Asian Agricultural Research 2018, 10(12): 62 -66 DOI: 10.19601/j.cnki.issn1943 -9903.2018.12.017

Effects of Bio-organic Selenium on Agronomic Economic Traits and Selenium Absorption and Distribution in Rice

Xiaoling LONG[1], Duanwu CAI[1], Jinlong LIU[1], Wei ZHENG[1,2*]

1. Institute of Agricultural Economics and Technology, Hubei Academy of Agricultural Sciences, Wuhan 430064, China; 2. Hubei Collaborative Innovation Center for Grain Industry, Jingzhou 434025, China

Abstract Under the same conditions of selenium application and application period, different application concentration treatments were set carry out the field plot experiments. The results showed that different treatments had no effect on the growth and development of rice plants; different treatments had an effect on the economic traits of rice; selenium treatment increased the number of filled grains per panicle, seed setting rate and 1 000-grain weight, thus increasing yield; the level of yield was Se4 > Se3 > Se2 > Se1 > Se0; different treatments had a greater effect on the milled rice rate; selenium treatment increased the milled rice rate; the milled rice rate of Se3 and Se4 treatments were 65% and 64%, respectively, which was significantly higher than that of the control group; the general law of selenium absorption of rice was leaf > stem > rice; the selenium content in leaves, stems and rice of different treatments was the highest in Se3 treatment; both the selenium content of rice (total selenium and organic selenium) and the ratio of organic selenium to total selenium in the selenium treatment met the local food safety standard of Hubei Province *Selenium content of Selenium-enriched Foods* (DBS42/002-2014); selenium-treated rice plants had a high selenium utilization rate, in the range of 51.26% -64.12%, exceeding 50%.

Key words Bio-organic selenium, Rice, Agronomic economic traits, Absorption and distribution

1 Introduction

Rice is the second largest grain crop in the world, and its sown area and total yield are second only to wheat. China's rice planting area accounts for about 30% of the grain crop planting area, while total rice yield accounts for more than 40% of the total grain yield. Both of its sown area and total yield rank first in the grain crops. In China, about 65% people take rice as the staple food[1]. Among the nutrients of rice, about 80% are starch, but the starch granules are extremely small, easy to be absorbed by the human body, about 7% are protein, about 2% are fat, other nutrients such as cellulose, minerals and vitamin B group are rich, and rice contains little crude fiber and no cholesterol [2]. The nutrients in rice have high digestibility and absorption rate, especially when the protein content is small, but the protein is easily absorbed and utilized by the human body, and rice is rich in lysine and threonine. With the development of society and the improvement of people's living standards, the diet of people has changed from having enough to eat to eating well, eating safely and eating healthily. The development of selenium-enriched industry just conforms to this historical trend and can satisfy the demands of people's growing and better life. Rice is an ideal carrier for daily selenium supplement. Selenium-enriched rice is the most convenient and popular selenium-enriched product. The development of high-quality green and safe selenium-enriched rice industry plays an important role and positive significance in promoting the structural reform of agricultural supply front, implementing rural revitalization strategy, improving people's daily dietary structure, and promoting the national health.

Selenium is an essential trace nutritional element for the human body. Selenium is a component of glutathione peroxidase (GSH-Px) of both animal and human body and a prosthetic group of the active part of the enzyme family. It has functions of preventing and resisting cancer, protecting cardiovascular and cerebrovascular systems, protecting liver, protecting eyes, removing toxins and resisting heavy metals, anti-oxidation, enhancing immunity, delaying aging and improving reproductive functions; it can prevent more than 40 kinds of diseases such as Keshan disease and Kaschin-Beck disease, cardiovascular diseases, cancer, and diabetes [3-7]. In China, 72% of the regions are located in the selenium-deficient and low-selenium belts. The food produced in low-selenium soils generally has low selenium content, while the lack of dietary selenium intake seriously affects people's health. Therefore, merely relying on natural foods, it is difficult to meet the normal needs of the human body; the low selenium and selenium-deficient state of the human body are seriously threatening people's health and causing potential harm [8-9]. In China, nearly two-thirds of people are deficient in selenium or at the edge of selenium deficiency [10]. The recommended daily intake of selenium by Chinese Nutrition Society is 60 μg. The safe and suitable range for daily intake of selenium in normal adults is 60 -250 μg. In 2017, the National Health and Family Planning Commission of the People's Republic of China (NHFPC) formulated a standard and

Received: September 20, 2018 Accepted: December 17, 2018
Supported by Key Technology R & D Program of Hubei Province (Research and Development, and Demonstration Type) (2015BBA178); Special Project for Selenium-enriched Industry Development in Hubei Province (XKJ201501-17).
* Corresponding author. E-mail: nkyzhengwei@163.com

recommended the highest safe intake of selenium of 400 μg [11-14]. The selenium elements found in nature can be divided into chemical selenium and bio-selenium. Chemical selenium generally refers to inorganic selenium (sodium selenite and sodium selenate) and synthetic organic selenide and chemical nano-selenium; bio-selenium is formed by bio-conversion of selenium and organic substances in the living body, generally selenoprotein, selenium peptide, selenium amino acid, selenium polysaccharide, selenium nucleic acid [15-17], *etc.* or bio-nano selenium converted by selenium-enriched microorganisms [18]. Chemical selenium has high toxicity and low absorption rate. Compared with chemical selenium, bio-selenium has the advantages of safe use, no toxic side effects, high absorption and utilization rate, high nutritional value, *etc.*, so it is the first choice for selenium supplement. Microbial selenium-enriched fermentation is an important subject for the development of selenium using biological resources and has broad prospects. Selenium protein, selenium polypeptide, selenium amino acid, selenium polysaccharide and selenium nucleic acid are all excellent selenium supplement agents that are easy to be absorbed by animals and plants, and have good pharmacological and health effects.

At present, the organic selenium can be obtained through microbial conversion, plant conversion and animal conversion [18]. Most of the microbial conversion methods use yeast [19] and lactic acid bacteria [20], but the conversion efficiency of inorganic selenium into bio-selenium is not high, and the highest is only 30%, at least 70% of inorganic selenium are left. The successful conversion of bio-selenium using other selenium-enriched microorganisms has been studied successfully [21]. In the selenium-deficient and low selenium areas, increasing the selenium content in crops is an effective way to increase the selenium nutrition for human body [22], while in selenium-enriched areas, selenium content in agricultural products is difficult to meet the standard merely by relying on selenium in soil [23]. To obtain agricultural products with high organic selenium content, it is necessary to rely on bio-enrichment of selenium, in other words, through bio-conversion. However, at present, agricultural production usually adopts sodium selenite to spray outside of roots to obtain selenium-enriched agricultural products. This method has low selenium utilization rate and the efficiency of conversion to organic selenium is not high. As a result, the content of organic selenium in selenium-enriched agricultural products is very low, and it is harmful to both crops and human health, the safety is low, the amount of use is large, and the times of use are many, leading to secondary pollution to both the soil and water body. We carried out an experiment through applying bio-selenium converted from microorganisms to the rice, in order to provide references for producing rice meeting the local food safety standard of Hubei Province *Selenium content of Selenium-enriched Foods* (DBS42/002-2014) and containing high content of organic selenium on the high quality, green, and safe principles.

2 Materials and methods

2.1 Basic conditions of experiment We carried out this experiment in the Ye Baihua Responsibility Field of the 9th Group of Yefang Village, Hongshan Town, Yingshan County, Hubei Province in 2016. The experimental soil did not contain selenium. The experimental variety was Ezhong No. 5, and the seed amount used in field was 2 kg. The rice seeds were sowing on April 21. In paddy field, 150 kg of urea fertilizer was applied 20 d after sowing in one hectare; transplanted on May 23, spacing in the rows and spacing between rows were 16.5 cm × 26.4 cm, double transplanting, east-west row, applied 750 kg of 16-10-10 compound fertilizer for one hectare field, and 7 d after transplantation, applied 75 kg of 16-10-10 compound fertilizer for one hectare field. Other management measures were the same as general field.

2.2 Experiment design The bio-organic selenium preparation for the experiment was a patented product independently developed by the selenium-enriched research team of Hubei Academy of Agricultural Sciences (Patent No. 201610338121.6). The experiment set 0 (Se0, control), 10 (Se1), 20 (Se2), 30 (Se3) and 40 mg/L (Se4) of selenium concentration (calculated as Se), 3 repetitions, a total of 15 plots, plot area of 20 m^2 (4 m × 5 m). Each plot was applied with 9 mL of bio-organic selenium preparation (selenium content of bio-organic selenium preparation was 5 000 mg/L, calculated as Se). Specifically, 45 mg of selenium (calculated as Se) each plot, equivalent to 4 500 mL of bio-organic selenium preparation and 22.5 g of selenium (calculated as Se) per ha. Selenium was sprayed once on the leaf surface at the beginning of the filling on August 18.

2.3 Sampling analysis On September 15th, samples were collected in the field, each plot selected 5 sampling 5 points, taking 3 pockets per point, a total of 15 pockets to count the number of effective spikes per hectare, and randomly selecting 10 panicles from 15 pockets for each plot. The rice was harvested on September 16, each plot was harvested and threshed separately, counted the actual yield of plot, calculated the yield per hectare. For different treatments of the 3 repetitive plots, each plot randomly selected half samples to mix, separate the grains, leaves, and stem, sent to the National Selenium Product Quality Supervision and Inspection Center for testing the selenium content in different parts of rice plants, and the rest half samples were processed by small processing machine to polished rice, and calculated the milled rice rate. The significance of differences between treatments was analyzed using SAS v9.4 software.

3 Results and analysis

3.1 Effects of different treatments on agronomic traits of rice

3.1.1 Effects of different treatments on rice plant height and number of effective panicles per unit area. The plant heights for different treatments and the number of effective panicles per hectare are listed in Table 1. According to Table 1, there was no difference in plant height between different treatments and the number of effective panicles per hectare because the growth and development of rice had already been completed and the plant height and the effective panicle per unit area had been formed when selenium was applied. In other words, selenium application exerts no effect on plant height and the number of effective panicles per unit area.

Table 1 Effects of different treatments on rice plant height and number of effective panicles per unit area

Treatment concentration//mg/L	Plant height//cm	Number of effective panicles (panicle/pocket)	Number of effective panicles (panicle/15 pockets)	Number of effective panicles (10^4 panicle/ha)
0	107.4	13.67	205	313.80
10	106.5	13.80	207	316.80
20	106.3	14.20	213	325.95
30	106.1	14.00	210	321.45
40	107.4	14.33	215	328.95

3.1.2 Effects of different treatments on seed setting traits of rice. Effects of different treatments on seed setting traits of rice (the total number of grains per panicle, the number of filled grains per panicle, and the seed setting rate) are listed in Table 2. According to Table 2, the total number of grains per panicle and the number of filled grains per panicle of the four selenium treatments were higher than that of the control group, they were the highest in the concentration of 30 mg/L, having significant differences with the control group, and concentrations of 10 and 20 mg/L, having no significant differences with the concentration of 40 mg/L; the seed setting rate was also the highest in concentration of 30 mg/L, but the differences were not significant between different treatments.

Table 2 Effects of different treatments on seed setting traits of rice

Treatment concentration//mg/L	Total number of grains per panicle	Number of filled grains per panicle	Seed setting rate//%
0	160.1 a	140.6 a	87.8
10	159.0 a	141.0 a	88.7
20	161.1 a	142.4 a	88.4
30	166.5 b	151.3 b	90.9
40	164.1 ab	146.4 ab	89.2

3.1.3 Effects of different treatments on 1 000-grain weight and milled rice rate of rice. According to Table 3, the 1 000-grain weight of the treatment with the concentration of 40 mg/L was the highest, and the difference between the treatment and the concentration of 10 mg/L was significant, and the difference between the treatment and other treatments was not significant; the selenium treatment increased the milled rice rate by 1 – 5 percentage points, the highest was treatment with concentration of 30 mg/L, and the milled rice rate was 65%, which was significantly different from the control group.

3.1.4 Effects of different treatments on yield traits of rice. Effects of different treatments on yield traits of rice are listed in Table 4. According to Table 4, the yield of selenium treatment plot was higher than that of the control, the highest was treatment with concentration of 40 mg/L, the plot yield was 18.67 kg, increasing by 10.9% compared with 16.83 kg of the control group, the difference reached significant level; the second was the treatment with concentration of 30 mg/L, the plot yield was 17.83 kg, increasing by 5.9% compared with 16.83 kg of the control group, the difference reached significant level.

Table 3 Effects of different treatments on 1 000-grain weight of rice

Treatment concentration//mg/L	1 000-grain weight//g	Milled rice rate//%
0	24.5 a	60 a
10	24.7 a	61 ab
20	25.1 ab	62 ab
30	25.2 ab	65 c
40	25.7 b	64 bc

Table 4 Effects of different treatments on yield traits of rice

Treatment concentration//mg/L	Grain yield of the plot//kg	Grain yield//kg/ha	Stem and leaf yield of the plot//kg	Grain-straw ratio
0	16.83 a	8 421.0 a	23.33	0.72
10	17.33 ab	8 671.5 ab	23.17	0.75
20	17.50 ab	8 754 ab	23.50	0.75
30	17.83 bc	8 920.5 bc	23.00	0.78
40	18.67 c	9 337.5 c	24.00	0.78

3.1.5 Effects of different treatments on absorption and distribution of rice. The results (Table 5) indicate that the general law of selenium absorption of rice was leaf > stem > rice; the selenium content in leaves, stems and rice of different treatments was the highest in treatment with concentration of 30 mg/L. The selenium content in leaves treated with selenium concentrations of 20, 30, and 40 mg/L were significantly higher than that with concentration of 10 mg/L, and the difference between treatments with concentrations of 20, 30 and 40 mg/L was not significant; the selenium content in stems treated with selenium was significantly higher than that of the control, but the difference between selenium treatments was not significant; both the selenium content of rice (total selenium and organic selenium) and the ratio of organic selenium to total selenium in the selenium treatment met the local food safety standard of Hubei Province *Selenium content of Selenium-enriched Foods* (DBS42/002-2014) (total selenium of rice is 0.2 – 0.5 mg/kg, and the ratio of organic selenium to total selenium ≥80%); the total selenium of rice in treatments of 30 and 40 mg/L was close to but not higher than the upper limit of the standard, and the ratio of organic selenium to total selenium was 83.6% and 84.9%, respectively, and significantly higher than the treatments of concentrations of 10 and 20 mg/L, the differences between concentrations of 30 and 40 mg/L and between concentrations of 10 and 20 mg/L were not significant, the ratio of organic selenium to total selenium of both exceeded 80%, but the difference was not significant, indicating that the ratio of organic selenium to total selenium was very stable; the selenium utilization rate of rice plants treated with selenium was 51.26% – 64.12%, higher than 50%, indicating that the utilization rate was very high.

Table 5 Effects of different treatments on absorption and distribution of rice

Treatment concentration // mg/L	Selenium content in leaves // mg/kg	Selenium content in stems // mg/kg	Selenium content in rice // mg/kg			Selenium utilization rate of rice // %
			Total selenium	Organic selenium	Ratio of organic selenium to total selenium // %	
0	0.122 a	0.080 a	0.044 a	0.040 a	90.9	–
10	0.748 b	0.528 b	0.331 b	0.276 b	83.4	64.12
20	1.254 c	0.524 b	0.317 b	0.259 b	81.7	59.61
30	1.290 c	0.540 b	0.432 c	0.361 c	83.6	56.39
40	1.247 c	0.535 b	0.430 c	0.365 c	84.9	51.26

Note: both the total selenium and organic selenium content were tested by National Selenium Product Quality Supervision and Inspection Center (Hubei).

4 Conclusions and discussions

4.1 Conclusions Under the same conditions of selenium application and application period, we carried out different application concentration treatments on the field plot, and reached the following conclusions. (i) Different treatments had no effect on the growth and development of rice plants. The selenium application period was carried out in the early stage of grain filling, rice growth and development has been completed at this time. Selenium application having no effect on rice growth and development does not mean that selenium has no influence on growth and development of rice. (ii) Different treatments had an effect on the economic traits of rice; selenium treatment increased the number of filled grains per panicle, seed setting rate and 1 000-grain weight, thus increasing yield; the level of yield was Se4 > Se3 > Se2 > Se1 > Se0; (iii) Different treatments have a greater effect on the milled rice rate; selenium treatment increased the milled rice rate; the milled rice rate of Se3 and Se4 treatments were 65% and 64%, respectively, which was significantly higher than that of the control group. (iv) The general law of selenium absorption of rice was leaf > stem > rice, which is consistent with studies of other scholars. The selenium content in leaves, stems and rice of different treatments was the highest in Se3 treatment Both the selenium content of rice (total selenium and organic selenium) and the ratio of organic selenium to total selenium in the selenium treatment met the local food safety standard of Hubei Province *Selenium content of Selenium-enriched Foods* (DBS42/002-2014); (v) Selenium-treated rice plants had a high selenium utilization rate, in the range of 51.26% – 64.12%, exceeding 50%.

4.2 Discussions (i) At present, agricultural production mainly uses inorganic selenium, chemically synthesized selenide and selenium ore fines for biological enhancing. Such selenium is essentially a toxic and harmful chemical input, and there is a high risk, for example, low safety, secondary pollution, and low crop utilization, as a result, the amount of use is large. The selenium content of the product is not up to standard, especially the content of organic selenium is low. In the context of the state constantly strengthening agricultural product safety and agricultural product production environment, it is recommended to highly promote the use of safe, efficient and pollution-free bio-organic selenium.

(ii) it is recommended to produce selenium-enriched agricultural products on the high quality and green principle. In terms of the rice variety, it is recommended to select high-quality conventional rice varieties; in the production environment, production process and product quality, it is necessary to implement green food standard; in the use of selenium, it is recommended to form standardized and normalized bio-organic selenium as selenium sources, grasp the optimal amount of use, optimal concentration, optimal model, and optimal period, so as to accurately meet the standard.

(iii) Studies have shown that the application of bio-organic selenium has a certain effect on economic traits, yield traits and quality traits of rice, and the results are not consistent with findings of Huang Taiqing *et al.* [24], possibly because they used inorganic selenite as the selenium source.

(iv) The production of selenium-enriched agricultural products should firstly determine the content of selenium in the edible parts, especially the inorganic selenium content, because only when crops actively absorb the selenium and convert the selenium into their nutritional substances, may they contain high organic selenium content. The study of Zhang *et al.* [25], indicated that only when there is certain amount of selenomethionine in the root, may selenium be trabsoirted through the nitrate transporter NRT1.1B to the grains, and the situation is the same for leaves. Thus, exogenous bio-organic selenium plays an important role in increasing the selenium content of agricultural products such as rice, especially the content of organic selenium. We should not exaggerate the effect of selenium on crop agronomic traits and quality traits to avoid the problem of selenium content, especially the problem that the content of organic selenium not up to standard. According to the comprehensive analysis of the results of this study, when using bio-organic selenium for exogenous bio-enhancement of rice, it is recommended to use 4 500 mL/ha (22.5 g of Se), and the application concentration is 30 – 50 mg/L; the leaves should be sprayed once in the early stage of rice filling.

References

[1] ZHANG JE. The issues and countermeasures for safe production of rice in China[J]. Reclaiming and Rice Cultivation, 2007, 23(4): 1 – 7. (in Chinese).

[2] YANG YX, WANG GY, PAN XC. Chinese food ingredient list[M]. Beijing: Peking University Medical Press, 2009. (in Chinese).

[3] ROTRUCK JT, POPE AL, GANTHER HE, *et al*. Selenium: Biochemical role as a component of glutathione peroxidase[J]. Science, 1973, 179 (2): 588 – 590.

[4] CHANG WC, CHEN SH, WU LF, *et al*. Cytoprotective effect of reduced glutathione in arsenical-induced endothelial cell injury[J]. Toxicology, 1991, 69(1): 101 – 110.

[5] XU HE. Fundamentals of hygiene toxicology[M]. Beijing: Peking Union Medical College Union Publishing House, 1991. (in Chinese).

[6] WHANGER PD. China, a country with both selenium deficiency and toxicity: Some thoughts and impressions[J]. The Journal of Nutrition, 1989, 119(2): 1236 – 1239.

[7] XU BH, SUN Y. The effects of prevention and treatment of selenium on human cancers[J]. Chinese Journal of New Drugs, 1998, 7(3): 176 – 179. (in Chinese).

[8] HATFIELD DL, BERRY MJ, GLADYSHEV VN. Selenium: Its molecular biology and role in human health[M]. New York: Springer Science + Business Media, 2006.

[9] Environmental and Endemic Diseases Research Group, Institute of Geography, Chinese Academy of Sciences. Study on the relationship between low selenium zone and Keshan disease and Kashin-Beck disease in China [J]. Environmental Science, 1986, 7(4): 89 – 93. (in Chinese).

[10] HUANG KX, XU HB. Chemistry and biochemistry of selenium and its application in life science[M]. Wuhan: Huazhong University of Science and Technology Press, 2009. (in Chinese).

[11] XIA YM. Review of studies on selenium nutrition in human body in China[J]. Acta Nutrimenta Sinica, 2011, 33(4): 329 – 334. (in Chinese).

[12] XIA YM, HILL KE, LI P, *et al*. Study on the selenium requirement for Chinese[J]. Acta Nutrimenta Sinica, 2011, 33(2): 109 – 113. (in Chinese).

[13] GE KY. Chinese nutrition science book[M]. Beijing: People's Medical Publishing House, 2004. (in Chinese).

[14] WS/T 578.3-2017. Chinese dietary reference intakes-Part 3: Trace element[S]. National Health Commission of the People's Republic of China, 2018-04-01. (in Chinese).

[15] LI HW, ZHAO SY. Research on antioxidative activity of se-polysaccharide and synergistic action of Se-polysaccharide and catalase[J]. Chinese Journal of Analytical Chemistry, 2010, 38(9): 1256 – 1260. (in Chinese).

[16] LIU Q, JIANG L. The molecular biology of selenoproteins and their effects on diseases[J]. Progress in Chemistry, 2009, 15(5): 819 – 830. (in Chinese).

[17] WANG XF, TAO GQ, CHEN YY. Studies on the culture of selenium-accumulating yeast and extraction of selenium Nucleic acid[J]. Journal of Chinese Institute of Food Science and Technology, 2006, 6(6): 52 – 57. (in Chinese).

[18] China Selenium-rich Agricultural Industry Technology Innovation Alliance. Blue book on the development of selenium-rich agriculture in China (2017)[M]. Beijing: China Agricultural Science and Technology Press, 2017. (in Chinese).

[19] WANG SP, ZHOU YY, TENG B, *et al*. Study on the transforming rat of organic selenium yeast[J]. Journal of Northeast Agricultural University, 1997, 28 (4): 378 – 383. (in Chinese).

[20] KULP TR, PRATT LM. Speciation and weathering of selenium in Upper Cretaceous chalk and shale from South Dakota and Wyoming, USA[J]. Geochemical Et Cosmo chemical Acta, 2004, 68(18): 3687 – 3701.

[21] ZHENG W, ZHANG ZQ, LIAO LJ, *et al*. Screening and identification of a strain of rich organic selenium and its transformation ability[J]. Hubei Agricultural Sciences, 2016, 55(24): 6389 – 6394. (in Chinese).

[22] VARO P, ALFTHAN G, EKHOLM P, *et al*. Selenium intake and serum selenium in Finland: Effects of soil fertilization with selenium[J]. The American Journal of Clinical Nutrition, 1988, 48(2): 324 – 329.

[23] ZHANG YP, HU XM, WU Y, *et al*. Soil selenium enrichment factors of crop planting areas in Tianmen, Hubei Province[J]. Resources Environment & Engineering, 2015, 29(6): 822 – 824. (in Chinese).

[24] HUANG TQ, JIANG ZP, XING Y, *et al*. Effects of exogenous selenium on paddy rice growth, selenium uptake and accumulation[J]. Agro-Environment and Development, 2017, 34(5): 449 – 455. (in Chinese).

[25] ZHANG LH, HU B, DENG K, *et al*. NRT1.1B improves selenium concentrations in rice grains by facilitating selenomethinone translocation [J]. Plant Biotechnology Journal, 2018, 10 (11): 13 – 37.

(From page 61)

[5] PENG FT, ZHANG Q, JIANG YM, *et al*. Effect of nitrogen application on nitrogen absorption, distribution and yield of strawberry[J]. Plant Nutrition and Fertilizer Science, 2006, 12(3): 400 – 405. (in Chinese).

[6] CAO CX, LONG T, CHENG XL, *et al*. Field efficacy trials of *Bacillus subtilis* against powdery mildew of strawberry[J]. Hubei Agricultural Sciences, 2011, 50 (20): 4188 – 4189. (in Chinese).

[7] CHEN Y, ZHAO TH, XU L, *et al*. Field efficacy test of fluopyram on cucurbits and strawberry powdery mildew[J]. Chinese Agricultural Science Bulletin, 2012, 28(13): 281 – 284. (in Chinese).

[8] ZHANG Y, WANG LY, LIU SQ, *et al*. Occurrence and control of strawberry grey mould in Hunan Province[J]. Journal of Microbiology, 2015, 35(1): 79 – 84. (in Chinese).

[9] XING SJ, MA HL, DU ZY, *et al*. Effect of potash fertilizer on yield and quality of strawberry[J]. Deciduous Fruits, 2000, 32(2): 12 – 13. (in Chinese).

[10] NEUWEILER R. Nitrogen fertilizer in integrated outdoor strawberry production[J]. Acta Hort, 1997, 439 (2): 747 – 751.