Analysis on Demonstration Application of Silicon Fertilizer in Field Cultivation of Rice

Fan YANG[1*], Lingyun DAI[2]

1. Yandu Grain and Oil Crops Technical Guidance Station, Yancheng City, Jiangsu Province, Yancheng 224000, China; 2. Yandu Agricultural Science Research Institute, Yancheng City, Yancheng 224055, China

Abstract [**Objectives**] This study was conducted to investigate the scientific application of silicon fertilizer in rice cultivation, one of the staple crops. [**Methods**] In 2022, Yandu District carried out a special experiment and field demonstration study on the effects of foliar application of Zhengda water-soluble silicon fertilizer on rice production. [**Results**] The preliminary results showed that ① Zhengda water-soluble silicon fertilizer could effectively improve the growth and development of rice and improve the population quality. The peak number of tillers, productive tiller percentage, number of effective panicles and number of effective grains per panicle increased by 6.7%, 5.8%, 5.5%, and 1.2%, respectively. ② The yield and processing quality were improved. After applying silicon fertilizer, the yield per unit area increased by about 6.8%, and the unpolished rice yield, milled rice yield and head rice yield increased by 0.7%, 1.94% and 2.15% respectively. [**Conclusions**] The demonstration application of silicon fertilizer in field cultivation of rice in Yandu District further proves previous research conclusions and has important practical significance.

Key words Rice; Silicon fertilizer; Foliar application; Effect

DOI:10.19759/j.cnki.2164 - 4993.2024.01.007

Based on the measurement of soil composition, silicon is the second largest element. Accordingly, the application of silicon as a fertilizer has not been paid attention to. Silicon fertilizer had not attracted the attention of agricultural scientists and technicians in China until Japan began to study silicon fertilizer in the 1940s and it was popularized nationwide in 1955, and it was continuously applied in agricultural production practice in China[1-5]. In China, silicon fertilizer has become the fourth largest plant nutrient element after N, P and K, and has been widely used, which can improve the yield and quality of tea, flue-cured tobacco, pepper, cucumber and corn[6-13]. Accordingly, the scientific application of silicon fertilizer in rice cultivation, one of the staple crops, has naturally become the focus of agricultural science and technology work.

Proper application of silicon fertilizer can improve the lodging resistance of rice plants[14-16]. It can promote the growth of rice tillers and reduce shrunken grain rate[17]. It can improve rice yield and quality[18-21]. However, the application effect of silicon fertilizer will be different in different main rice producing areas due to the difference of geological soil and daily field management mode. Jiangsu is one of the main rice producing areas in China, and Lixiahe area is one of the main rice producing areas in Jiangsu. Therefore, its yield and quality play an extremely important role in stabilizing the rice market in China. As the hinterland of Lixiahe River, Yandu has always attached great importance to the improvement of rice cultivation techniques. Therefore, it is of great practical significance to use this area as a demonstration application area of silicon fertilizer in rice field cultivation. The specific demonstration research situation is given below.

Received: October 23, 2023 Accepted: December 26, 2023

Fan YANG (1988 -), female, P. R. China, agronomist, devoted to research and popularization of cultivation techniques for grain and oil crops.

* Corresponding author.

Materials and Methods

Experimental design

Special test design

① The experiment was arranged in random blocks, with eight treatments. Each plot had an area of 70 m^2 (3.5 m × 20 m), and no replicates were set.

② The experimental site was located in Yujun Family Farm, Dali Village, Yanlong Street, Yandu District, Jiangsu Province.

③ The test variety was Nanjing 9108, an excellent tasty rice variety.

④ Management measures: Machine transplanting of blanket seedlings was adopted. Dry seeds were sown on May 15, 2022, and seedlings were transplanted in the field on June 12, 2022. The basic seedlings were 1.26 million plants/hm^2. Fertilizers were applied as follows: pure N_2O 1 057 kg/hm^2, P_2O_5 90 kg/hm^2, K_2O 90 kg/hm^2, and basic and tillering fertilizer : panicle fertilizer = 6 : 4.

Field demonstration design

① The experiment adopted randomized block arrangement, and the demonstration area had two treatments. Each plot had an area of 1 320 m^2 (33 m × 40 m), and no replicates were set.

② The experimental site was located in Fengxiang Village, Qinnan Town, Yandu District, Jiangsu Province, and the family farm in Dali Village, Yanlong Street.

③ The test variety was Nanjing 9108, an excellent tasty rice variety.

④ Management measures: Demonstration 1 was Fengxiang Village Demonstration Zone in Qinnan Town, and Demonstration 2 was Yanli Village Demonstration Zone in Yanlong Street. Both

demonstration 1 and demonstration 2 adopted machine transplanting of blanket seedlings. For demonstration 1, dry seeds were sown on May 20, 2022, and seedlings were transplanted in the field on June 18, with 1.29 million basic seedlings/hm^2. Fertilizers were applied as follows: base fertilizer (compound fertilizer) 525 kg/hm^2, tillering fertilizer (urea) 187.5 kg/hm^2, flower-promoting fertilizer (urea) 187.5 kg/hm^2, potassium fertilizer 112.5 kg/hm^2 and flower-protecting fertilizer (urea) 75 kg/hm^2. In demonstration 2, dry seeds were sown on May 15, 2022, and seedlings were transplanted in the field on June 14, with 1.23 million basic seedlings/hm^2. Fertilizers were applied as follows: base fertilizer (compound fertilizer) 375 kg/hm^2, tillering fertilizer (urea) 225 kg/hm^2, flower-promoting fertilizer (urea) 322.5 kg/hm^2, potassium fertilizer 75 kg/hm^2 and flower-protecting fertilizer (urea) 75 kg/hm^2.

Silicon fertilizer treatments

Silicon fertilizer selection At present, there are mainly three kinds of silicon fertilizers: water-soluble, citric acid-soluble and biological silicon fertilizers[1-3]. According to the soil characteristics of local rice planting areas, Zhengda water-soluble silicon fertilizer was selected as the experimental fertilizer.

Application time and amounts According to consulting relevant literature and combining our usual application experience in agricultural technology extension, the application time and amounts of silicon fertilizer are shown in Table 1.

Table 1 Special test design of Zhengda water-soluble silicon fertilizer (application time and amounts)

Treatment	Spraying at 15 d after transplanting 15 kg/hm^2	Foliar application in the jointing stage//1.5 kg/hm^2	Foliar application in the booting stage//1.5 kg/hm^2
1			
2	√		
3		√	
4			√
5	√	√	√
6	√	√	
7	√		√
8		√	√

Table 2 Field demonstration design of Zhengda water-soluble silicon fertilizer (application time and amounts)

Treatment	Spraying at 15 d after transplanting 15 kg/hm^2	Foliar application in the jointing stage 1.5 kg/hm^2	Foliar application in the booting stage 1.5 kg/hm^2
Demonstration 1-1			
Demonstration 1-2	√	√	√
Demonstration 2-1			
Demonstration 2-2	√	√	√

Field farming records and operating procedures

① The time and effects of sowing, transplanting, drug spraying and fertilization were recorded.

② The growth period, growth and development of rice, the occurrence of diseases and pests and agro-meteorological disasters were observed. Ten consecutive plants were selected at fixed points in demonstration fields for observation, and the total number of tillers was investigated once every 7 d.

③ Twenty consecutive holes were randomly selected in different experimental fields in the experimental area and demonstration areas to investigate effective panicles, and five holes of effective panicles were sampled to investigate the number of grains per panicle and 1 000-grain weight. Each experimental field was harvested separately, and the grains were air-dried, and measured for moisture content and weight, and the actual yield was calculated based on a moisture content of 14.5%. Three months after harvesting in the demonstration fields and storage, the processing quality was determined according to the national standard.

Results and Analysis

Effects of silicon fertilizer application on rice growth and development

Effects on rice tillers According to statistical analysis on demonstration data, the application of silicon fertilizer could effectively promote the growth and development of rice, and improve tiller growth and the formation of panicles. The peak number of rice seedlings in the demonstration areas with silicon fertilizer application reached 5.453 million plants/hm^2, which was 6.7% higher than that without silicon fertilizer application. Meanwhile, the productive tiller percentage reached 68.8%, which was 5.8% higher than that without silicon fertilizer. Therefore, in large-scale production and cultivation management, basic seedlings can be reduced by applying silicon fertilizer, and the population growth and development advantages can be improved by controlling the population, so as to improve yield and quality (Table 3 and Table 4).

Table 3 Rice tiller dynamics of treatments with and without application of silicon fertilizer in demonstration 1 10^4 plants/hm^2

Date	Application of silicon fertilizer	No application of silicon fertilizer
Jun. 27	138.0	142.5
Jul. 4	205.5	186.0
Jul. 11	307.5	288.0
Jul. 18	336.0	324.0
Jul. 25	409.5	381.0
Agu. 1	538.5	486.0
Agu. 8	469.5	445.5
Agu. 15	417.0	394.5
Agu. 22	396.0	378.0
Sept. 5	382.5	364.5
Oct. 26	370.5	352.5

Effects on rice growth period Lixiahe area is a rice-wheat rotation area, and the period of vacant field is very short. Therefore, if the rice growth period is obviously prolonged, it will directly affect whether the succeeding winter wheat can be sown on time. According to statistical analysis on field demonstration data, the application of silicon fertilizer had little effect on the growth process and the whole growth period of rice. After the jointing

stage, the growth process of the Zhengda water-soluble silicon fertilizer treatment was delayed by 1 – 2 d compared with that of the no application treatment, and the length of the whole growth period was only increased by about 2 d (Table 5), which was equivalent to an increase of about 1.2%. That is to say, the growth of rice caused by applying silicon fertilizer was prosperous, and the delayed maturation had little effect on crop rotation, so it could be ignored.

Effects of silicon fertilizer application on rice yield composition

Statistical analysis on the data of yield components in the demonstration areas (Table 6) showed that after applying silicon fertilizer, the number of effective panicles, effective grains per panicle, seed-setting rate, 1 000-grain weight, theoretical yield and actual yield increased by about 5.5%, 1.2%, 0.4%, 0.4%, 7.5% and 6.8%, respectively. It showed that the application of silicon fertilizer could improve the yield composition of rice in Lixiahe area of Jiangsu Province, mainly by increasing the number of effective panicles and the number of grains per panicle.

Table 4 Rice tiller dynamics of treatments with and without application of silicon fertilizer in demonstration 2 10^4 plants/hm^2

Date	Application of silicon fertilizer	No application of silicon fertilizer
Jun. 23	133.5	136.5
Jun. 30	192.0	196.5
Jul. 7	267.0	246.
Jul. 14	354.0	319.5
Jul. 21	468.0	441.0
Jul. 28	552.0	517.5
Agu. 4	498.0	447.0
Agu. 11	411.0	384.0
Agu. 18	382.5	364.5
Spet. 1	364.5	348.0
Oct. 26	348.0	328.5

Table 5 Growth periods of treatments with and without application of silicon fertilizer

Demonstration	Treatment	Seeding date	Transplanting date	Heading date	Maturation date	Whole growth period//d
Demonstration 1	Application of silicon fertilizer	May 20	Jun. 18	Sept. 5	Oct. 31	164
	No application of silicon fertilizer	May 20	Jun. 18	Sept.4	Oct. 29	162
Demonstration 2	Application of silicon fertilizer	May 15	Jun. 14	Sept. 3	Oct. 28	162
	No application of silicon fertilizer	May 15	Jun. 14	Sept. 1	Oct. 27	160

Table 6 Yield components of treatments with and without application of silicon fertilizer

Demonstration	Treatment	Number of effective panicles 10^4 panicles/hm^2	Number of grains per panicles grains/panicle	Seed-setting rate//%	1 000-grain weight g/1 000 grains)	theoretical yield kg/hm^2	actual yield kg/hm^2
Demonstration 1	Application of silicon fertilizer	370.5	128.6	90.6	25.2	10 878.0	10 293.0
	No application of silicon fertilizer	352.5	127.3	90.2	25.1	10 159.5	9 631.5
Demonstration 2	Application of silicon fertilizer	348.0	136.1	92.3	25.4	11 104.5	10 467.0
	No application of silicon fertilizer	328.5	134.2	91.9	25.4	10 290.0	9 814.5

Effects of silicon fertilizer application on rice processing quality

The processing quality of rice harvested in the demonstration fields was determined (Table 7). The application of water-soluble silicon fertilizer could improve the processing quality of rice. According to the averages calculated for the two demonstration sites, the unpolished rice yield, milled rice yield and head rice yield were all improved, and the values were 0.705%, 1.94% and 2.15% higher than those without silicon fertilizer.

Table 7 Effects of water-soluble silicon fertilizer on rice processing quality %

Site	Treatment	Unpolished rice yield	Milled rice yield	Head rice yield
Demonstration 1	Application of silicon fertilizer	82.41	70.30	68.12
	No application of silicon fertilizer	81.93	69.03	65.92
Demonstration 2	Application of silicon fertilizer	83.17	70.45	68.72
	No application of silicon fertilizer	82.24	68.74	66.62

Conclusions and Discussion

In recent years, China's rice production has continued to be high, and the multiple cropping index is high. The available silicon of rice taken away from the soil by crops every year is far greater than the sum of nitrogen, phosphorus and potassium nutrients. It is difficult to maintain the balance by natural weathering of soil silicon. Coupled with the leaching and leakage loss of silicon, the available silicon content of rice in the soil is seriously missing. Adding silicon fertilizer can supplement the content of silicon in soil, balance soil nutrients, increase rice yield and improve quality, so it is one of the important technical measures for cultivation.

Experiments, especially demonstration studies, showed that the use of silicon fertilizer in Yandu District in the hinterland of Lixiahe area in Jiangsu Province could effectively improve the yield

composition of rice, mainly by increasing the number of effective panicles and the number grains per panicle. The conclusions summarized from this demonstration further support relevant research conclusions[21-23].

For the same rice variety, the formation process of rice yield in each year is mainly influenced by cultivation techniques and agrometeorological conditions. However, this study and demonstration only lasted for one year, and the influencing components of agro-meteorological conditions were not separated in data processing. Accordingly, the research conclusions need to be improved in the further demonstration and application research in the next few years.

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Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU