Effects of Application of BB Fertilizer on the Yield, Quality and Economic Benefits of Citrus

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Abstract. The effects of four different fertilization treatments [i.e., Conventional fertilization, 45% imported compound fertilizer, Sacofo compound fertilizer (N-P2O5-K2O=20-10-10), BB fertilizer for citrus (N-P2O5-K2O=19-8-13)] on yield, quality and economic benefit of Newhall navel orange were studied through three-year field plot experiment. The results showed that compared with conventional fertilization treatment, the application of Citrus BB fertilizer could not only increase the yield of Newhall navel orange by 13.65%, increase the soluble solids (TSS) content by 51.50%, soluble sugar (WSS) content by 56.64%, vitamin C (Vc) content by 8.87%, reducing the titratable acid (TA) content by 22.83%, increase the solid-acid ratio of navel orange fruit by 96.31%, sugar-acid ratio by 102.97%, but also enhance the economic benefit by 15496 yuan/hm². Therefore, the special BB fertilizer for citrus is suitable for further popularization and application in citrus orchards on hilly red soil hills in Fujian Province and even in southern China, where the climate and soil conditions are similar to those in Fujian Province.

1. Introduction

China is one of the major citrus producing areas in the world. According to the data of China Statistical Yearbook 2018, in 2017, the citrus planting area of China was 2.587 million hm², the total yield reached 38.168 million tons, which was 1.03% higher than that of 2016, and the yield increased by 6.27%. In 2017, the citrus planting area of Fujian Province was 18.57 million hm², and the output was 3.15 million tons, which was one of the nine major citrus producing areas in China[1].

Fertilization is one of the most important agronomic measures for citrus trees to obtain high yield and quality. At present, there are many studies on the effects of nitrogen, phosphorus and potassium fertilizers on the yield and quality of citrus fruits (such as soluble solids, titratable acids, vitamin C, etc.) at home and abroad, while there are few studies on the effects of nitrogen, phosphorus and potassium fertilizers on the yield and quality of Newhall navel oranges (such as soluble sugar and main organic acids)[2]. Moreover, due to the obvious differences in climate, soil and management strategies in different regions, we can not copy the rigid[3].

BB Fertilizer, namely Bulk Blending Fertilizer, is several single granular Fertilizer and compound Fertilizer in according to certain proportion mixing and become a kind of compound Fertilizer material[4]. The main advantages of BB fertilizer are: comprehensive nutrients, high concentration, significant yield increase effect; Simple processing, low production cost, no pollution; The formula is flexible and can realize small batch production as low as several hundred kilograms[4]. At present, the production of BB fertilizer in the world accounts for about 40% ~ 50% of total fertilizer production, while the production of BB fertilizer in developed countries such as the United States, Japan and
Canada accounts for more than 70% of total fertilizer consumption\cite{5}. However, the development of BB fertilizer in China is still in its infancy, with a very low market share\cite{6}.

BB fertilizer for citrus (N-P$_2$O$_5$-K$_2$O=19-8-13) was developed by Institute of Soil and Fertilizer, Fujian Academy of Agricultural Sciences, based on the nutrient characteristics of red soil orchard soil in southern China, and combined with the demand rule of Citrus for nitrogen, phosphorus and potassium. After many years of experiments, the suitable nutrient formula of nitrogen, phosphorus and potassium was put forward and entrusted with Fujian Longdebao Geodetic Formula Technology Development Co., Ltd.

In order to verify the field application effect of BB fertilizer for citrus, a field trial was conducted with four treatments, such as Habits fertilization, 45% imported compound fertilizer, SaKeFu compound fertilizer (N-P$_2$O$_5$-K$_2$O = 20-10-10), and Citrus BB fertilizer (N-P$_2$O$_5$-K$_2$O= 19-8-13), to test the effect on yield, quality and economic efficiency for Newhall navel orange. And the results would provide scientific basis for the promotion and application of special BB fertilizer products in hilly citrus gardens in southern China's red soil and similar climate and soil conditions.

2. Materials and Methods

2.1. Basic Conditions for Trial Field

The test site is located at the umbilical orange planting base of Meixian Town, Youxi County, Fujian Province. It is located in the northeast of Youxi County, Sanming City, Fujian Province. The terrain is high in the West and low in the East. The mountains in the territory are undulating, and the small valleys and small basins fall between them. Between 90 and 760 m. It is a subtropical maritime monsoon climate with an average annual temperature of 19.6 °C, a frost-free period of 300 d, an average annual rainfall of 1600 to 1800 mm, and a sunshine of 1864.6 h. The basic properties of the tested soil: pH 4.81, organic matter 23.7 g/kg, total nitrogen 1.34 g/kg, alkalalysis 68.5 mg/kg, effective phosphorus 177.89 mg/kg, available potassium 268.82 mg/kg, exchange magnesium 0.191 cmol/kg, effective sulfur 34.61 mg/kg.

2.2. Trial Design

The test consists of 4 treatments, namely: treatment 1, Customary fertilization (urea 1 kg/plant, potassium chloride 0.18 kg/plant, 45 % imported compound fertilizer 0.45 kg/plant); Treatment 2, 45% imported compound fertilizer (3.53 kg/plant); Treatment 3, Common compound fertilizer (2.65 kg/strain); Treatment 4, Special BB fertilizer for citrus (2.79 kg/plant). Repeat 3 times per treatment. The citrus varieties tested were Newhall umbilical orange with a tree age of 9a and a planting density of 675 plants per hm$^2$. Four umbilical orange trees with relatively uniform growth were selected for each test cell, and random group arrangement was adopted for each test cell. The types of fertilizers tested were as follows: dedicated BB fertilizer for citrus (N-P$_2$O$_5$-K$_2$O= 19-8-13), produced by Fujian Longdebao Soil Survey Formula Technology Development Co., Ltd.; Ordinary compound fertilizer, using "SaKeFu mixed fertilizer(N-P$_2$O$_5$-K$_2$O=20-10-10)", produced by Pengwei Agricultural Resources Co., Ltd. of Longkou City; Urea (containing N 46%), potassium chloride (60% containing K$_2$O), and 45% imported compound fertilizer (N-P$_2$O$_5$-K$_2$O= 15-15-15).

The fertilization method is: fertilization 4 times a year. Among them, winter fertilizer (January) was applied uniformly to fermented chicken dung 5kg/plant, spring fertilizer (April) accounted for 40 % of the total fertilizer application, young fruit fertilizer (May) accounted for 30% of the total fertilizer application, and strong fruit fertilizer (July) accounted for 30% of the total fertilizer application. Before fertilization, the topsoil of the drip water line along the edge of the crown is about 20 cm wide and deep, and then the fertilizer is evenly spread in the ditch, mixed with the soil, and finally covered with soil. Harvest and measure production in early November of each year. The experiment began in January 2015 and ended in December, 2017. In addition to different treatments, other field cultivation management measures are completely consistent.
2.3. Methods of Test and Analysis
Every year before the mature umbilical orange is harvested in early November, there are 3 fruits with the same random picking orientation, size, maturity and other indicators from the middle and upper parts of each plant for the test tree crown. Each treatment takes 12 fruits for fruit quality measurement. Moreover, Soluble Solids (TSS) content was determined by hand-held sugar meters, Titrable Acid (TA) was determined by NaOH neutralization titration, Vitamin C (Vc) content was determined by 2,6-indiphol sodium, Soluble Sugar (WSS) was determined by ferrocyanic oxidation [6,7]. And data processing uses Excel 2003 software, variance analysis uses SPSS19.0 software, and LSD multiple comparison method.

3. Results and Analysis

3.1. Effects of Different Fertilization on Fruit Yield of Newhall Cord Orange
The experimental results (Figure 1.) showed that: compared with the customary fertilization treatment (treatment 1), the application of citrus special BB fertilizer (treatment 4) and the application of 45% imported compound fertilizer (treatment 2) could be significantly ($P < 0.05$) to increase the production level of Newhall navel oranges, the average increase rate for the three years was 13.65% and 11.09%, respectively, equivalent to 4208 kg/hm$^2$ and 3420 kg/hm$^2$. However, there was no significant difference between the yield of umbilical orange and that of conventional fertilizer treatment (treatment 1) with common compound fertilizer treatment (treatment 3) ($P > 0.05$).

![Figure 1. Effects of different fertilization treatments on fruit yield of Newhall navel orange](image)

3.2. Effects of Different Fertilization Treatments on Fruit Quality of Newhall Navel Orange
The results of the experiment (Table 1) showed that compared with the conventional fertilization treatment (Treatment 1), the fruit quality of Newhall navel orange could be improved to some extent by applying several different compound (mixed) fertilizers. Among them, the content of soluble solids (TSS), soluble sugar (WSS) and vitamin C (Vc) increased by 20.53%~51.50%, 31.06%~56.64% and 1.50%~8.87% respectively, and the content of titratable acid (TA) decreased by 7.61%~22.83%, and increased the solid-acid ratio of navel orange fruit 30.46%~96.31%, sugar-acid ratio 41.85%~102.97%. Among them, the application of BB fertilizer for citrus (treatment 4) had the best effect on improving the quality of navel orange fruit. The content of soluble solids (TSS) was significantly higher ($P < 0.01$) than that of conventional fertilization (treatment 1) and common compound fertilizer (treatment 3), and significantly ($P < 0.05$) than that of 45% imported compound fertilizer (treatment 2); the content of soluble sugar (WSS) was significantly higher ($P < 0.01$). The content of vitamin C (Vc) and titratable acid (TA) in conventional fertilization treatment (treatment 1) was significantly higher than that in conventional fertilization treatment (treatment 3), but the difference was not significant ($P > 0.05$) with 45% imported compound fertilizer (treatment 2). The content of vitamin C (Vc) and...
titratable acid (TA) in conventional fertilization treatment (treatment 1) was significantly higher than that in conventional fertilization treatment (treatment 1). The ratio of solid to acid and sugar to acid was extremely significant or significantly better than that in conventional fertilization treatment 1. So, in those designed treatments, the quality of fruit of treatment 4 is the best.

**Table 1. Effects of different fertilization treatments on fruit quality of Newhall navel orange**

| Treatment number | Treatment contents | TSS (%) | TA (%) | WSS (%) | Ve (mg/100ml) | solid-acid ratio | sugar-acid ratio |
|------------------|--------------------|---------|--------|---------|---------------|------------------|------------------|
| Treatment 1      | conventional fertilization | 9.01Bc  | 0.92a  | 8.21 Bc | 63.36b        | 9.79Dd           | 8.92Cd           |
| Treatment 2      | 45% imported compound fertilizer | 12.63ABb | 0.78b  | 12.28 Aa | 68.65a        | 16.19Bb          | 15.74Ab          |
| Treatment 3      | conventional fertilization | 10.86Bc | 0.85ab | 10.76 ABB | 64.31b       | 12.78Cc          | 12.66Bc          |
| Treatment 4      | Citrus BB Fertilizer | 13.65Aa | 0.71b  | 12.86 Aa | 68.98a        | 19.23Aa          | 18.11Aa          |

Note 1: Each data in the table is the average of three repetitions, the same below.
Note 2: For the different letters after the same column values in the table, the difference is very significant in capital letters (P < 0.01), and significant in lowercase letters (P < 0.05), the same below.

3.3. Effect of Different Fertilization Treatment on Economic Benefit of Newhall Navel Orange

From the analysis results of economic benefits of Newhall navel orange under different fertilization treatments (Table 2), it can be seen that the order of economic benefits of different fertilization treatments is: BB fertilizer for citrus (Treatment 4) > 45% imported compound fertilizer (Treatment 2) > conventional fertilization (Treatment 1) > common compound fertilizer (Treatment 3). Among them, compared with the conventional fertilization (treatment 1), the application of BB fertilizer for citrus (treatment 4) could increase the economic benefit by 15496 yuan/hm² with an increase rate of 13.09%, and the application of 45% imported compound fertilizer (treatment 2) could increase the economic benefit by 9146 yuan/hm² with an increase rate of 7.72%. However, the economic benefit of applying common compound fertilizer (treatment 3) was slightly lower than that of conventional fertilization (treatment 1).

**Table 2. Effects of Different Fertilization Treatments on Economic Benefits of Newhall Navel Orange**

| Treatment number | Yield (kg/hm²) | output value (Yuan/hm²) | Fertilizer cost (Yuan/hm²) | Economic Benefits (Yuan/hm²) | Ratio increase (%) |
|------------------|---------------|------------------------|---------------------------|-----------------------------|-------------------|
| Treatment 1      | 30825         | 123300                 | 4882                      | 118418                      | \                |
| Treatment 2      | 34245         | 136980                 | 9416                      | 127564                      | 7.72              |
| Treatment 3      | 31185         | 124740                 | 7806                      | 116934                      | -1.25             |
| Treatment 4      | 35033         | 140130                 | 6216                      | 133914                      | 13.09             |

Note: fermented chicken manure 670 yuan / t; urea 2100 yuan / t; 45% imported compound fertilizer 3000 yuan / t; 45% imported compound fertilizer 2600 yuan / t; citrus BB fertilizer 2100 yuan / t; Sacofu compound fertilizer (20-10-10) 3100 yuan / t; potassium chloride 2400 yuan / t; navel orange 4 yuan / kg.

4. Discussion and Conclusion

Crop specialized fertilizer product is the embodiment of comprehensive balanced fertilization technology, and an important link to realize the one-stop agrochemical science and technology service of "determining soil nutrients, determining fertilizer formula, producing fertilizer products and guiding scientific fertilizer use". Shu Changcheng[8] studied the fertilizer effects of different formulations of special citrus fertilizer in Qujiang District of Zhejiang Province. The results showed that formula 1 (N-P₂O₅-K₂O=10-4-6, Organic matter content 25%) and formula 2 (N-P₂O₅-K₂O=8-3-4, Organic matter content 20%) of special citrus fertilizer could be obtained by applying 3000 kg/hm² and 3975 kg/hm²
respectively in the whole year. The fruit quality is better with higher yield. Liang Suiquan et al.\cite{9} and Hu Yun et al.\cite{10} studied the application of Xingnong brand special citrus fertilizer (N-P2O5-K2O=11-7-7) mixed equal amount cake fertilizer as summer citrus fertilizer in citrus orchard of Yixing County, Hubei Province, and achieved better yield increase and better fruit quality. Therefore, there are great differences in climate, soil, management strategy and fruit varieties in different regions. There are also great differences in the distribution of nitrogen, phosphorus and potassium nutrients recommended for citrus special fertilizer products.

This experiment was carried out on hilly red soil orchards in Fujian Province to test the application effect of BB fertilizer for citrus (N-P2O5-K2O=19-8-13). The results showed that compared with the conventional fertilization treatment (treatment 1), the application of BB fertilizer for citrus (treatment 4) not only increased the yield of Newhall navel orange by 13.65%, increased the content of soluble solids (TSS) by 51.50%, soluble sugar (WSS) by 56.64%, vitamin C (Vc) by 8.87%, decreased the content of titratable acid (TA) by 22.83%, and increased the ratio of solid to acid and sugar to acid by 96.31% and 102.97%, respectively. And the economic benefit was increased by 15496 yuan/hm². Therefore, the special BB fertilizer for citrus is suitable for further popularization and application in citrus orchards on hilly red soil hills in Fujian Province and even in southern China, where the climate and soil conditions are similar to those in Fujian Province.

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