

Effects of Composite Inorganic, Organic Fertilizer and Foliar Spray of Multi-nutrients on Growth, Yield and Quality of Cherry Tomato

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ABSTRACT

Evaluating fertilizer quality is important in selecting the appropriate fertilizers for agricultural production. In this experiment, the effectiveness of Composite Inorganic Fertilizer (CIF), Composite Organic Fertilizer (COF) and Foliar Spray of Multi-Nutrients (FSMN) on the growth, yield, and fruit quality of cherry tomato (*Lycopersicon esculentum* Mill.) were compared. The results showed that the applications of fertilizers enhanced the leaf area, photosynthesis rate, fruit setting rate, and average fruit weight, and yield. The fruit setting rate and average yield in COF treatment increased by, respectively, 25.16% and 81.91% when compared to the control (without fertilization). Also, the contents of reducing saccharide, vitamin C, and lycopene in tomato fruit improved, especially in the COF treatment, in which the contents of saccharide, vitamin C, and lycopene were higher than the control by 40.84%, 28.74% and 13.97%. Treatment CIF had similar effects on growth and yield when compared to COF, but the influence of CIF on the fruit quality was lower than that of COF. Meanwhile, treatment CIF also had the highest contents of nitrate and nitrite in the fruit (2.32 and 1.42 mg kg⁻¹, respectively). In this study, FSMN was ineffective when used separately.

Keywords: Nutrition, Lycopene, Photosynthesis, Saccharide, Vitamin C.

INTRODUCTION

Fertilizer is an organic or inorganic material, containing one or more essential nutrients, which is used to provide nutrients for the growth of crops and increasing productivity and quality of agricultural products (Zhang *et al.*, 2010). Researchers have shown the importance of fertilizers in agricultural production. Firstly, they make crop plants grow and develop better and attain high productivity. Fertilizers increase plant height, quantity, and length of lateral stem, leaf area, and leaf chlorophyll (SPAD), tree root system etc. on many kinds of crop plant (Aminifard *et al.*, 2012; Zafar

et al., 2011; Najm *et al.*, 2010; Wang *et al.*, 2007; Chapagain and Wiesman, 2004). Secondly, using fertilizers increases crop productivity (Çolpan *et al.*, 2013; Aminifard *et al.*, 2012; Yang *et al.*, 2012; Riahi *et al.*, 2009; Heeb *et al.*, 2006). According to statistics of Food and Agriculture Organization of the United Nations (FAO), fertilizer helps to increase 40-60% of crop yields (Zhang *et al.*, 2010; FAO, 1981). Thirdly, fertilizers improves the quality of agricultural products such as saccharide, vitamin, organic acid, mineral contents, micro-quantity substance, dry matter content, etc. (Junior *et al.*, 2013; Cesare *et al.*, 2010; Dursun *et al.*, 2009; Zaller, 2006; Kobryn and Hallmann, 2005; Pirkko *et al.*,

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2003). In addition, fertilizers also have effects on soil, water, air and insect. According to the latest data in 2012, the total amount of fertilizers used in 2012 was 240,711,000 tons with the biggest amount being 37.1% in East Asia area (mostly in China), followed by USA with 23.7% (FAO, 2012).

In the actual production and use of fertilizer, large amount of new fertilizers is launched in the market to replace former fertilizers that are not meeting plants requirements for high production. In China, there are many government policies regarding expense, technology, and market to support the development of new fertilizers. Fertilizer improvement is always a key issue in the agricultural production in this country (Wang and Yang, 2012; Xia and Hu, 2011). In this study, we aimed to compare the effects of three types of fertilizer: composite inorganic fertilizers in granular (produced by Stanley Fertilizer Co., Ltd.), foliar spray of multi-nutrients solution (produced by Shanghai Huazhiduyuan Arts and Technology Co., Ltd.), and composite organic fertilizer as liquid (provided by Institute of Chemical Technology, East China University of Science and Technology). The plant for the comparative study was decided to be cherry tomato, a type of fruit which is famous for its delicious flavor and rich nutrition. Cherry tomato is produced mostly in China. According to statistics of Faostat, China's tomatoes output account for 30.98% of the world output (Faostat, 2012). This study aimed to contribute to development of evaluation and selection of fertilizers and provide more data for analysis of the relation between fertilizers and cherry tomato.

MATERIALS AND METHODS

Materials

Composite Organic Fertilizer (COF) is a new liquid fertilizer of East China University of Science and Technology,

Institute of Chemical Technology. It is from agricultural waste (cotton stalks). A liquid was isolated from the cotton stalks by pulping the cotton stalks with potassium hydroxide and ammonia liquor. The liquid can be directly used as organic fertilizer after balancing of nutrient elements (N-P₂O₅-K₂O). The physico-chemical properties of COF are shown in Table 1.

Composite Inorganic Fertilizer (CIF) is a granular fertilizer containing humic and some trace elements. Its main ingredients are N-P₂O₅-K₂O= 15-15-15 (%), and is produced by Stanley Fertilizer Co., Ltd. The main ingredients of Foliar Spray of Multi-Nutrients solution (FSMN) are N-P₂O₅-K₂O= 2.5-2.5-2.75 (%), B, and Fe nutrients, produced by Shanghai Huazhiduyuan Arts and Technology Co., Ltd. CIF and FSMN are commonly sold in the China market.

The plant used in the experiment was cherry tomato (Red Virgin tomato, produced by Beijing Jindi Yongfeng Agricultural Science and Technology Co., Ltd.).

Table 1. Physico-chemical properties of Composite Organic Fertilizer (COF).

Parameter ^a	Value
pH value	7.15
Density (g mL ⁻¹)	1.20
Solid content (%)	0.19
Organic matter (%)	8.43
Total nitrogen (N) (%)	5.00
Total phosphorus (P) (%)	5.00
Total potassium (K) (%)	5.41

^a The percentage organic matter, total nitrogen (N), total phosphorus (P), total potassium (K) were calculated from their relative contents in 100 g dry samples.

Tomato Planting and Management

Seeds of cherry tomato were sown in trays (cell size 5×5×7 cm) filled with mixture of peat-lite (provided by Yangguang Horticulture Co., Ltd) and kept under plant growth incubator (produced by Henan

Yunfei Sci and Tech Development Co., Ltd) during 4 weeks. Daytime temperature of incubator was 22–30°C, nighttime temperature was 16–24°C, and air humidity was 50%. Cherry tomato seedlings were transplanted in plastic pots with the size of 18×20 cm (approximately 3.5 kg soil pot⁻¹) on June 20, 2012, and kept in the greenhouse (Daytime temperature was 22–30°C, nighttime temperature was 16–24°C). After trans-planting, all seedlings were watered immediately to 70–80% of field capacity.

The physico-chemical properties of the soil used in experiment are illustrated in Table 2. Soil moisture was kept at 70–80% of field capacity. The fertilizer treatments were started seven days after transplanting (June 27). Tomatoes were harvested on September 28, 2012.

Experimental Design

The experiment includes four treatments, eight replications, and completely randomized plots experimental design. Treatment 1: Without fertilization (control), irrigate by water only. Treatment 2: Application of COF at concentration of 0.5%, 100 mL plant⁻¹ time⁻¹, once-weekly. Treatment 3: Spray on leaf, irrigate root by FSMN, use concentration of 1%, 100 mL plant⁻¹ time⁻¹, once-weekly (according to recommendation of producer). Treatment 4: Application of CIF with content of 3.0 g pot⁻¹

Table 2. The physico-chemical properties of soil in the experiment.

Parameter	Value
pH	8.02
Water-soluble salts (EC) mS cm ⁻¹	1.23
Volume-weight (g cm ⁻³)	1.16
Aeration porosity (%)	41.88
Organic matter (%)	1.10
Total nitrogen (N) (mg kg ⁻¹)	2430
Total phosphorus (P) (mg kg ⁻¹)	1190
Total potassium (K) (mg kg ⁻¹)	1670

¹ for four times of fertilization (after 15 and 40 days, for creating and cropping fruit). Total quantity of N, P, and K used in each treatment was similar.

Determination of Physiological Targets and Yield Components

Leaf area was determined by disc method (Lu and Li., 2011). Respiration rate was determined according to He *et al.* (1997). Photosynthetic rate was determined by P-Photosynthesis System Yaxin-1102 (Beijing Yaxinliyi Sci and Tech Co., Ltd.), and it was measured at 10:00 - 11:30 am., 28°C, humidity 42.5%. Leaf area, respiration rate, and photosynthetic rate were defined at the time of strongest development of cherry tomato's stem and leaves. Yield components of cherry tomato were determined for the eight plants of each treatment.

Determination of Nutritional Ingredients of Cherry Tomato

The methods of saccharide content (MA-PRC, 2007), organic acid content (MA-PRC, 2003) and contents of nitrate and nitrite (MA-PRC, 2010) were realized according to the national regulations. Vitamin C content was analyzed according to Hao *et al.* (2011). Lycopene content was determined by Yang *et al.* (2010) method. The chromatographic system Shimadzu LC-2010A/C UV-VIS detector and Linearity (2.5 AU), GL-Sciences column (Inertsil[®] ODS-SP 5 μm 4.6×250 mm) was used in the analysis of organic acid and vitamin C contents. The spectrophotometer system Shanghai Metash UV-5200 (AF 0809019), wavelength Range 190-1100 nm was used in the analysis of nitrate, nitrite and lycopene contents.

Statistical Analysis

The experimental analysis of variance (ANOVA) was performed with the analysis



Toolpak VBA Excel 2010 for Windows, and mean comparisons were done using the Least Significant Difference (LSD) test at $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

Influence of Fertilizers on Physiological Characteristics of Cherry Tomato

As shown in Table 3, all treatments increased leaf area of tomato by 19.6–24.5% when compared to the Control (CK). Leaf area of COF and CIF were similar and higher than FSMN treatment by, respectively, 3.28–4.10%. Leaf respiration rate was not significantly different among the treatments ($P < 0.05$). Leaf respiration rate of CK was higher than treatments of fertilizers, indicating that tomato plants in treatment without fertilizer need more respiratory activity to balanced growth. Leaf photosynthetic rate varied significantly in the four treatments. Three formulas treated by fertilizers gave higher rate of photosynthetic by 14.2– 21.7% than the CK ($P < 0.01$), the highest in treatment of COF ($8.68 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), followed by CIF ($8.43 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) and lowest in treatment FSMN ($8.14 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$). Results indicated that the three types of fertilizer were effective in regulating the physiological processes of tomato plants, in which COF gave the best effectiveness. Those results are the same as the studies conducted by Yang *et al.* (2012) who

studied the effects of different calcium fertilizer levels on physiology, fruit yield, and quality of tomato and Xie *et al.* (2013) who studied the effects of different organic fertilizer on pear tree growth. The other studies also had similar results (Li *et al.*, 2007; Amujoyegbe *et al.*, 2007).

Influence of Fertilizers on Yield Components of Cherry Tomato

Yield components of cherry tomato in the COF and CIF treatments were much higher than FSMN and CK ($P < 0.01$). As shown in Table 4, three treatments of fertilizers shortened the day of the first flower by 5-12 days when compared to the CK. The day of the first flower in COF treatment was 60 days, which was 4 days earlier than CIF and 7 days than FSMN. Fruit setting rate in COF and CIF treatments were similar and higher than FSMN by 18%. Meanwhile, there was no significant difference in fruit mean weight between fertilizers treatments, with the COF and CIF treatments having similar average yield and higher than that of FSMN by 26%. Experiments of yield components indicated that, under the same cultivation conditions (including seeds and care skills), the difference in yield components and average yield among the treatments were strongly influenced by fertilizer. The results are characteristic influences of three types of fertilizers on a cherry tomato varieties, similar to other studies (Kobry and Hallmann, 2005; Heeb *et al.*, 2006; Dursun

Table 3. Physiological characteristics of cherry tomato and comparative result of fertilizers.^a

Treatments	Area of leaf ($\text{m}^2 \text{ plant}^{-1}$)	Respiration rate ($\text{mg CO}_2 \text{ g}^{-1} \text{ h}^{-1}$)	Photosynthetic rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)
Control	1.02 ± 0.14	1.53 ± 0.03	7.13 ± 0.12
COF	1.27 ± 0.13	1.49 ± 0.03	8.68 ± 0.13
FSMN	1.22 ± 0.08	1.50 ± 0.04	8.14 ± 0.14
CIF	1.26 ± 0.15	1.50 ± 0.02	8.43 ± 0.14
LSD 5%	0.10	0.02	0.08
LSD 1%	NS	NS	0.21

^a Values are means ± standard deviation of measures (n= 8), NS= Not Significant. Leaf area, respiration rate and photosynthetic rate were defined at the time of strongest development of cherry tomato's stem and leaf.

Table 4. Yield components of cherry tomato and comparative result of fertilizers.^a

Treatments	No. of days to first flower (day)	Fruit setting rate (%)	Fruit mean weight (g fruit ⁻¹)	Average yield (g plant ⁻¹)	Average yield (kg treatment ⁻¹)
Control	72.0 ± 0.87	49.80 ± 0.57	5.80 ± 0.14	296.50 ± 10.35	8.90
COF	60.5 ± 0.77	62.33 ± 0.48	5.86 ± 0.17	539.59 ± 11.06	16.19
FSMN	67.7 ± 0.97	52.78 ± 0.68	5.84 ± 0.13	425.74 ± 11.78	12.77
CIF	64.4 ± 0.89	62.27 ± 0.55	5.86 ± 0.24	536.95 ± 10.86	16.11
LSD 1%	1.45	1.84	0.26	16.78	

^a Values are means ± standard deviation of measures (n= 8).

et al., 2009; Paksoy and Acar, 2009) who studied the effects of fertilizers in agriculture.

Influence of Fertilizers on Nutritional Ingredients of Cherry Tomato

Table 5 shows that treatments of fertilizers increased reducing saccharide, organic acid, and vitamin C contents, respectively, compared with the CK. Reducing saccharide, organic acid and vitamin C contents decreased in the following order: COF > CIF > FSMN > CK (Table 5). Other nutritional ingredients of tomato fruit in three treatments of fertilizers were similar and higher than that of CK. As well known, there is ample evidence that fertilizer stimulates growth and fruit quality of various crop species, including tomatoes (Çolpan *et al.*, 2013; Chapagain and Wiesman, 2004; Heeb *et al.*, 2006; Kobryn and Hallmann, 2005). In nutritional analysis, advanced analytical methods were used to provide accurate

data of fertilizer effectiveness on nutritional ingredients of tomato fruit. These results also confirmed that effect of COF on the tomato fruit's nutritional ingredients was better than the other two fertilizers.

In addition, we also analyzed contents of nitrate and nitrite in the tomato fruit (Table 6). These results showed that content of nitrate in tomato fruit was about 1.43–2.32 mg kg⁻¹. More specifically, with the rate of fertilizer in the experiment, nitrate content was highest in treatment CIF (2.32 mg kg⁻¹), followed by FSMN (1.87 mg kg⁻¹), with the lowest quantity in treatment COF (1.73 mg kg⁻¹). Content of nitrite was about 0.43–1.42 (mg kg⁻¹), highest in treatment CIF (1.42 mg kg⁻¹), and lowest in COF (1.09 mg kg⁻¹). Nitrate and nitrite contents in the cherry tomato fruit in this study were similar to those reported by Zhou *et al.* (2007) and lower than nitrate and nitrite limitation in vegetable by FAO/WHO (Schuddeboom, 1993).

Table 5. The quality of cherry tomato fruit and comparative result of fertilizers.

Treatments	Reducing saccharide (%) ^a	Organic acid (mg 100 g ⁻¹) ^b	Vitamin C (mg 100 g ⁻¹) ^b	Lycopene (mg 100 g ⁻¹) ^b	Dry matter (%) ^a
Control	2.61	4.41	19.90	8.67	6.60
COF	3.67	4.72	25.62	9.88	6.70
FSMN	2.89	4.51	22.42	8.83	6.68
CIF	3.64	4.65	24.04	9.83	6.69
LSD 1%	0.64	0.08	0.12	0.16	0.04

^a Values: The percentage of reducing saccharide and dry matter were calculated from their relative contents in 100 g fresh samples, ^b Values: The contents (mg) of organic acid, Vitamin C, Lycopene were calculated from their relative contents in 100 g fresh samples.



Table 6. Contents of nitrate and nitrite in the tomato fruit and comparative result of fertilizers.

Treatments	Nitrate NO ₃ ⁻ (mg kg ⁻¹) ^a	Nitrite NO ₂ ⁻ (mg kg ⁻¹) ^a
Control	14.3	0.43
COF	17.3	1.09
FSMN	18.7	1.31
CIF	23.2	1.42
LSD 1%	0.14	0.11

^a Contents of nitrate (NO₃⁻) and nitrite (NO₂⁻) were calculated from their relative contents in 1,000 g fresh samples.

CONCLUSIONS

Compared to two types of common fertilizers in the China market (CIF and FSMN), Composite Organic Fertilizer (COF) enhanced photosynthetic activity, increased yield, and improved the fruit quality of cherry tomato. Although CIF and COF had similar effects on the yield, CIF gave the highest contents of nitrate and nitrite in the fruit. FSMN was ineffective when used separately. The results showed that Composite Organic Fertilizer (COF) can replace chemical fertilizers, considering the fact that the soil is being polluted by long-term use of synthetic fertilizers (inorganic fertilizer).

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اثرات کود مرکب معدنی، کود آلی و برگپاشی چند عنصر غذایی روی رشد و کیفیت گوجه فرنگی گیلاسی

ت. ن. نگوین، ل. ه. تنگ، ی. ک. پنگ، ج. ی. نی، وی. ن. چنگ

چکیده

در تولید محصولات کشاورزی، ارزیابی کیفیت کود برای انتخاب کود مناسب مهم است. در این پژوهش، موثر بودن کود معدنی مرکب (CIF)، کود آلی مرکب (COF)، و برگپاشی چند عنصر غذایی (FSMN) روی رشد، عملکرد، و کیفیت میوه گوجه فرنگی گیلاسی *Lycopersicon esculentum* Mill.) با هم مقایسه شد. نتایج نشان داد که مصرف کودها منجر به افزایش سطح برگ، نرخ فتوسنتز، تشکیل میوه (میوه بندی)، و میانگین وزن هر میوه و مقدار عملکرد شد. نرخ میوه بندی و میانگین عملکرد در تیمار COF در مقایسه با تیمار شاهد به ترتیب به مقدار ۲۵/۱۶٪ و ۸۱/۹۱٪ زیادتر شد. نیز، مقدار ساکارید کاهنده (reducing saccharide)، ویتامین ث و لیکوپن در میوه گوجه فرنگی افزایش یافت به ویژه در تیمار COF که در آن در مقایسه با شاهد مقدار ساکارید کاهنده، ویتامین ث و لیکوپن بین ۱۳/۹۷٪ تا ۴۰/۸۴٪ افزایش یافت. تیمار CIF هم اثرات مشابهی روی رشد و عملکرد در مقایسه با COF داشت ولی تاثیر آن روی کیفیت میوه از تاثیر COF بود. در عین حال، تیمار CIF مقدار نترات و نیتريت بیشتری در میوه داشت (به ترتیب ۲/۳۲ میلی گرم در کیلو گرم و ۱/۴۲ میلی گرم در کیلو گرم). در پژوهش حاضر، مصرف FSMN به تنهایی تاثیری نشان نداد.