Effects of organic manure application on blueberry fruit quality and soil condition

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Abstract. The present study investigated organic manure of southern highbush blueberry cultivated in southwestern China. We studied the efficiency of three organic fertilizers produced from locally accessible resources, namely rapeseed residue (RS-R), cattle manure (Cat-M), and chicken manure (Chi-M). Fruit quality, and soil chemical properties were analyzed. Rapeseed residue at the highest concentrations (2 or 3 kg RS-R plant⁻¹) improved fruit sweetness (total soluble sugar and water-soluble sugar contents) and anthocyanin content, and depressed soil pH.

1. Introduction
The economic development in southwestern China has flourished in recent years and has been accompanied by proliferation of agricultural production on the periphery of the main cities. However, our personal observations in recent years indicate that many blueberry orchards’ main reason for the poor management is suboptimal fertilization. The quality of blueberries is partly dependent on fertilizer conditions. Application of organic fertilizers increases soil macro-porosity and stimulates soil biological activity, which are important for fibrous root development and assimilation of soil minerals[1]. The Oil cake is the residual seed meal obtained as residue from extraction of edible oil from oil-seed crops, such as rapeseed, peanut, sesame, coconut, soy, and neem. The Oil cake is a type of organic manure and also acts as a pest repellent. Animal manures can improve soil structure and enhance soil retention of nutrients and water, thereby enhancing soil fertility. Animal manures excite soil microbial activity and promote availability of trace minerals in the soil[2]. These positive effects of the Oil cake and animal manures on blueberry fruit quality have been confirmed empirically[3-5]

Rapeseed residue is the most common oil-cake fertilizer applied in southwestern China. To improve blueberry qualities in orchards of southwestern China, we investigated the efficiency of organic fertilizers derived from locally accessible resources, namely rapeseed residue, cattle manure, and chicken manure. Under the situation of developing blueberry industry in southwestern China, this paper explores the influence of organic fertilizer types on blueberry fruit, and provides scientific basis for improving quality of organic blueberry in.
2. Materials and methods

2.1 Study site and plant materials
The experiment was conducted in the Sichuan Agricultural University’s cooperative research blueberry orchard on Nanbao Mountain (30°43’ N, 103°22’ E) at Qiongloi, Chengdu city, Sichuan Province, China. The altitude of the site is 1350 m. The average temperature is 14.3 °C, and the annual accumulated temperature above 10 °C is 4500–5500 °C. The average annual precipitation is 1100 mm, and annual sunshine duration is 1107.9 h, and the frost-free period is 280 d. The soil at the site is a yellow soil of high fertility[6].

The southern highbush blueberry cultivar ‘O’Neal’ was used in the study. In 2018, the plants fruited for the third year. Plants were spaced 2 m × 1 m apart.

2.2 Experimental design and treatments
Three organic fertilizer treatments (OF), namely rapeseed residue (RS-R), cattle manure (Cat-M), and chicken manure (Chi-M), were applied. In addition, three amounts (1, 2, and 3 kg) of each organic fertilizer were administered; thus, a total of ten treatments, including a control check [CK(OF), no organic fertilizer], were applied. The experimental treatments were replicated on six plants, with a guard plant situated between each treatment. The organic fertilizers were applied on 30 November 2017. To the treated plants a single inorganic fertilizer application (100 g) of a sulfur-based compound fertilizer was applied 20 d after flowering.

2.3 Fruit quality
Single fruit weight as well as the contents of total soluble solids (TSS), water-soluble sugars (WSS), titratable acid (TA), vitamin C (Vc), and total anthocyanins were determined. Mature fruit were harvested on 20 July 2018. Fruit in the central portion of the crown were collected. Single fruit weight was determined by weighting 30 berries and calculating the single fruit. The TSS content was measured using a portable refractometer (TD-45, TPYN Inc., Zhejiang, China). The WSS content was determined by using the anthrone–sulfuric acid colorimetric method. The TA content was quantified by using the NaOH titration method. The Vc content was determined by using xylene-2,6-dichlorophenolindophenol colorimetry. The anthocyanin content was determined by using the pH differential method[7].

2.4 Soil chemical properties
Soil samples were collected before organic fertilizer application (on 30 November 2017) and after fruit harvest (20 July 2018). The soil samples were collected at 0–30 cm depth along the dripline in three directions of each plant and mixed to form one replicate. Soil pH was measured using pH meter (901P Bante Instruments Co., Ltd, Shanghai, China). The contents of soil organic matter (OM), available N, available P, and available K were determined in accordance with the methods of Bao[8]. Briefly, OM content was determined using the potassium chromate method (hydration heating), and available N content was determined with the alkaline hydrolysis diffusion method. Available P content was determined with the double acids (HCl and H2SO4) method, and available K content extracted with NH4OAc solution was measured using a flame photometer.

2.5 Statistical analysis
One-way analysis of variance (ANOVA) and the Student–Newman–Keuls q test were performed at the 5% significance level with IBM SPSS Statistics 19.0 software (IBM Corporation, Armonk, NY, USA). Contrast analyses were used to separate the interactions.
3. Results

3.1 Fruit quality in organic fertilizer treatments
All organic manure treatments increased the single fruit weight compared with that of the control CK(OF); the Chi-M treatments and RS-R 3kg showed significantly increased effects (Fig. 1a). The TSS content was also increased in all organic manure treatments (Fig. 1b). The TSS contents in the RS-R 2kg, RS-R 3kg, and Chi-M 1kg treatments were higher than those in the other OF treatments. The WSS content was significantly increased in all OF treatments compared with that of the CK(OF) (Fig. 1c). The highest WSS content was recorded in the RS-R 3kg treatment (7.33 ± 0.11%), followed by the Cat-M 1kg and Chi-M 1kg treatments (Fig. 1c). Fruit TA contents were higher in the RS-R 2kg, Cat-M 1kg, and Chi-M 1kg treatments than that in all other treatments (Fig. 1d). The TA contents in CK(OF), RS-R 1kg, Cat-M 2kg, and Cat-M 3kg were relatively low and no significant differences were observed among these treatments. The fruit Vc contents in all OF treatments were superior to that of the control CK(OF) fruit (Fig. 1e). The total anthocyanin contents increased consistent with elevation in fertilizer amount; for example, the anthocyanin content in the RS-R 3kg treatment was greater than that of RS-R 2kg, which in turn was greater than that of RS-R 1kg (Fig. 1f).

Figure 1. Fruit quality in organic fertilizer test.
TSS: total soluble solids. WSS: water-soluble sugars. TA: titratable acid. Vc: vitamin C. CK(OF): control treatment in organic fertilizer test. RS-R: rapeseed residue. Cat-M: cattle manure. Chi-M: chicken manure.
3.2 Soil chemical properties in organic fertilizer treatments
Soil pH values declined in response to rapeseed residue and cattle manure application (Table 1). All treatments contributed to an improved OM content (Table 1). The soil available N content was the highest in the treatment Chi-M 2kg (43.38 ± 1.58 mg kg⁻¹) followed by Chi-M 3kg (41.67 ± 2.29 mg kg⁻¹) (Table 1). The soil available P content of the Chi-M 3kg treatment (34.46 ± 0.76 mg kg⁻¹) was significantly higher than that of all other treatments (Table 1). Average soil available K content in the chicken manure treatments was higher than that of rapeseed residue or cattle manure. The available K content increased in conjunction with the amount of fertilizer application (Table 1).

4. Conclusion
The present study focused on the effects of organic fertilizers on blueberry fruit quality. The results provide a foundation for optimal fertilization of southern highbush blueberry in southwestern China. We confirmed the important influence of organic fertilizer application on blueberry plants. In the current study, we compared the effects of three organic fertilizers (rapeseed residue, cattle manure, and chicken manure) on blueberry fruit quality. The highest dose of rapeseed residue resulted in higher contents of TSS, WSS, and anthocyanins. Rapeseed residue fertilizers were beneficial in maintaining the soil pH at a low value, which favors blueberry growth. In addition, the OM content was significantly higher in all organic fertilizer treatments compared with that of the non-fertilized control.

Table 1. Soil chemical properties in organic fertilizer test.
| Treatment | pH     | Organic matter content (g kg⁻¹) | Available nitrogen content (mg kg⁻¹) | Available phosphorus content (mg kg⁻¹) | Available potassium content (mg kg⁻¹) |
|-----------|--------|--------------------------------|-------------------------------------|---------------------------------------|--------------------------------------|
| CK(OF)    | 4.511±0.070a | 10.09±2.20a 12.86±1.98f | 20.62±1.60cd | 269.42±24.44cd |
| RS-R 1kg  | 4.279±0.571a | 13.75±1.02a 16.33±2.23ef | 21.11±3.78cd | 153.73±10.01ef |
| RS-R 2kg  | 4.277±0.249a | 13.68±0.35a 30.59±0.60b | 25.66±1.72bc | 213.23±11.86de |
| RS-R 3kg  | 4.306±0.942a | 13.73±0.91a 22.26±2.67cd | 24.54±1.71bcd | 130.60±15.83ef |
| Cat-M 1kg | 4.314±0.479a | 13.44±2.65a 22.59±1.03cd | 22.72±2.46bcd | 244.63±15.37cd |
| Cat-M 2kg | 4.554±0.539a | 14.10±1.66a 23.38±3.51cd | 19.79±1.74d | 314.04±83.85ce |
| Cat-M 3kg | 4.223±1.023a | 14.17±0.34a 19.93±1.68de | 26.28±0.85bc | 110.77±16.10f |
| Chi-M 1kg | 4.615±0.570a | 13.59±0.75a 26.27±2.58c | 18.95±1.82d | 312.39±51.43c |
| Chi-M 2kg | 4.536±1.297a | 13.93±0.58a 43.38±1.58a | 27.19±3.69b | 500.78±48.12b |
| Chi-M 3kg | 4.763±0.682a | 14.08±1.65a 41.67±2.29a | 34.46±0.76a | 646.21±55.53a |

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