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Journal of the Air & Waste Management Association
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uawm20

Effects of foliar application with compost tea and filtrate biogas slurry liquid on yield and fruit quality of Washington navel orange (Citrus sinenesis Osbeck) trees

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Accepted author version posted online: 24 Apr 2012. Version of record first published: 26 Jun 2012

To cite this article: Alaa El-Din Kh. Omar, Elsayed B. Belal & Abd El-Naiem A. El-Abd (2012): Effects of foliar application with compost tea and filtrate biogas slurry liquid on yield and fruit quality of Washington navel orange (Citrus sinenesis Osbeck) trees, Journal of the Air & Waste Management Association, 62:7, 767-772

To link to this article: http://dx.doi.org/10.1080/10962247.2012.676381

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TECHNICAL PAPER

Effects of foliar application with compost tea and filtrate biogas slurry liquid on yield and fruit quality of Washington navel orange (*Citrus sinenesis* Osbeck) trees

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Sixteen-year-old navel orange trees at a private orchard located in Kafer El-Sheikh Governorate, Egypt, were used in this study. Compost tea (CT) and filtrate biogas slurry liquid (FLB) were applied at two different concentrations (50% and 100%); control trees were sprayed with water. Trees treated with CT at 100% were the highest in yield, fruit weight, and vitamin C, whereas the highest percentage of fruit set, fruit number, and soluble solid content (SSC), lowest fruit drop, and highest reducing and total sugars were in trees treated with 100% FLB. Concentrations at 50% for both foliar application (CT and FLB) improved yield and fruit characteristics than control treatment. Generally, using a foliar application of compost tea and filtrate biogas slurry liquid at (100%) treatments as food nutrients could be recommended to improve the yield and fruit quality of navel orange fruits under the current study conditions.

Implications: Consequently from the previously mentioned results, it was clear the great role of compost tea (CT) and filtrate biogas slurry liquid (FLB) as two sources of foliar application of organic fertilization for Washington navel orange grown in a clay loamy soil, as they are indispensable for improvement of the nutritional status of the navel orange trees and production of maximum yield and quality of orange, as well as minimizing the cost of production and in turn increasing the income of orange orchard. So, it should be recommended the superiority of application of FLB and CT, especially 100%, which gave the best results in yield and physical and chemical characteristics of navel orange fruits.

Introduction

Egyptian climate is well suited for orange production, which accounts for over half of the total fruit production in Egypt (Agriculture Statistics of Egypt, 2010). Total Egyptian orange exports achieved 653,000 Mt (Spreen, 2010). Navel orange is considered the main orange variety in Egypt during winter.

The problems associated with the use of hazardous chemicals for crop protection and weed control have received increasing attention worldwide, since pests, diseases, and weeds become resistant to chemical pesticides and environmental pollution. Organic fertilizers are increasingly playing a more important role as substitutes to chemical fertilizers, where most organic fertilizers are made out of many kinds of agricultural wastes such as animal dung and plant residues (Larptansuphaphal and Jitumroochokchai, 2009). However, there are reports showing that using organic fertilizers increased the development of some diseases (Chauhan et al., 2000). In many studies, application of compost extracts (compost tea), which are filtrated solution of compost materials and water mixtures, showed promising results on crop protection after a soaking period referred to as “extraction time” (Ghorbani et al., 2006). The concept behind compost tea is quite simple, though the actual process of making compost tea becomes scientific and very complex. The idea is that compost (full of beneficial microorganisms) is mixed with water and then supplemented with nutrients for the growth of microorganisms. This procedure reduces the pollution caused by nutrients through reducing the amounts of fertilizers added to soil (Abou El-nour, 2002). The effects of compost application either as extracts to the foliage or as soil amendments on plant disease control may be due to direct antifungal or resistance-inducing/plant-strengthening effects. However, the mechanism by which compost extracts work is not well known but seems to vary depending on the host-pathogen relationship and the mode of application (Goldstein, 2002). Moreover, several studies revealed that foliar application is more efficient than soil fertilization, under arid and semiarid conditions

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DOI: 10.1080/10962247.2012.676381

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(Amberger, 1991; El-Fouly and El-Sayed, 1997; El-Fouly and Rezk, 1986). Also, organic fertilizers such as liquid pig manure, matured cattle manure, and sugarcane husks applied directly to the soil showed promising results in control of some crop diseases (DeCeuster and Hoitink, 1999; Viana et al., 2000). Liquid biogas is prepared similarly to the herbal tea in which the material is fully immersed in barrel during the fermenting period, then strained and diluted and used as a foliar spray or soil drench.

The goal of this research is to study beneficial effects of compost tea (CT) and filtrate biogas slurry liquid (FLB) on yield and fruit quality of navel orange fruits.

Materials and Methods

This study was carried out during 2009 and 2010 seasons on Washington navel orange (*Citrus sinensis* Osbeck) trees grown at Kafr El-Sheikh Governorate, Egypt. The selected trees were 16 years old, budded on sour orange rootstock, and planted at 5 × 5 m apart in a clay loamy soil with water table of 1.5 m. The selected trees were uniform in both vegetative growth and fruit-bearing load. The experiment in each season included five treatments applied on May 15 and July 15, as follows:

1—Control (sprayed with water on the two days of treatments).
2—Compost tea (CT) 50%.
3—Compost tea (CT) 100%.
4—Filtrate biogas slurry liquid (FLB) 50%.
5—Filtrate biogas slurry liquid (FLB) 100%.

Preparation of aerobic compost tea and filtrate biogas slurry

Compost tea

Rice straw compost was made from rice straw Sakha 101 residues, cattle dung manure at Agricultural Botany Department, Faculty of Agriculture, Kafrelsheikh University, Egypt. Rice straw was shred. Then all other materials were mixed and arranged in heaps at 2 m width × 1.5 m height × 5 m length, which were regularly turned and moistened with water (55–65%) for 70 days to ensure appropriate composting conditions (turned windrow system). The heaps were covered with plastic to reduce the moisture evaporation from the surface of the piles, consequently preventing the dynamics of the piles. Heaps were moistened when needed and weekly turned to ensure adequate aeration and high decomposition. The compost was inoculated with starter from mesophilic and thermophilic lignolytic and cellulolytic microorganisms to accelerate the degradation rate (3×10^7 colony-forming units [cfu]/g rice straw) (Belal and El-Mahrouk, 2010). Maturity of compost was shown when the temperature inside the heap decreased and was similar to air temperature around the heap, also decreasing the carbon/nitrogen (C/N) ratio of compost at the end of composting comparing with the raw materials. C/N ratio of rice straw compost at the beginning of composting process was 30:1 and it was 15.2 at the end of composting period. Heaps were inoculated at maturity stage with *Trichoderma harzianum* and plant growth promoter rhizobacteria (PGBR) (4×10^8 cfu/g mature compost). Compost tea was prepared by brewing compost and water at a ratio of 1:5 *w/v* (compost:water) with continuous aeration. Tap water was added to the brewing tank approximately 24 hr prior to use to allow volatilization of chlorine (Naidu et al., 2010). After that, compost tea was filtrated. The filtrated solution was diluted two times for foliar spraying. Physicochemical characteristics of compost tea are given in Table 1.

Filtrate biogas slurry

Filtrate biogas slurry was prepared from biogas slurry after production of biogas from rice straw and cattle manure (Eltawil and Belal, 2009). Biogas slurry was diluted with tap water at a ratio 1:5 *w/v* (biogas slurry:water) and filtrated. The filtrate was diluted two times using for foliar spraying. Physicochemical characteristics of biogas slurry are given in Table 1.

June drop and preharvest fruit drop: The percentage of fruit drop was calculated according to the following equation:

$$\text{June drop}\,\% = [\text{Total no. of setted fruits at late June}/\text{Total no. of flowers}] \times 100$$

$$\text{Preharvest drop}\,\% = [(\text{Total no. of final fruit sets} - \text{Total no. of mature fruits})/\text{Total no.of final fruit sets}] \times 100$$

At harvest time (December 10), fruit samples of each replicate (three replicates, one tree per replicate) were picked separately for determining physical attributes (total yield of each tree [kg/tree] and fruit weight [g]) and chemical attributes (soluble solids content [SSC %], titratable acidity [%], and vitamin C

Table 1. Physicochemical characteristics of soils (clay and sandy), compost, and biogas slurry

Parameter	Compost	Biogas Slurry
pH	7.4	7.3
Electrical conductivity	1.8	0.9
% organic matter	17.5	13.1
Nitrogen (ppm)	311.4	1476.5
Potassium (ppm)	9.8	10.9
Phosphates (ppm)	126.3	119.1
Cadmium (ppm)	0.3	0.64
Nickel (ppm)	0.83	2.22
Lead (ppm)	1.3	2.1
Manganese (ppm)	5.2	4.9
Copper (ppm)	3.5	3.1
Iron (ppm)	10.1	14.2
Seed germination test %	93	91
Total count of bacteria	3×10^8	1×10^3
Total count of fungi	6×10^6	1×10^2
Total count of actinomycetes	3×10^7	0
Phytopathogenic agents (fungi, bacteria, and nematodes)	0	0
Total *E. coli* form counts	0	0
Total *Salmonella* counts	0	0

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[mg/100 mL juice]), as described by the Association of Official Analytical Chemists (AOAC) (1990).

Statistical analysis

The differences between the treatment groups and the control group were analyzed in complete randomized model with three replicates, one tree per each replicate according to (Little and Hills, 1972), using SPSS Statistics 17.0 software (Statistical Packages for the Social Sciences, released 23 August 2008; SPSS Institute, Chicago, IL). Duncan's new multiple-range test was used to identify which treatment conditions were significantly different from each other (Duncan, 1965). $P \leq 0.05$ was set as limit of significance.

Results

Effect of foliar application on physical characteristics

Fruit set (%)

The results showed that all tested treatments significantly increased fruit set percentage in both seasons as compared with control. Treatment 5 (T5) (FLB 100%) achieved the highest fruit set percentage (7.43% and 7.52%) as compared with that of T1 (control) (5.74% and 5.76%) in 2009 and 2010 seasons, respectively (Figure 1).

Fruit drop (%)

All the experimental treatments significantly decreased fruit drop percentage as compared with control. Maximum fruit drop percentage (11.44%) was observed from control trees, whereas minimum fruit drop (7.60 %) was achieved in FLB 100% treatment, in the first season (Figure 2).

Fruit weight (g)

The weight of fruit was, however, significantly increased by all foliar treatments, of which the maximum weight of 300.88 g was attained with FLB 100% treatment. The CT and FLB foliar application with respect to weight was found to be statistically significant. Minimum weight (225.70 and 218.64 g) was observed from control trees in both seasons (Figure 3).

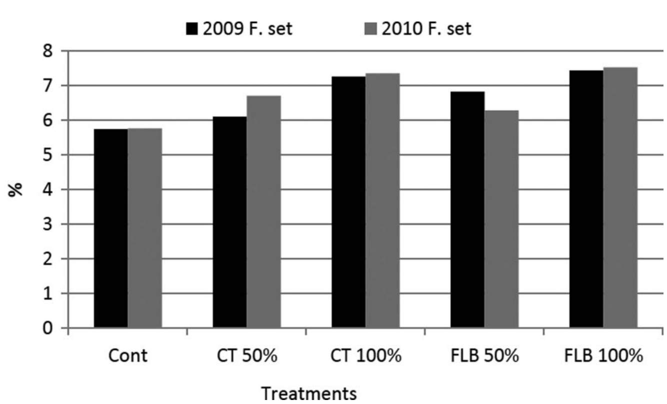

Figure 1. Effect of foliar application with compost tea and filtrate biogas slurry on fruit set (%) of Washington navel orange during 2009 and 2010 seasons.

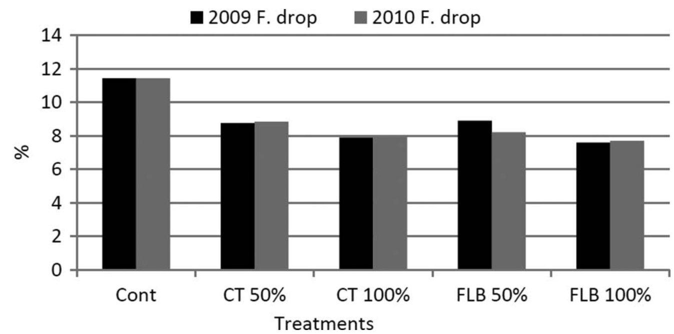

Figure 2. Effect of foliar application with compost tea and filtrate biogas slurry on fruit drop (%) of Washington navel orange during 2009 and 2010 seasons.

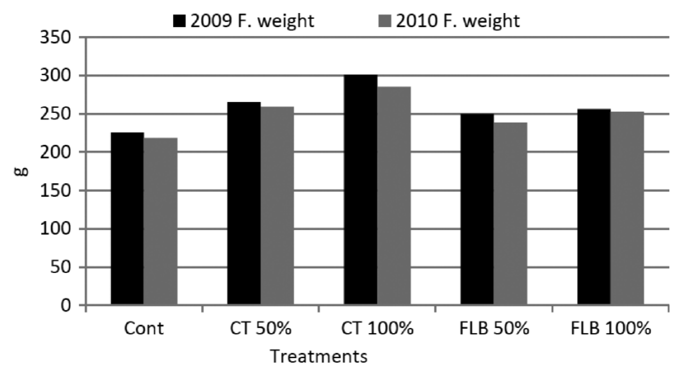

Figure 3. Effect of foliar application with compost tea and filtrate biogas slurry on fruit weight (g) of Washington navel orange during 2009 and 2010 seasons.

Fruit number

The number of fruit per tree showed significant differences among treatments. Greatest number of fruit per tree (285.00) was achieved in fruits with FLB 100% treatment, which was statically different in foliar application either applied in 2009 or in 2010 season. The lowest number of fruit per tree (221.28 and 240.76) was observed in control treatment in both seasons, respectively (Figure 4).

Yield (kg/tree)

Results showed that foliar application with CT and FLB (50% and 100%) significantly increased the fruit yield of navel

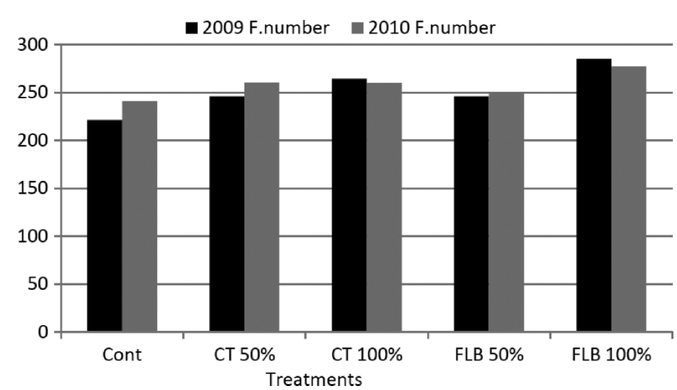

Figure 4. Effect of foliar application with compost tea and filtrate biogas slurry on fruit number of Washington navel orange during 2009 and 2010 seasons.

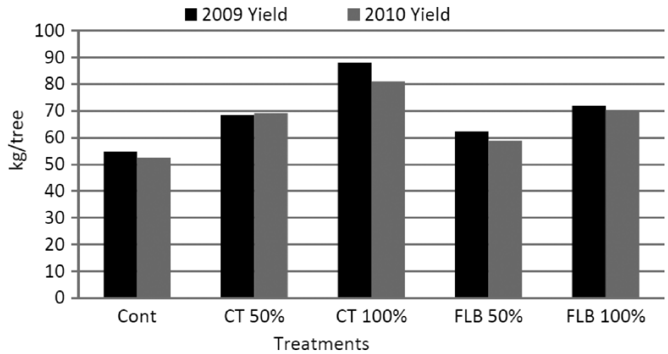

Figure 5. Effect of foliar application with compost tea and filtrate biogas slurry on yield (kg/tree) of Washington navel orange during 2009 and 2010 seasons.

oranges compared with the control treatment (Figure 5). The maximum fruit yield of 88.03 kg/tree was obtained from the treatment receiving 100% CT, followed by 81.01 kg/tree from FLB 100% treatment. The yield differences among such treatments were statistically at par with each other, indicating foliar sprays of CT and FLB were effective in increasing the fruit yield over control.

Effect of foliar application on chemical characteristics

SSC (%)

CT and FLB application significantly affected SSC % in both seasons. However, the response of navel orange to different foliar applications was different (Figure 6). Maximum SSC percentage (12.86%) was recorded in trees supplied with FLB 100%. Minimum SSC percentage (11.78%) was observed from CT 50% treatment in both seasons.

Acidity (%)

There was no evident significant effect caused by the CT, FLB, and control treatments in experiment during both seasons. CT 50% observed the lowest percentage of acidity content (0.82%) in the second season as compared with other treatments (Figure 7).

Vitamin C

Vitamin C in fruits was significantly affected by different foliar applications. The greatest amount of vitamin C (58.29 mg/100 mL juice) was recorded in CT 100% application and

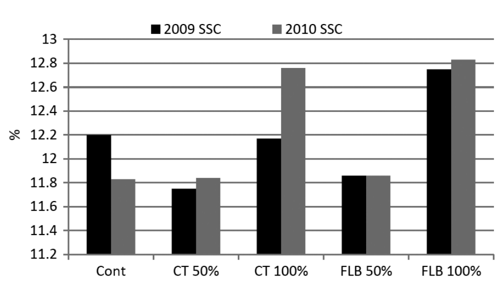

Figure 6. Effect of foliar application with compost tea and filtrate biogas slurry on SSC (%) of Washington navel orange during 2009 and 2010 seasons.

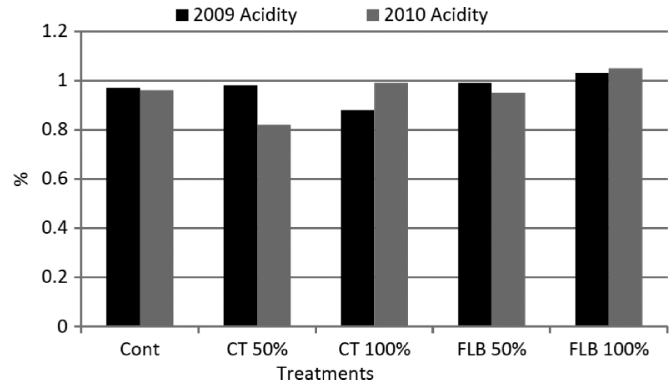

Figure 7. Effect of foliar application with compost tea and filtrate biogas slurry on acidity (%) of Washington navel orange during 2009 and 2010 seasons.

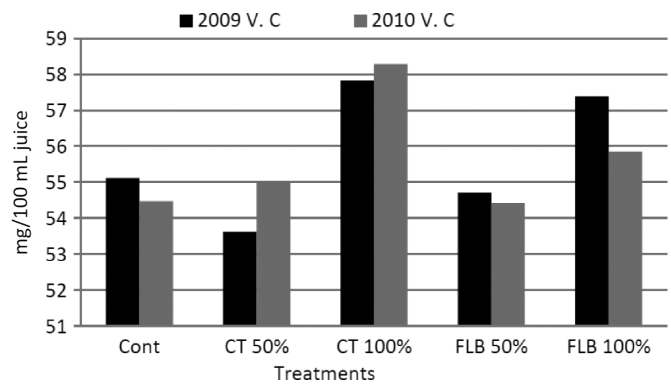

Figure 8. Effect of foliar application with compost tea and filtrate biogas slurry on vitamin C (mg/100 mL juice) of Washington navel orange during 2009 and 2010 seasons.

lowest (55.85 mg/100 mL juice) in control in both seasons (Figure 8).

Reducing sugars (%)

Results of reducing sugars were illustrated in Figure 9. There was an increase in reducing sugars content of navel orange fruit through foliar applications irrespective of the concentrations of application compared with the control treatment. FLB 100%

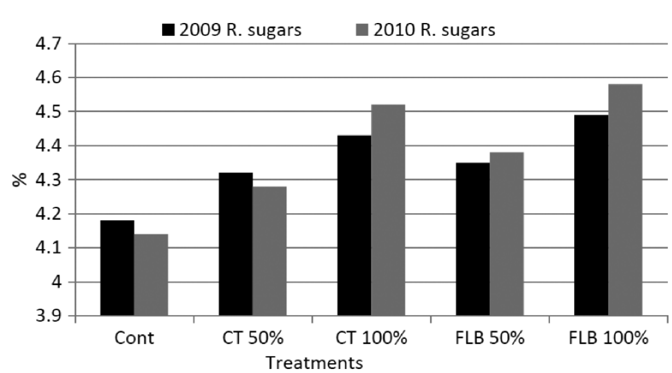

Figure 9. Effect of foliar application with compost tea and filtrate biogas slurry on reducing sugars (%) of Washington navel orange during 2009 and 2010 seasons.

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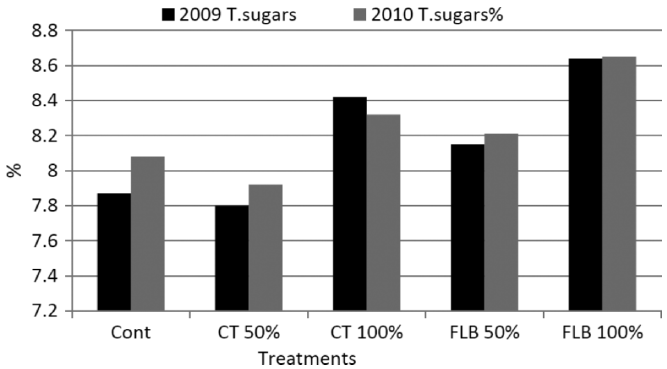

Figure 10. Effect of foliar application with compost tea and filtrate biogas slurry on total sugars (%) of Washington navel orange during 2009 and 2010 seasons.

treatment gave a significant increase in the second seasons as compared with other treatments. Control fruit was the lowest reducing sugars percentage (4.18% and 4.14%) in both seasons, respectively.

Total sugars (%)

A significant variation was recorded in trees treated with CT, FLB, and control treatments. Analysis of variance showed that higher total sugars were taken by the trees receiving high and low concentrations of CT and FLB as compared with untreated trees in control treatment in both seasons (Figure 10).

Discussion

Yield and physical characteristics

Several researchers revealed that foliar feeding is more efficient than soil fertilization (Havlin et al., 2005; Omaima and El-Metwally, 2007; Tariq et al., 2007). Data concerning the effect of CT and FLB as two sources of foliar application of organic fertilization on yield and physical characteristics of navel orange trees are illustrated in Figures 3, 4, and 5. Data revealed that there were significant difference in the fruit set, fruit drop, and the yield per tree due to source of organic used. On the other hand, levels of concentration significantly affected the fruit set, fruit drop, and the yield per tree. It was also noticed through our study that the yield per tree was increased with increasing level of concentration up to 100%/tree as compared with control and the other level of concentration (50%). The increase in fruit yield was related to both large fruit weight and greater set of fruits. Figure 5 shows that higher levels of concentration gave not only increase in fruit yield but also higher fruit number and lower fruit drop percentages. This suggests that the yield influence with increase organic fertilizer concentrate is a response to source of organic fertilizer. Furthermore, number and weight of fruits and the yield per tree respond more positively to the different concentrate application in the first season than in the second season.

These results are in agreement with those reported by Mostafa et al., 2009, who reported that the yield and fruit quality significantly increased when applied compost tea, which as foliar application was used on Washington navel orange trees and on Thompson seedless grapevines (Abd El-Maksood, 2006; El-Mansi, 2007; Ezz, 1999; Omar, 2005). Also, Fayed (2010) revealed that increase level application increase fruit production on Manfalouty pomegranate trees.

Chemical properties

Data showed that organic source affected significantly the most chemical properties of the Washington navel orange. Meanwhile, foliar application of organic fertilization level (100%) caused an increase in the soluble solids content, vitamin C, and total sugars percentages, whereas percentage of acidity content was unaffected by organic source and concentration as compared with the control.

The obtained results are in agreement with the findings of Mansour and Shaaban (2007), who reported that organic source applications significantly improved chemical properties of fruits as compared with mineral sources on Washington navel orange. Also, Fayed (2010) found that compost tea as foliar application gave a significant increase in total sugars in fruits on Manfalouty pomegranate trees. Similarly, Abd El-Hamied (2007), who found that combination between compost tea and chicken manure extract at rate 1:10 (compost:water) improved fruit quality on Thompson seedless grapevines.

Conclusion

Consequently from the previously mentioned results, it was clear the great role of compost tea (CT) and filtrate biogas slurry liquid (FLB) as two sources of foliar application of organic fertilization for Washington navel orange grown in a clay loamy soil, as they are indispensable for improvement of the nutritional status of the navel orange trees and production of maximum yield and quality of orange, as well as minimizing the cost of production and in turn increasing the income of orange orchard. So, it should be recommended the superiority of application of (FLB) and (CT), especially 100%, which gave the best results in yield and physical and chemical characteristics of navel orange fruits.

Acknowledgments

The authors thank the Deanship of Scientific Research and Research Center, College of Food and Agricultural Sciences, King Saud University, Kingdom of Saudi Arabia, for funding this research.

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