Tebeigai Soil Conditioner Can Increase Eggplant Yield, Reduce Heavy Metal Content and Improve Soil Acidification

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Abstract. The acidification of farmland soil in the red soil region of South China has led to the decrease of agricultural products, quality and soil degradation, which is in urgent need of improvement. In this paper, a field trial was implemented to study the effect of applying different amount of Tebeigai soil conditioner (namely 750, 1125, 1500, 1875 and 2250 kg/ha) on eggplant’s yield, heavy metal content and basic physical and chemical properties of soil in red soil area. The results showed that: compared with the control treatment, the application of different doses of Tebeigai soil conditioner could increase eggplant yield by 15.5\%–55.8\%; reduce As content of eggplant fruit by 12.8\%–51.8\%, Cr content by 33.7\%–57.1\%, Pb content by 1.9\%–19.2\%, Cd content by 14.3\%–30.4\%; at the same time, the soil pH increased by 5.8\%–18.6\%, exchangeable acid (potential acid) decreased by 37.6\%–82.3\%; and the contents of available Pb, Cd and Cr were decreased by 7.0\% ~ 21.6\%, 15.1\% ~ 29.6\% and 1.0\% ~ 21.4\%, respectively.

1. Introduction

In the red soil region of South China, the problem of farmland soil acidification has become increasingly prominent due to the dual factors of regional natural high temperature and heavy rainfall and human-made high-intensity development\cite{1}, especially in recent years due to the aggravation of the harm of acid deposition and the large-scale application of physiological acid fertilizer\cite{2}. At the same time, the reduction of soil pH promotes the activation of heavy metals in cultivated soil, increases the risk of crops absorbing and accumulating toxic and harmful heavy metals, and poses a great threat to the edible safety of agricultural products\cite{3}.

Tebeigai soil conditioner is made of oyster shell, which is a kind of waste from the production of seashells in the coastal areas of Fujian Province. It is processed by advanced production processes such as "protective baking and staged activation" and particle size separation. It has the characteristics of keeping organic nutrients of oyster shell to the greatest extent, even granulation (0.28mm) and large specific surface area\cite{4,5}. It is an excellent acid soil conditioner. At present, it has been reported that the application of Tebeigai soil conditioner products on the acid soil in the red soil area can significantly increase the yield of peanut, Panax notoginseng, leafy vegetables and other crops and alleviate the effect of soil acidification\cite{6-8}, but the application effect on other crops is rarely reported.

In order to speed up the popularization and application of Tebeigai soil conditioner product in the crops in the red soil area of South China, the field plot test method was used in this study, and Solanaceae plants were used as the test crops. The effects of different amounts of this soil conditioner product on eggplant’s yield, heavy metal content of vegetables and basic soil properties in the red soil area were studied. The purpose of this study is to provide a scientific basis for the application of
Tebeigai soil conditioner products for the treatment of acidified soil and the production of high-yield and high-quality vegetable products in red soil area.

2. Materials and Methods

The experiment was arranged in the vegetable production base of Cuisong Modern Agricultural Development Co., Ltd. in Jian’ou City, Fujian Province. The soil type was yellow mud field soil, the texture was clay loam, and the soil fertility was medium. There were 6 treatments, 3 repetitions, each field test plot was 20 m², and each test plot was arranged randomly. On the basis of conventional fertilization, different doses of Tebeigai soil conditioner were applied in each treatment. The treatments were: Treatment 1, Control (without using Tebeigai soil conditioner); Treatment 2, Low dose Tebeigai soil conditioner (750 kg/ha); Treatment 3, Medium-low dose Tebeigai soil conditioner (1125 kg/ha); Treatment 4, Medium dose Tebeigai soil conditioner (1500 kg/ha); Treatment 5, Medium-high dose Tebeigai soil conditioner (1875 kg/ha); Treatment 6, High dose Tebeigai soil conditioner (2250 kg/ha). Tebeigai soil conditioner products were produced and provided by Fujian Mata Agricultural Development Co., Ltd.

In addition to the different dosage of Tebeigai soil conditioner products, other tillage measures (such as planting system, fertilization, irrigation and drainage, etc.) were completely consistent in daily field management. The soil conditioner products of each treatment were uniformly applied in combination with land preparation on March 20, 2019. The tested crop was eggplant, and the variety was Minque NO.1. The seedlings was raised on January 10, 2019, transplanted on March 21, and mature eggplants were collected successively from May 16 to May 29. The mature eggplant fruits were harvested separately in each test plot, and the yield was recorded. The cumulative yield of eggplant fruits collected in the whole growth period was the yield of this test plot. On May 25, 1kg of eggplant fruit samples were randomly collected from each plot as agricultural product samples to be tested. In the corresponding experimental area, soil samples of cultivated layer were collected in multiple points according to the “S” shape, and 1kg of soil samples were taken by quartering method as soil samples to be tested.

The soil sample analysis and determination methods[9] were: NY / T 1121.2-2006 for pH; NY / T 1121.6-2006 for organic matter; NY / T 1121.6-2006 for hydrolytic nitrogen; NY / T 1121.7-2014 for available phosphorus; NY / T 889-2004 for available potassium; HJ 631-2011 for exchangeable acid; HJ 804-2016 for available cadmium; HJ 804-2016 for available chromium; HJ 804-2016 for available arsenic; HJ 804-2016 for effective lead; DB35 / T 1459-2014 for effective arsenic; DB35 / T 1459-2014 for effective mercury.

The method of plant sample analysis and determination[9] were: Mercury and arsenic are determined by microwave digestion atomic fluorescence spectrometry; lead, cadmium and chromium are determined by Microwave Digestion Graphite furnace atomic absorption spectrophotometry.

The data were processed by Microsoft excel-2003 office software and SPSS11.0 statistical software.

3. Results and Analysis

3.1. Effect of Different Amount of Tebeigai Soil Conditioner on Eggplant Yield

The test results (Figure 1) showed that the application of different amount of Tebeigai soil conditioner could increase the yield of eggplant to a certain extent. Compared with the treatment without using soil conditioner (treatment 1), the increase of Eggplant Yield was 15.5%~55.8%. Among them, treatment 4 (1500 kg/ha) had the best effect on Eggplant Yield. The results of variance analysis showed that treatment 4 was significantly better than treatment 6 and treatment 1 (P < 0.01), and significantly better than treatment 2 (P < 0.05), but the difference between treatment 3 and treatment 5 was not significant (P > 0.05); treatment 3 and treatment 5 were also significantly better than treatment 1 (P < 0.05), but better than treatment 2 (P < 0.05) There was no significant difference between treatment 6 and treatment 6 (P > 0.05).

The linear regression equation of Tebeigai soil conditioner amount (x) and Eggplant Yield (y) was fitted, and the quadratic equation y = -282.14x² + 2126.4x + 2470(R² = 0.9197**)was obtained, which could be fitted well (Fig. 1).
Figure 1. Effect of different amount of Tebeigai soil conditioner on Eggplant Yield

Note: the difference between the big and small letters after the data in the histogram is very significant \( (P < 0.01) \) and significant \( (P < 0.05) \).

3.2. Effect of Different Amount of Tebeigai Soil Conditioner on Heavy Metal Content of Eggplant

The results of the experiment (Table 1) showed that the As and Cr content of eggplant could be reduced to a certain extent by applying different amount of Tebeigai soil conditioner, the reduction range was 12.8% ~ 51.8% and 33.7% ~ 57.1% respectively; the reduction range of Pb content of eggplant was 1.9% ~ 19.2% (except for treatment 3); the reduction range of Cd content of eggplant was 14.3% ~ 30.4% (except for treatment 3 and treatment 6); and the Hg content of eggplant was 14.3% ~ 30.4% (except for treatment 3 and treatment 6). It showed a slight increase trend.

Table 1. Effects of different dosages of Tebeigai soil conditioner on heavy metal content in eggplant

| Treatment | Hg (mg/kg) | Increase rate (%) | As (mg/kg) | Increase rate (%) | Pb (mg/kg) | Increase rate (%) | Cd (mg/kg) | Increase rate (%) | Cr (mg/kg) | Increase rate (%) |
|-----------|------------|-------------------|------------|-------------------|------------|-------------------|------------|-------------------|------------|-------------------|
| Treatment 1 | 0.077Bb    | \( \_ \)         | 0.753a     | \( \_ \)         | 0.071a     | \( \_ \)         | 0.373ab    | \( \_ \)         | 5.883a     | \( \_ \)         |
| Treatment 2 | 0.076Bb    | -1.7              | 0.453ab    | -39.8            | 0.061ab    | -13.6            | 0.290ab    | -22.3            | 2.690a     | -54.3            |
| Treatment 3 | 0.078Bb    | 0.9               | 0.470ab    | -37.6            | 0.074a     | 4.2              | 0.463a     | 24.1             | 2.527a     | -57.1            |
| Treatment 4 | 0.091Aa    | 18.6              | 0.363b     | -51.8            | 0.070a     | -1.9             | 0.320ab    | -14.3            | 3.877a     | -34.1            |
| Treatment 5 | 0.081ABb   | 5.6               | 0.643ab    | -14.6            | 0.057a     | -19.2            | 0.260b     | -30.4            | 3.360a     | -42.9            |
| Treatment 6 | 0.081ABb   | 5.6               | 0.657ab    | -12.8            | 0.064a     | -10.3            | 0.387ab    | 3.6              | 3.900a     | -33.7            |

Note: After the same column data, different upper and lower case letters show significant difference \( (P < 0.01) \) and significant Level \( (P < 0.05) \), the same as below.

The results of variance analysis showed that: compared with treatment 1, treatment 4 was significantly \( (P < 0.05) \) better than treatment 1 in reducing As content of eggplant, but not significantly \( (P > 0.05) \) compared with other treatments (treatment 2, treatment 3, treatment 5 and treatment 6); and (2) in reducing Cd content of eggplant, except treatment 5 significantly \( (P < 0.05) \) was better than treatment 3, but there was no significant difference among the other treatments \( (P > 0.05) \); (3) there was no reduction effect on the Hg content of eggplant, except for the significant difference between treatment 4 and other treatments \( (P < 0.01) \) or \( (P < 0.05) \), there was no significant difference among the other treatments \( (P > 0.05) \); (4) there was no significant reduction effect on the Pb and Cr content of eggplant between all treatments \( (P > 0.05) \).

3.3. Effects of Different Dosage of Tebeigai Soil Conditioner on Soil pH and Exchangeable Acid Content After Eggplant Harvest

Results (Table 2) showed that the application of different amount of Tebeigai soil conditioner could improve the pH of soil after eggplant harvest to a certain extent, with an increase range of 5.8% ~
18.6%; and could reduce the exchangeable acid (potential acid) of soil after eggplant harvest to a certain extent, with a decrease range of 37.6% ~ 82.3%. Among them, treatment 5 had the best effect on increasing soil pH and reducing exchangeable acid content. The results of variance analysis showed that: (1) treatment 5 and treatment 6 were significantly (P < 0.05) better than treatment 1, but the difference between treatment 2, treatment 3 and treatment 4 was not significant (P > 0.05); (2) treatment 5 was significantly (P < 0.05) better than treatment 1, but the difference between them was not significant (P < 0.05). And there was no significant difference between them (P > 0.05).

Table 2. Effects of different dosage of Tebeigai soil conditioner on soil pH and exchangeable acid content after eggplant harvest

| Treatment | Value | pH Increase rate(%) | Exchangeable acid Increase rate(%) |
|-----------|-------|---------------------|-----------------------------------|
| Treatment 1 | 5.7b  | \       | 4.05a \               |
| Treatment 2 | 6.1ab | 5.8     | 2.08ab -48.7          |
| Treatment 3 | 6.2ab | 8.1     | 2.53ab -37.6          |
| Treatment 4 | 6.4ab | 12.2    | 1.10ab -72.9          |
| Treatment 5 | 6.8a  | 18.6    | 0.72b -82.3          |
| Treatment 6 | 6.7a  | 16.9    | 2.41ab -40.5          |

3.4. Effect of Different Amount of Tebeigai Soil Conditioner on Soil Available Heavy Metals Content After Eggplant Harvest

Table 3. Effect of different amount of Tebeigai soil conditioner on soil available heavy metals content after eggplant harvest

| Treatment | Available Hg (mg/kg) | Increase rate(%) | Available As (mg/kg) | Increase rate(%) | Available Pb (mg/kg) | Increase rate(%) | Available Cd (mg/kg) | Increase rate(%) | Available Cr (mg/kg) | Increase rate(%) |
|-----------|---------------------|------------------|---------------------|------------------|---------------------|------------------|---------------------|------------------|---------------------|------------------|
| Treatment 1 | 0.006a             | \                | 0.183b             | \                | 1.807a             | \                | 0.062a             | \                | 2.860a             | \                |
| Treatment 2 | 0.007a             | 15.8             | 0.205ab            | 12.0             | 1.510a             | -16.4            | 0.052ab            | -15.1            | 2.247a             | -21.4            |
| Treatment 3 | 0.009a             | 36.8             | 0.222ab            | 21.3             | 1.417a             | -21.6            | 0.052ab            | -16.0            | 2.917a             | 2.0              |
| Treatment 4 | 0.007a             | 10.5             | 0.236ab            | 28.9             | 1.497a             | -17.2            | 0.050ab            | -19.3            | 2.547a             | -11.0            |
| Treatment 5 | 0.008a             | 26.3             | 0.295a             | 61.1             | 1.587a             | -12.2            | 0.046b             | -24.8            | 2.363a             | -17.4            |
| Treatment 6 | 0.007a             | 15.8             | 0.289a             | 57.6             | 1.680a             | -7.0             | 0.043b             | -29.6            | 2.830a             | -1.0             |

Results (Table 3) showed that the content of Pb, Cd and Cr in eggplant soil decreased with the application of different Tebeigai soil conditioner, among which the available Pb content decreased by 7.0% ~ 21.6%, the available Cd content decreased by 15.1% ~ 29.6%, and the available Cr content decreased by 1.0% ~ 21.4%; The content of Hg and As showed an increasing trend, in which the available Hg content increased by 10.5% ~ 36.8%, and the available As content increased by 12.0% ~ 61.8%.

The results of variance analysis showed that: (1) treatment 5 and treatment 6 were significantly (P < 0.05) better than treatment 1, but the differences between treatment 2, treatment 3 and treatment 4 were not significant (P > 0.05); (2) treatment 5 and treatment 6 were significantly (P < 0.05) higher than treatment 1, but there was no significant difference between treatment 2, treatment 3 and treatment 4 (P > 0.05); (3) the effect on the content of available Hg, Pb and Cr in soil was not significant.

4. Conclusions

Results showed that the application of proper amount of Tebeigai soil conditioner could increase eggplant yield by 15.5% ~ 55.8%, decrease As content by 12.8%~51.8%, Cr content by 33.7%~57.1%, Pb content by 1.9% ~19.2%, Cd content by 14.3%~30.4%, increase soil pH value by 5.8%~18.6%,
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