 DOI: 10.19601/j.cnki.issn1943 -9903.2020.03.011

Effects of Soil Testing and Formulated Fertilization on Yield and Economic Benefit of Major Crops in Burundi

Kaiqiang LIU[1], Yuyi HUANG[2]*, Yanfei HUANG[2], Guifen CHEN[2], Guoqing GAO[3]

1. Guangxi Academy of Agricultural Sciences, Nanning 530007, China; 2. Agricultural Resources and Environment Research Institute, Guangxi Academy of Agricultural Sciences, Nanning 530007, China; 3. Rice Research Institute, Guangxi Academy of Agricultural Sciences, Nanning 530007, China

Abstract [**Objectives**] The purpose of this study was to provide technical support for high-yield cultivation of major crops in Burundi, thereby increasing local farmers' income and promoting sustainable development of agriculture in Burundi. [**Methods**] In the IMBO and MOSO test stations of the Burundi Academy of Agricultural Sciences and the Burundi Fruit and Vegetable Extension and Service Center, soil testing and formulated fertilization test and demonstration was carried out in rice, maize and cabbage. The test set up three treatments, soil testing and formulated fertilization (STFF), local routine fertilization (RF) and non-fertilization (CK) to investigate the effects of soil testing and formulated fertilization on the yield and economic benefit of the crops. [**Results**] In the plot test, the yield and net economic benefit of rice, maize and cabbage were both highest in the STFF treatment. Compared with those in the RF treatment, the yield of rice, maize and cabbage increased by 19.0%, 25.7% and 33.0%, respectively, and the net economic benefit increased by 4 292, 2 837 and 8 232 yuan/ha, respectively. In the field test, the yield and net economic benefit of rice, maize and cabbage were also both highest in the STFF treatment. The yield increased by 18.1%, 24.3% and 25.9%, respectively, and the net economic benefit increased by 4 142, 2 881 and 8 665 yuan/ha, respectively compared with those in the RF treatment. [**Conclusions**] Soil testing and formulated fertilization not only increased rice, maize and cabbage yield per unit area, but also increased farmers' income in Burundi. It is one of the important technical measures to promote the increase of agricultural production and income in Burundi.

Key words Burundi, Soil testing and formulated fertilization technology, Yield, Economic benefit

1 Introduction

The Republic of Burundi (hereinafter referred to as Burundi) is located in central Africa and is located on the south side of the equator. It belongs to the tropical region and is very close to the natural agricultural conditions in tropical and subtropical regions of China. Many tropical and subtropical agricultural production technologies and crop varieties have good promotion value in Burundi[1-2]. Burundi is one of the ten least developed countries recognized by the United Nations, and its basic agricultural materials such as fertilizers are basically imported, so the agricultural production costs are high. At the same time, Burundi is known as a "mountainous country", and its ecological conditions are diverse. Through detailed and in-depth investigation and research in the previous period, it has been concluded that irrational fertilization that is not in line with local conditions is one of the main reasons that have led to low crop yield and low fertilizer utilization in Burundi. In soil testing and formulated fertilization, on the basis of rational application of organic fertilizer, the fertilization types, amounts, time and methods of nitrogen, phosphorus, potassium, and medium and trace element fertilizers are proposed according to crop's fertilizer demand law, soil fertility and fertilizer efficiency, based on soil testing and fertilizer field tests[3]. This technology is a mature agricultural production technology in China and has been widely applied and popularized. Carrying out research and demonstration and popularization of soil testing and formulated fertilization technology for major crops such as rice, maize and cabbage in cooperation with relevant organizations in Burundi, strengthening training of scientific and technical personnel and jointly carrying out localization research on soil testing and formulated fertilization technology by utilizing China's advanced soil testing and formulated fertilizing technology will help to increase local crop yield and effectively alleviate the contradiction between supply and demand of chemical fertilizers, thereby making reasonable allocation of limited fertilizer sources, reducing agricultural costs, increasing local farmers' income, and ensuring sustainable agricultural development in Burundi. The implementation of soil testing and formulated fertilization technology is of great significance to reduce production costs, increase food production, and increase farmers' income. At the same time, it has a profound impact on improving fertilizer utilization rate, improving the nutrient status of cultivated land, protecting the ecological environment, and achieving sustainable development of agriculture. According to the experimental data of China's relevant agricultural departments, soil testing and formulated fertilization can increase the yield of grain crops by 20% -30% and the yield of vegetables and cash crops by 30% -

Received: January 17, 2020 Accepted: March 5, 2020

Supported by Special Scientific and Technological Assistance Program of Ministry of Science and Technology of the People's Republic of China to Developing Countries (Demonstration and Popularization of Key Technologies for Increasing Grain Yield in Africa); Scientific Research and Technology Development Plan Project of Guangxi Zhuang Autonomous Region, China (Gui Ke He 1346009-4, Gui Ke He 14125007-2-7).

* Corresponding author. Yuyi HUANG (1961 -), male, researcher, engaged in research on soil improvement technology and efficient use of fertilizers.

50% than usual[4]. For example, compared with conventional fertilization, soil testing and formulated fertilization increased the yield of rice, maize, sugarcane, potato, cucumber, tomato, green pepper and eggplant by 7.4%, 9.4%, 8.33%[5], 8.21%[6], 27.38%, 8.87%, 6.78%, and 31.33% respectively[7]. It has played a good effect in saving cost and improving efficiency of cash crops. In this paper, by collecting data on fertilizer uses and fertilization technologies of rice, maize and vegetable production and soil fertility in Burundi and combining domestic and foreign soil testing and formulated fertilization technologies, the fertilization rates of nitrogen, phosphorus and potassium for rice and maize production in Burundi were recommended, and the effects of soil testing and formulated fertilization on yield and economic benefit of major crops in Burundi were investigated to establish a soil testing and formulated fertilization technology for rice, maize and cabbage that is adapted to local ecological conditions.

2 Materials and methods

2.1 Test materials The test varieties were local conventional varieties, TOX (rice), Ecavel 1 (maize) and M1 and B1 (cabbage), which were all major varieties in Burundi. The test variety of rice was provided by Burundi Academy of Agricultural Sciences and the test varieties of cabbage were provided by Burundi Fruit and Vegetable Extension and Service Center.

2.2 Test site and soil nutrients The IMBO test station is located in the IMBO Plain in Gihanga, Bujumbura, with an altitude of 811 m. It is in the local low-altitude area and is the main rice-producing area in Burundi, with 4 850 ha of paddy field. Generally, rice is grown only once a year in the rainy season. In view of the drainage and irrigation channels built by international aid organizations such as the European Union (EU), the drainage and irrigation conditions of this station are relatively superior. The soil of the station is alluvial sandy loam, and the plough layer is 20 – 25 cm deep. The texture of the soil is sandy loam, with pH of 5.52, average organic matter content of 0.85%, average total nitrogen content of 0.09%, average available phosphorus content of 15.9 mg/kg, average available potassium content of 489 mg/kg and average cation exchange capacity (CEC) of 4.72 meq/100 g (Table 1). The MOSO test station is located in southeast, and in the area where the Nile originated. It is a medium-altitude region, with an altitude of 1 197 – 1 241 m. The annual average temperature is 22 – 27 ℃. The average annual rainfall is 1 000 – 1 200 mm. The rainy season is from February or mid-March to mid-June, and from October or mid-November to January or February of the following year. The station is in the Musasa and Muyovozi river basins, so its water resource is relatively abundant. The soil of the station is alluvial soil, located in low-lying hilly areas, surrounded by mountains, with rivers available for irrigation. The texture of the soil is loose sandy loam, with plough layer 25 – 30 cm deep. The core test demonstration area was 1 ha. The previous crops were maize and legume crops. The soil had a pH of 6.11, relatively high organic matter content (3.58%), extremely high available potassium content, and medium-high available phosphorus content (Table 1).

The test base of the Fruit and Vegetable Extension and Service Center is located in the suburb of Bujumbura, at an altitude of 756 m. The annual average temperature is 20 – 25 ℃, and the highest can reach 33 ℃. The average annual rainfall is 1 000 – 1 140 mm. The base has better basic conditions and it is an important base for the promotion and demonstration of fruits and vegetables in Burundi. The soil is alluvial, and its texture is sandy loam with pH of 6.13, low organic matter content, low available phosphorus content, and high available potassium content (Table 1).

Table 1 Nutrient status of soil in the test bases

Base name	pH	Organic matter//%	Total nitrogen//%	Available phosphorus//mg/kg	Available potassium//mg/kg	CEC meq/100 g
IMBO	5.52	0.85	0.09	15.9	489	4.72
MOSO	6.11	3.58	0.29	19.2	958	5.75
Fruit and Vegetable Extension and Service Center	6.13	1.76	0.12	11.6	1 001	6.03

2.3 Test methods

2.3.1 Plot tests of soil testing and formulated fertilization technology. The tests on the effects of soil testing and formulated fertilization on rice, maize and cabbage yield were carried out. All tests set up 3 treatments: soil testing and formulated fertilization (STFF), local routine fertilization (RF), and non-fertilization (CK). There were three replicates for each treatment, and all the plots were arranged randomly.

The rice test was conducted in the IMBO test base. The sowing, transplanting and harvest were carried out on January 6, February 16 and June 10, 2015, respectively. The area of each plot was 300 m^2. The area of each of the plots in the blank treatment was 200 m^2. The plant and row spacing was 15 cm × 20 cm. The test fertilizers were urea (containing 46% N), diammonium phosphate (18-46-0) and ternary compound fertilizer (17-17-17). According to the target yield of 6 500 kg/ha and the nitrogen, phosphorus and potassium contents of the test soil, the recommended fertilization rates of N, P_2O_5 and K_2O were 79.2, 61.3 and 0.0 kg/ha, respectively. The local customary fertilization amounts of N, P_2O_5 and K_2O were 86.0, 17.0 and 17.0 kg/ha, respectively.

The maize test was conducted at the IMBO test base. Maize was sown on January 10 and harvested on June 20, 2015. The area of each plot was 200 m^2, and in the blank treatment, the area of each plot was 100 m^2. The plant and row spacing was 50 cm × 75 cm. Maize seeds were sown in holes, 3 seeds/hole, and after thinning, two plants were remained in each hole. Potassium chloride (containing 60% K_2O) was applied, and the rest of the fertilizers were the same as the rice test. According to the target yield of 6 000

kg/ha and the nitrogen, phosphorus and potassium contents of the test soil, the recommended fertilization rates of N, P_2O_5 and K_2O were 146.8, 98.9 and 0.0 kg/ha, respectively. The local customary fertilization amounts of N, P_2O_5 and K_2O were 40.0, 59.8 and 30.0 kg/ha, respectively.

The cabbage test was conducted at the base of the Fruit and Vegetable Extension and Service Center. The sowing, transplanting and harvest were carried out on January 17, February 15 and May 20, 2015, respectively. The area of each plot was 200 m^2. The area of each plot in the blank treatment was 50 m^2. The plant and row spacing was 40 cm × 50 cm. The test fertilizers were the same as the rice test. According to the target yield of 50 000 kg/ha and the nitrogen, phosphorus and potassium contents of the test soil, the recommended fertilization rates of N, P_2O_5 and K_2O were 221.8, 149.5 and 0.0 kg/ha, respectively. The local customary fertilization amounts of N, P_2O_5 and K_2O were 71.5, 25.5 and 25.5 kg/ha, respectively.

2.3.2 Field validation of soil testing and formulated fertilization technology. In order to obtain test technical parameters of a larger area, based on the results of the plot tests, the effects of soil testing and formulated fertilization on the yield of the major crops in large-scale cultivation were investigated. There were two treatments in all demonstration areas: soil testing and formulated fertilization (STFF) and local routine fertilization (RF). The large-scale filed validation test of rice was carried out at the IMBO test station from 2014 to 2016, and soil testing and formulated fertilization technology demonstration in two-season rice was conducted. The core demonstration area had a total area of 2.3 ha and it radiated 280 ha. The fertility of the soil in the demonstration area was comparable to that in the plot test. The test rice varieties were V14 and TOX3154. The target yield was 6 500 kg/ha. In the soil testing and formulated fertilization area, diammonium phosphate (133 kg/ha) was applied as base fertilizer, urea (48 kg/ha, 15 d after transplanting) was applied as tillering fertilizer and urea (72 kg/ha, 30 d after transplanting) was applied as earing fertilizer. According to local custom, no base fertilizer was applied, nitrogen-phosphorus-potassium ternary compound fertilizer (100 kg/ha) and urea (50 kg/ha) were applied as tillering fertilizer and urea (100 kg/ha) was applied as earing fertilizer. Base fertilizer was applied to the whole plough layer 1 – 2 d before transplanting. A thin layer of water was maintained during the top dressing.

The large-scale field validation test of maize was carried out at the MOSO test station from 2014 to 2015. Demonstration of soil testing and formulated fertilization technology was carried out in one-season maize. The core demonstration area was 1.1 ha, and the radiation area was 75 ha. The fertility of the soil in the demonstration area was comparable to that in the plot test. The test maize variety was ZM621. The target yield was 5 000 kg/ha. In the soil testing and formulated fertilization area, diammonium phosphate (130 kg/ha) and urea (8 kg/ha) were applied as base fertilizer, urea (50 kg/ha, 20 d after emergence) was applied as stalk fertilizer, and urea (108 kg/ha, 40 d after emergence) was applied as earing fertilizer. According to local custom, diammonium phosphate (130 kg/ha) and potassium chloride (50 kg/ha) were applied as base fertilizer, no stalk fertilizer was applied, and urea (37 kg/ha) was applied as earing fertilizer.

The large-scale field validation test of cabbage was conducted at the base of Fruit and Vegetable Extension and Service Center from 2014 to 2016. The demonstration of soil testing and formulated fertilization technology was carried out in two-season cabbage. The demonstration area was 1.3 ha and the radiation area was 52 ha. For the first season, the test cabbage variety was M1 (medium), and for the second season, the test cabbage variety was B1 (large). The target yield was 60 000 kg/ha. The fertilizers applied were the same as those in the soil testing and formulated fertilization demonstration in rice. The fertilization amounts, fertilization time and fertilizer proportion were the same as those of the test plot of soil testing and formulated fertilization technology in cabbage.

2.4 Measured items and methods In the plot tests, the yield per unit area (kg/ha) was calculated according to the actual yield of the plots. In the validation tests, the yield was measured in accordance with China's yield measurement method for demonstration fields.

Net economic benefit (yuan/ha) = Yield per unit area (kg/ha) × Acquisition price (yuan/kg) – Fertilizer cost (yuan/ha).

The cost of N, P_2O_5 and K_2O was 7.0, 7.0 and 6.9 yuan/kg, respectively; and the acquisition price of rice, maize and cabbage was 4.7, 3.4 and 0.86 yuan/kg, respectively.

2.5 Statistical analysis Data processing and analysis was performed using Excel 2019.

3 Results and analysis

3.1 Effect of soil testing and formulated fertilization on yield of major crops As shown in Table 2, the yield of rice, maize and cabbage was all highest in the STFF treatment, and it was 5 910, 5 258 and 46 700 kg/ha, respectively, increased by 19.0%, 25.7% and 33.3%, respectively compared to the RF treatment. It can been seen that under the test conditions, the nitrogen, phosphorus and potassium fertilization rates recommended by soil testing and formulated fertilization are more scientific and reasonable than local customary fertilization, and are more conducive to increasing rice, maize and cabbage yield.

Table 2 Effect of soil testing and formulated fertilization on yield of rice, maize and cabbage

Treatment	Yield//kg/ha			Compared to CK//%			Compared to RF//%		
	Rice	Maize	Cabbage	Rice	Maize	Cabbage	Rice	Maize	Cabbage
STFF	5 910	5 258	46 700	131.9	96.9	80.3	19.0	25.7	33.0
RF	4 965	4 183	35 100	94.8	56.7	35.5	–	–	–
CK	2 549	2 670	25 900	–	–	–	–	–	–

3.2 Effect of soil testing and formulated fertilization on economic benefit of major crops The economic benefit of rice, maize and cabbage was also highest in the STFF treatment, and it was 26 790, 16 157 and 37 563 yuan/ha, respectively, increased by 4 292, 2 837 and 8 232 yuan/ha, respectively in comparison to the RF treatment (Table 3). Although potassium fertilizer was removed from the fertilization formula recommended, the net economic benefit of rice, maize and cabbage was still increased. It suggests that soil testing and formulated fertilization can not only increase the yield of rice, maize and cabbage, and it can also increase the income of growers. It is one of the important technical measures to promote agricultural production and income.

Table 3 Effect of soil testing and formulated fertilization on economic benefit of rice, maize and cabbage

Treatment	Economic benefits // yuan/ha			Cost of fertilizer // yuan/ha			Net benefit // yuan/ha		
	Rice	Maize	Cabbage	Rice	Maize	Cabbage	Rice	Maize	Cabbage
STFF	27 777	17 877	40 162	987	1 720	2 599	26 790	16 157	37 563
RF	23 336	14 222	30 186	838	902	855	22 498	13 320	29 331
CK	11 980	9 078	22 274	0	0	0	11 980	9 078	22 274

3.3 Yield-improving effect of soil testing and formulated fertilization technology in field validation test In the case of large-scale planting, in comparison to the RF treatment, the STFF treatment increased the yield of rice, maize and cabbage by 911 (18.1%), 910 (24.3%) and 12 109 kg/ha (25.9%), respectively (Table 4), indicating that soil testing and formulated fertilization has a significant effect on promoting the yield of rice, maize and cabbage in Burundi, so it can be vigorously promoted.

Table 4 Comparison of yield between soil testing and formulated fertilization and local routine fertilization

Season	Treatment	Yield // kg/ha			Compared to RF // %		
		Rice	Maize	Cabbage	Rice	Maize	Cabbage
1	STFF	6 130	4 650	41 240	18.6	24.3	29.1
	RF	5 170	3 740	31 950	–	–	–
2	STFF	5 798	–	80 952	17.5	–	22.6
	RF	4 935	–	66 024	–	–	–

3.4 Income-improving effect of soil testing and formulated fertilization technology in large-scale application Table 5 shows that the net income of rice, maize and cabbage was all highest in the STFF treatment. On average, the net economic benefit of rice, maize and cabbage was 27 051, 14 690 and 49 939 yuan/ha, respectively, increased by 4 142, 2 881 and 8 865 yuan/ha, respectively in comparison to the RF treatment.

Table 5 Economic benefit analysis of soil testing and formulated fertilization

Season	Treatment	Economic benefit // yuan/ha			Cost of fertilizer // yuan/ha			Net benefit // yuan/ha		
		Rice	Maize	Cabbage	Rice	Maize	Cabbage	Rice	Maize	Cabbage
1	STFF	28 811	15 810	35 466	980	1 120	2 604	27 831	14 690	32 862
	RF	24 299	12 716	27 477	838	907	855	23 461	11 809	26 622
2	STFF	27 251	–	69 619	980	–	2 604	26 271	–	67 015
	RF	23 195	–	56 781	838	–	855	22 357	–	55 926

4 Discussions

China-Africa agricultural cooperation started in the late 1950s, and so far, Chinese government has implemented more than 200 agricultural aid projects in Africa, which provide training in rice cultivation, freshwater aquaculture, vegetable cultivation and agricultural machinery for 42 African countries, and remarkable results have been achieved[8-9]. Since 2010, based on Burundi's ecological conditions and variety characteristics, agricultural experts from Guangxi have selected 229 new crop varieties for trial planting in the local area. After many years of testing, 15 new varieties that are suitable for local production conditions and consumption needs have been screened out, including 6 rice varieties, 3 maize varieties and 6 vegetable varieties[10]. Excellent variety needs excellent method. Excellent variety is the internal cause of increased yield, while the development of variety potential requires the support of cultivation techniques to achieve[11]. Since agricultural production materials such as fertilizers in Burundi basically depend on imports, the cost of fertilization is high, so the amount of chemical fertilizer used is very small. The soil fertility has been severely declining, seriously affecting the development of high-yield potential of crop varieties. Based on existing excellent varieties in Burundi, by utilizing the mature soil testing and formulated fertilization technology, research and demonstration of soil testing and formulated fertilization technology for major crops such as rice, maize and cabbage in Burundi were carried out to make fertilizer input more reasonable and scientific, thereby meeting the nutritional needs by the entire growth and development process of the crops and reducing the cost of fertilizer input, and eventually increasing production and income and promoting sustainable development of agriculture in Burundi.

In Honghe Farm of Heilongjiang Province, the yield of maize under formulated fertilization increased by 2.56% compared to conventional fertilization[12]. The test results of the soil testing and formulated fertilization promotion and demonstration area in Tengchong City show that after soil testing and formulated fertilization, the average yield of rice increased by 487.5 kg/ha (7.8%); and the average yield of maize increased by 420 kg/ha (7.2%)[13]. In the soil testing and formulated fertilization promotion and demonstration area in Burundi, the yield of rice increased by 911 kg/ha (18.1%) on average, and the yield of maize increased by 910 kg/ha (24.3%) on average. The study results of Zhao Dan show that according to the target yield of 89 955 and 82 458 kg/ha, the economic benefit of Chinese cabbage under soil testing and formulated fertilization increased by 3 459 and 4 520 yuan/ha, respectively in comparison to conventional fertilization[14]. In this study, according to the target yield of 50 000 and 60 000 kg/ha, the economic benefit of cabbage in the soil testing and formulated fertilization treatment was found to be increased by 8 232 and 8 665 yuan/ha respectively compared with the routine fertilization. It shows that the application and popularization of soil testing and formulated fertilization technology for rice, maize and cabbage in Burundi are significantly better than China's similar tests in terms of increasing yield or income. The possible reason is that there is a common situation of excessive fertilization in China, while in Burundi, the soil is barren, the amount of fertilizer used is very low, and the fertilization is unbalanced, which seriously affect the development of high-yield potential of excellent crop varieties, so compared with China, the increase in crop yield after soil testing and formulated fertilization in Burundi was more significant, thus improving the economic benefit of the crops. The soil testing and formulated fertilization technology plays a prominent role in agricultural production. In particular, it has an important role in helping African countries to reduce agricultural production investment, improve agricultural economic benefits and resolve the imminent food security issue.

5 Conclusions

By utilizing the mature soil testing and formulated fertilization technology in China and cooperating with relevant scientific research units in Burundi, the research and demonstration and popularization of soil testing and formulated fertilization technology for rice, maize and cabbage, the major crops in Burundi were carried out. As a result, the yield and economic benefit of the crops were improved, the contradiction between supply and demand of fertilizers was effectively alleviated, the rational distribution of limited fertilizer sources was realized, the agricultural production costs were reduced, local farmers' income was increased, resources were saved and sustainable development of agriculture in Burundi was promoted.

References

[1] HUANG YY, CHEN YM, YAN FY, *et al.* Status quo of agricultural development in Burundi[J]. Guangxi Agricultural Sciences, 2010, 41(11): 1240-1243.

[2] LIU KQ, HUANG YY, WEI Y, *et al.* Breeding system and promotion model of Burundi improved crop variety[J]. Journal of Southern Agriculture, 2015, 46(4): 729-734. (in Chinese).

[3] LI XQ. Testing soil for formulated fertilization[J]. Jilin Agriculture, 2019, 31(23): 85. (in Chinese).

[4] SUN GY. Study on the effect of corn soil testing formula fertilization[J]. Agriculture and Technology, 2019, 39(20): 103-104. (in Chinese).

[5] LUO YP. The present situation and development directions of equilibrium fertilization extension in Guangxi[J]. Journal of Guangxi Agriculture, 2008, 23(6): 73-76. (in Chinese).

[6] SHAO K. Study on the effect of formula fertilization and fertilizer utilization rate of potato[J]. Agricultural Science and Technology and Information, 2018, 35(8): 7-9. (in Chinese).

[7] TANG BG, ZENG HY, CAI JH, *et al.* A preliminary study on the effect of formula fertilization on vegetables[J]. Modern Agricultural Science and Technology, 2010, 39(24): 295-296. (in Chinese).

[8] YUN WJ. Sino-African agricultural cooperation in the 21st century[J]. West Asia and Africa, 2000, 21(5): 38-42, 79. (in Chinese).

[9] JIANG HP. Thoughts and policy suggestions on agricultural cooperation between China and Africa[J]. Management of Agriculture Science and Technology, 2008, 27(6): 5-7. (in Chinese).

[10] LI XX. The technology of grain production in Burundi has been successfully demonstrated in our region[N]. Guangxi Daily, 2015-09-08. (in Chinese).

[11] ZHU DF, ZHANG YP, CHEN HZ, *et al.* Innovation and practice of high-yield rice cultivation technology in China[J]. Scientia Agricultura Sinica, 2015, 48(17): 3404-3414. (in Chinese).

[12] CHU XY, WANG Y, ZHANG L. Effect of soil testing and formula fertilization on Corn Yield and fertilizer utilization rate in Honghe farm[J]. Modernizing Agriculture, 2019, 41(6): 21-22. (in Chinese).

[13] ZHOU DS. Research and application of soil testing and formula fertilization technology in Tengchong City[J]. Yunnan Agricultural Science and Technology, 2019, 48(6): 32-34. (in Chinese).

[14] ZHAO D. Study on the application of soil testing and formula fertilization technology in Taibai Chinese cabbage and head cabbage[D]. Xianyang: Northwest A&F University, 2015. (in Chinese).