kg hm^{-2}) and large P (6 kg hm^{-2}).

CONCLUSIONS

In the fields of fertilizer-application reduction, related studies investigate specific regions and discuss general issues such as fertilizer management, agricultural policies, and large-scale operations (Yiming *et al*., 2016; Wu *et al*., 2021; Huifeng *et al*., 2020; Yiyun, 2018). These studies mainly focus on certain types of fertilizers, with few on the mixed application of multiple fertilizers. Little literature discusses the efficiency and amount of chemical fertilizer input and the interaction of multiple fertilizers on rice yields. This paper explores the interaction effect of fertilizer application on rice yield based on data regression analysis, and investigates the sensitivity of rice yield per hectare to fertilizer application using the sensitivity analysis method.

The empirical findings show that the average rice yield increases with increasing nitrogen-fertilizer and potassium-fertilizer application within the statistical data range;

Table 3. Horizontal division of fertilizer intervals.

Fertilizer	Levels		
	-1	0	1
A (Nitrogen)	[0.6,0.9]	[0.9,1.2]	[1.2,1.5]
B (Phosphorus)	[0.15-0.25]	[0.25-0.35]	[0.35-0.45]
C (Potassium)	[0-0.1]	[0.1-0.2]	[0.2-0.3]

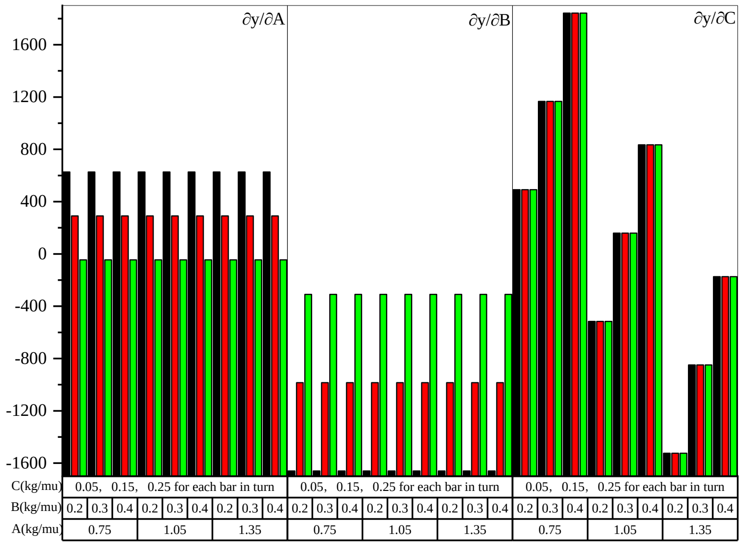

Figure 6. Sensitivity of the average yield to chemical fertilizers. Y (Yields), A (Nitrogen), B (Phosphorus), and C (Potassium).

while the average rice yield decreases as phosphorus application increases. Simultaneously, increasing N and K fertilizers applications improves the average rice yield. Reducing the amount of P fertilizer and increasing the proportion of K fertilizer positively affect the average rice yield. The results indicate that continuing to increase fertilizer use may not necessarily increase yield.

The sensitivity analysis indicates that the average rice yield is most sensitive to K-fertilizer application rate. The sensitivity value maximizes at a small amount of N (11.2 kg/hm^2) and a large amount of P (6 kg/hm^2). The average yield of rice can be affected by changing the applied amount of K fertilizer at a small amount of N (11.25 kg/hm^2) and a large amount of phosphorus fertilizer (6 kg/hm^2).

Based on the research conclusion, whether individually or interactively, increasing the input of nitrogen and potassium fertilizers in rice production contributes to the average rice yield in a specific statistical range. Excessively applying phosphorus fertilizer decreases the average rice yield. As a result, the application rates of N and K fertilizer are not excessive within the statistical data range. The input of P fertilizer exceeds the actual amount needed for crop production within the statistical range, leading to reduction of utilization efficiency. Despite the excessive use of P fertilizer, there is still great potential for the promotion of grain yield by chemical fertilizers overall. This can be confirmed by the study by Yao Chengsheng *et al*. (2022). At the same time, it is also pointed out that long-term and high-intensity fertilizer application has deteriorated the ecological environment and sustainable production capacity of rice fields. Therefore, it is recommended to vigorously promote soil testing and formula fertilization and foster the application of organic fertilizer resources and new fertilizer

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technologies Yao Chengsheng *et al*. (2022). The results proposes that sustainable agricultural development can be promoted through scientific fertilization while ensuring stable production and sufficient supply of food. This proposal can provide a reference basis for long-term food security decisions.

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چگونه از کودهای شیمیایی به گونه‌ای علمی استفاده کنیم تا عملکرد برنج افزایش یابد؟

م. ژونگ، د. هی، ج. یانگ، و و. که

چکیده

تأثیر منفی کوددهی بیش از حد بر توسعه پایدار کشاورزی درکانون توجه جهانی قرار گرفته است. بنابراین، هدف به حداکثر رساندن عملکرد برنج بدون تحمیل آسیب بیش از حد به محیط زیست است. این مقاله از تجزیه و تحلیل رگرسیون داده ها بر اساس داده های آماری (از سال 1990 تا 2020) یک منطقه برای بررسی تأثیر کاربرد کود بر عملکرد برنج استفاده می کند و تجزیه و تحلیل حساسیت را برای مطالعه حساسیت عملکرد برنج به مقدار کود شیمیایی مصرف‌شده بررسی می نماید. نتایج نشان می دهد که میانگین عملکرد برنج با افزایش مصرف کودهای نیتروژن (N) و پتاسیم (K) در محدوده داده های آماری افزایش یافت. در حالی که با افزایش مصرف کود فسفر (P) میانگین عملکرد برنج کاهش یافت. همزمان، افزایش مصرف کودهای نیتروژن و پتاسیم باعث بهبود میانگین عملکرد برنج شد. کاهش مقدار کود فسفر و افزایش نسبت کود پتاسیم بر میانگین عملکرد برنج تأثیر مثبت داشت. تجزیه و تحلیل حساسیت نشان داد که میانگین عملکرد برنج بیشترین حساسیت را به مقدار کاربرد پتاسیم دارد. مقدار حساسیت در مقدار کمی کود نیتروژن (11.25 کیلوگرم بر هکتومترمربع) و مقدار زیادی کود فسفر (6 کیلوگرم بر هکتومترمربع) به حداکثر رسید. این یافته‌ها اثر متقابل نرخ‌های چندگانه کاربرد کود را بر عملکرد دانه نشان می‌دهد و مکانیسم نامشخص کاربرد یک کود تنها (single fertilizer) را بر عملکرد دانه در پژوهش‌های موجود نشان می‌دهد. این مقاله مبنایی نظری برای استفاده علمی از کود، کیفیت کشاورزی، بهبود کارایی و توسعه پایدار کشاورزی فراهم می‌کند.

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