Development of Acidification-resistant Organic Fertilizer for Improvement of Acid Red Soil in Guangxi

Wei HUANG[1], Zongkang WANG[2], Yongxian LIU[3], Yulin ZHU[1], Yu ZHANG[1], Daobo WANG[1*]

1. College of Agriculture, Yulin Normal University, Yulin 537000, China; 2. Shenzhen Batian Ecological Engineering Co., Ltd., Shenzhen 518057, China; 3. Institute of Agricultural Resources and Environment, Guangxi Academy of Agricultural Sciences, Nanning 530007, China

Abstract The soil in Guangxi has been severely acidified, restricting sustainable development of agriculture. In this paper, based on the screening of organic fertilizer additives, a method for the production of acidification-resistant organic fertilizer specific for acid red soil improvement was proposed, and the developed acidification-resistant organic fertilizer was used in sugarcane experiment. The results showed that in the treatment that the specific acidification-resistant organic fertilizer was applied, the yield of sugarcane significantly increased, the pH value of soil effectively increased, the physical and chemical properties of soil improved, and the contents of microorganisms and available nutrients in soil increased.

Key words Guangxi, Acid red soil improvement, Specific acidification-resistant organic fertilizer, Development

1 Introduction

Soil acidification in Guangxi will lead to accelerated loss of soil nutrients, soil consolidation, activation of heavy metals such as aluminum and manganese and change in soil microbial population and activity, affect root development and nutrient absorption of crops, and induce occurrence of diseases and pests in plants. It has posed a serious potential threat to agricultural production, the ecological environment and human health, and has a long-term impact on food security and environmental security. Therefore, soil acidification is a major issue of widespread concern in the fields of soil science, ecology and environmental science.

At present, lime, waste fly ash, alkaline slag, *etc.* are commonly used to improve acid or acidified soil[1]. Although some by-products of industry and mining, such as industrial alkaline slag, fly ash, carbonization filter mud and yellow phosphorus slag, can play an effect of improving acid and acidified soil, most of the industrial and mining by-products contain toxic metal elements, such as lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As). The excessive or long-term application of lime alone in agriculture will cause the soil to compact to form "lime-compacted filed". In addition, the cost of applying lime to farmers in poor areas is too high. A related study[2] found that lime application only improved the acidity of surface soil, but the acidity of bottom soil did not change much[2]. Another study[3] showed that the soil was re-acidified after applied with lime, that is, the soil was acidified again after the alkaline of the lime was consumed, moreover, the degree of acidification was more severe than that before the application of the lime.

2 Development of fertilizer specific for improvement of acid red soil in Guangxi

2.1 Screening of soil acidification-resistant organic fertilizer additive Soil acidification-resistant organic fertilizer additives include functional compound microbial agent and polar negatively charged amino acid and humic acid powder, as well as zeolite powder, oyster shell powder, xonotlite powder and fused calcium magnesium phosphate.

2.1.1 Functional compound microbial agent. Functional compound microbial agent can change the quantity and composition of microorganisms in soil, improve biological fertility of soil and increase the content of nitrate nitrogen in soil acidification-resistant organic fertilizer[4]. Amino acids and humic acids can balance soil pH and reduce ion concentrations[5]. Zeolite powder, oyster shell powder, xonotlite powder and fused calcium magnesium phosphate supplement calcium and magnesium to acid soil, thus adjusting the pH[6].

In the additive, the mass percentages of functional compound microbial agent, amino acids, humid acid powder, zeolite powder, oyster shell powder, xonotlite powder and fused calcium magnesium phosphate were 3%, 2%, 30%, 20%, 10%, 20% and 15%, respectively.

2.1.2 Preparation of soil acidification-resistant organic fertilizer additive. The preparation of soil acidification-resistant organic fertilizer additive included the following steps.

(i) The functional compound microbial agent and amino acids were formulated into a solution according to a mass ratio of 0.1 –10:1. The functional compound microbial agent included nitrobacteria, *Bacillus megaterium*, *Bacillus subtilis*, *Bacillus polymyxa*, *Bacillus licheniformis* and *Trichoderma.* Amino acids were polar negatively charged, including polyaspartic acid and polyglutamic acid. Humic acid powder refers to powdery humic acids. Humic acids included pure humic acid, nitro-humic acid, sodium

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* Corresponding author. E-mail: 363583837@qq.com

humate and potassium humate. Xonotlite powder was a kind of mineral powder containing low contents of iron and aluminum and high contents of calcium and silicon.

(ii) The solution obtained in step (i) was subjected to spray drying and embedding to prepare into compound bacterial microcapsules.

(iii) The humic acid powder, zeolite powder, oyster shell powder, xonotlite powder and fused calcium magnesium phosphate were mixed according to certain ratio to obtain a mixed material, and the mixed material had a pH value of 6 – 8.

(iv) The mixed material obtained in step (iii) was piled up for fermentation, and the fermentation lasted for 10 – 15 d. Then, it was dried and pulverized into a powdery mixture (particle size was above 100 mesh).

(v) The compound bacterial microcapsules obtained in step (ii) and the powdery mixture obtained in step (iv) were blended to prepare the soil acidification-resistant organic fertilizer additive.

3 Effects of Guangxi acid red soil improvement-specific fertilizer on soil

3.1 Effects on soil physical and chemical properties The experiment was conducted in the practice base in College of Agriculture, Yulin Normal University in Yulin National Agricultural Science and Technology Park. Before use, the pH of the soil was between 4.1 – 5.3. Due to long-term application of fertilizers and lime, the soil had become compacted. The organic fertilizer with 8% of soil acidification-resistant organic fertilizer additive was applied as base fertilizer for two consecutive years, and the application rate was 3 000 kg/ha. The status of the soil before and after the application of the soil acidification-resistance organic fertilizer was compared, and the results are shown in Table 1. In the control group, conventional organic fertilizer was applied; and in the treatment group, organic fertilizer supplemented with soil acidification-resistant organic fertilizer additive was applied. As shown in Table 1, after two years of application of the soil acidification-resistant organic fertilizer additive, the pH of the soil increased from 4.6 to 5.7 – 6.3, indicating that the acidification of the soil had been greatly improved; the bulk density of the soil decreased by 0.26 g/cm^3; the total porosity of the soil increased by 2.7%; the capillary porosity of the soil increased by 1.2%; the non-capillary porosity of the soil increased by 1.7%; and the water capacity of the field increased by 4.3%.

Table 1 Effects of application duration of soil acidification-resistant organic fertilizer on physical and chemical properties of soil

Treatment	Soil pH	Soil bulk density // g/cm^3	Total porosity	Capillary porosity	Non-capillary porosity	Field water capacity
Control	4.6	1.71	41.68	35.18	6.5	24.3
First year	5.3	1.58	42.51	36.31	6.2	26.7
Second year	6.0	1.45	44.58	36.18	8.2	28.6

3.2 Effects on soil microorganisms A base had been used for planting vegetables for 8 consecutive years before the experiment. It was applied with organic fertilizer containing 10% of soil acidification-resistant organic fertilizer additive (as base fertilizer) at a dose of 4 500 kg/ha for 3 consecutive years. The quantity of microorganisms in the top 0 – 20 cm of the soil before and after the application of the soil acidification-resistant organic fertilizer was compared. As shown in Table 2, the microorganisms in the soil mainly included nitrobacteria, actinomycetes, and fungi[7]. Compared with the control (conventional organic fertilizer), the quantities of nitrobacteria, fungi and actinomycetes in the soil applied with the soil acidification-resistant organic fertilizer increased by 122.3%, 23.4% and 12.1%, respectively, indicating that the biological fertility of the soil had been greatly improved. The changes in the composition and quantity of microorganisms in the soil had a positive impact on the aggregate stability and biological fertility of the soil.

Table 2 Effects of soil acidification-resistant organic fertilizer on soil microorganisms

Treatment	Bacteria 10^7 cfu/g	Fungi 10^4 cfu/g	Actinomycetes 10^7 cfu/g
Blank	1.13	5.44	1.05
Control	2.16	6.25	1.35
Acid-resistant organic fertilizer	4.80	7.71	1.51

3.3 Effects on soil nutrients A base had been planted with vegetables for two consecutive years, and the pH of the soil was 4.8 – 5.5 before the experiment. It was applied with organic fertilizer containing 10% of soil acidification-resistant organic fertilizer additive at a dose of 4 500 kg/ha for three consecutive years. The soil pH, organic matter contents and microelement contents before and after the application of the soil acidification-resistant organic fertilizer were compared, and the results are shown in Table 3. Compared to the control, the content of nitrates in the soil increased, and nitrate nitrogen could increase the microenvironment pH of crop roots; the content of exchangeable aluminum in the soil reduced by 28.8%; and the chemical fertility of the soil improved significantly.

4 Effects of Guangxi acid red soil improvement-specific fertilizer on yield and sugar content of sugarcane

The original pH value of the soil before experiment was between 3.6 – 5.0. In the experiment, it was applied with organic fertilizer containing 8% of soil acidification-resistant organic fertilizer additive at a dose of 3 000 kg/ha for three consecutive years. The yield of sugarcane before and after the application of the soil acidification-resistant organic fertilizer was compared. The results are shown in Table 4. In the control group, conventional organic fertilizer was applied; and in the treatment group, organic fertilizer containing soil acidification-resistant organic fertilizer additive was applied. As shown in Table 4, after one year of application of soil acidification-resistant organic fertilizer, the yield of sugarcane increased by 3.4% compared with that before the application; and after three years of application of soil acidification-resistant organic fertilizer, the yield of sugarcane increased by 13.3%, and the sugar content of the sugarcane increased by 13.9% compared with those before the application.

Table 3 Effects of soil acidification-resistant organic fertilizer on soil nutrients mg/kg

Treatment	pH	Ammonium nitrogen	Nitrate nitrogen	Available phosphorus	Available potassium	Exchangeable calcium	Exchangeable magnesium	Exchangeable aluminum
Blank	4.8	21.5	14.6	38.3	21.1	236	89.1	307
Control	5.7	25.1	17.6	47.3	28.9	280	111.3	236
Soil acidification-resistant organic fertilizer	6.1	23.9	25.7	63.7	43.2	334	130.1	168

Table 4 Effects of application duration of soil acidification-resistant organic fertilizer on yield and sugar content of sugarcane

Treatment	Yield//t/ha	Maximum single plant weight//kg	Sugar content (mass fraction)//%
Control	84.45	3.07	13.63
First year	87.00	3.21	13.84
Second year	90.75	3.19	14.87
Third year	95.70	3.42	15.53

5 Conclusions

After this additive was supplemented to organic fertilizer, due to the action of microorganisms, the macromolecules in the organic fertilizer were decomposed, and the small molecular organics could be combined with soil colloids, and at the same time, they could complex exchangeable aluminum. The multifunctional compound microorganisms in the additive can effective perform nitrification, which makes the proportion of nitrate nitrogen in organic fertilizer exceed 60%. After application, the pH value of the root microenvironment of crops can be increased by 1 – 2.

This additive has unique adsorption properties and it can improves soil's own acid resistance.

For example, the maximum natural water absorption capacity of polyglutamic acid can reach 1 108.4 times, and it improves acid resistance after combining with soil colloids. The organic fertilizer supplemented with soil acidification-resistant organic fertilizer additive can improve the pH of crop root microenvironment, microbial colony and soil structure, enhance the disease resistance and stress resistance of crops, and improve the fertility of soil.

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