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Research Article
Enhancing Organic Tomato Yield and Quality by Liquid Organic Fertilizer

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Abstract

Background and Objective: Liquid organic fertilizer increases fruit yield. Different crop and formulation may have different result. This study aims to determine the best formula of liquid organic fertilizer for organic tomato. **Materials and Methods:** The study consists of two activities: formulation of liquid organic fertilizer and the evaluation of liquid organic fertilizer on organic tomato growth and yield. The first activity was a material analysis that compared 9 different organic materials. The second activity was a glass house experiment that used different rate of solid manure and liquid organic fertilizer. **Results:** The first activity found that white leadtree had a great potential as a nitrogen source, elephant grass and goat manure had a high amount of phosphorus and rabbit manure had the highest amount of potassium content. The second activity found that the application 20 mL L^{-1} of liquid organic fertilizer increased the tomato yield up to 83% and improved vitamin C up to 66% than the control. **Conclusion:** Liquid organic fertilizer made from manure (rabbit and goat manure) and green manure (white leadtree and elephant grass) doses 20 mL L^{-1} enhanced the fruit yield and vitamin C of organic tomato.

Key words: Liquid organic fertilizer, *Lycopersicum esculentum*, manure, organic farming, organic matter

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Organic farming increases around the world. Research Institute of Organic Agriculture (FiBL) and IFOAM-Organics International at BIOFACH released that nearly 70 million hectares of farmland were organic[1]. This number was predicted would increase linearly with the consumer demand. In spite of the increasing demand of organic product, organic farming severe some problems, for example, low yield and the high of production cost. One of the highest production cost that contribute to the organic farming system is organic fertilizers. Organic fertilizers commonly contain a low nutrient. This condition makes organic fertilizers are needed in the huge number that lead to ineffective and inefficient cost. Because of this reason, liquid organic fertilizer was recently developed to improve the crop growth and to maintain the crop yield.

Tomato is one of the most important vegetable in the world. The economy and nutrition importance of this crop are undeniable. On a worldwide scale, the production of fresh tomatoes approximately 160 million tonnes per year and 25% of those are grown in the processing industry[2]. Organic tomato was reported has a better quality than conventional tomatoes. Organic tomato fruits content 57% more total soluble solids and 55% more vitamin C than conventional fruit[3]. This finding encourages the organic tomato production to improve and develop.

Liquid organic fertilizer was reported could improve the tomato fruit yield in different studies. A study reported that Ergonfill, a liquid organic fertilizer that was made from the hydrolysis of protein animal, increased cherry tomato fruit yield up to 40% than control in stress water condition[4]. Another study reported that a liquid worm fertilizer improved the tomato yield up to 40% than control[5]. In addition, liquid organic fertilizer made from animal-based fertilizer was reported could replace the chemical fertilizer in greenhouse conditions[6]. Different material sources of liquid fertilizer could give different effects on the tomato growth and fruit yield[7].

In spite of the great findings of the effect of liquid organic fertilizer on tomato yield, every location has different organic materials. Using organic materials that provide locally in the area as the liquid organic source is beneficial and practical for the local farmers. Different organic materials are abundant locally, plant also animal materials. It is important to analyze the nutrient content of those local materials to obtain a high quality of liquid organic fertilizer. This study aims to identify the organic material that potential as liquid organic fertilizer in West Java, Indonesia than study the effect of the liquid organic fertilizer from those materials to the organic tomato growth and yield.

MATERIALS AND METHODS

Experimental site: The study was conducted at experimental field of the Indonesian Vegetable Research Institute (IVEGRI) in 2015. The site is situated in highland Lembang, Bandung Barat, West Java, Indonesia (latitude: 6°48'S, longitude: 107°39'E, 1250 m.a.s.l). Climatic data were collected from Meteorological and Geophysical Agency of West Java. The annual rainfall was 2216 from January to December, 2015. Mean temperature ranges from 23.1-24.5°C with the minimum temperature from 18.1-20.6°C and the maximum temperature from 28.4-31.9°C. The average of relative humidity from 63-82%.

The soil type is andosol with soil pH = 5.4 (acid), high of organic carbon 7.26%, total nitrogen 0.55%, the C/N ratio 13, low of available phosphorus (P-Bray) 12 mg P kg^{-1} and high available potassium (K-Morgan) 804 ppm.

The study consisted of two experiments: (1) formulation of liquid organic fertilizer and (2) the evaluation of liquid organic fertilizer on organic tomato growth and yield.

Formulation of liquid organic fertilizer: The experiment was conducted from March to May, 2015. The organic materials were collected from different areas in West Java, Indonesia. The organic materials were collected and analyzed the chemical content, they were leaves of white leadtree (*Leucaena leucocephala*), leaves of velvet bean (*Mucuna pruriens*), leaves of snap bean (*Phaseolus vulgaris*), leaves of elephant grass (*Pennisetum purpureum*), chicken (*Gallus gallus domesticus*) manure, cow (*Bos taurus*) manure, rabbit (*Lepus negricollis*) manure, goat (*Capra aegagrus hircus*) manure and bat (Ordo:Chiroptera) manure.

Every plant samples were cleaned, cut and dried oven at 70°C (Memmert type UN 450). The dry samples were ground at 0.5 mm. For animal manure, the samples were mixed until homogenous and sieved with at 2.0 mm prior to analysis. N-Kjeldahl (%) was measured by distillation to calculate the N-organic and N-NH_4 using NaOH 40%. Phosphorus content was analyzed spectrophotometer using HNO_3 and $HClO_4$. Furthermore, potassium content was determined by atomic absorption spectroscopy.

Evaluation of liquid organic fertilizer on organic tomato growth and yield: The tomato cultivar Zamrud from Indonesian Vegetable Research Institute was used. 'Zamrud' is determinate cultivar and tolerant to wilting bacteria (*Rhizoctonia solanacearum*). 'Zamrud' seed was sown in a well-prepared nursery seedbed (andosol soil: manure 1:1 (v/v)). Since the seed was sown, it was watered by watering

can and no insecticide was used during the growth period. When seedling reached the four-leaf stage (15 cm height), they were transplanted by hand to the polybag size 5 kg. Every polybag has one seeding.

The pot trials were carried out in the greenhouse to understand the effect of liquid organic fertilizer on organic tomato growth and yield. Randomized complex block design with 6 treatments and 4 replications were employed to address the aims. The treatments were: (L0) 100% solid manure+0 mL L^{-1} liquid organic fertilizer (control), 100% solid manure+10 mL L^{-1} liquid organic fertilizer (L1), 100% solid manure+15 mL L^{-1} liquid organic fertilizer (L2), 100% solid manure+20 mL L^{-1} liquid organic fertilizer (L3), 75% solid manure+20 mL L^{-1} liquid organic fertilizer (L4) and 50% solid manure+20 mL L^{-1} liquid organic fertilizer (L5). A full dosage 100% of solid manure was 30 t ha^{-1} horse manure or equal to 1 kg/plant. The liquid organic fertilizer was foliar applied and was given at 15, 30 and 45 days after planting with spraying volume 300-500 L ha^{-1}.

Growth and yield data were obtained from five randomly chosen plants in each plot. Plant heights were measured from the soil surface to the top of the longest mature leaf; chlorophyll contents were measured at 6 weeks after planting using Spectrophotometer and 80% acetone solvents at $\lambda = 663$ nm and $\lambda = 650$ nm.

To measure the fruit yield, weight of fruits were obtained at 5 times of harvest time and sum all the weight to determine in g/plant. To measure the number of fruits, all the fruits that harvested for every time was counted manually and sum in the last measurement. In addition, to calculate the weight per fruit the total weight divided by the number of fruits.

To estimate the diameter and the length of the tomato fruits was measured with calipers. To measure the water content, the fruits were dried in oven 65°C (Memmert type UN 450) and measured on an electrical balance (Precisa type XB 62°C). Total soluble solid was measured by refractometer. Fruit texture was measured by a manual food texture tester (Atago N1). Vitamin C was analyzed by the titration method. The analysis of variance (ANOVA) was used SAS with a comparison of means using DUNCAN at $\alpha = 5\%$.

RESULTS

Formulation of liquid organic fertilizer: The result of organic materials was shown in Table 1. From the analysis result, it was found that white leadtree had the highest amount of nitrogen 5.41%, rabbit manure had the highest amount of phosphorus content 2.64%, elephant grass and goat manure had the highest content of potassium 2.58%. The organic materials that would be used as liquid organic fertilizer sources were white leadtree, rabbit manure, elephant grass and goat manure with formulation 2:2:1:1 (v/v/v/v).

Evaluation of liquid organic fertilizer on organic tomato growth and yield: The soil analysis before and after the experiment are presented in Table 2. Organic fertilization increases the soil pH from 5.4 to 5.7-6.0. Application of liquid organic fertilizer increased the C-organic insignificantly from 7.26 to 7.28-7.96% and nitrogen from 0.55 to 0.56-0.59%. Application of solid organic fertilizer and liquid organic fertilizer also increased the P-Bray from 13 mg P kg^{-1} to 57-80 mg P kg^{-1}. However, there was a decreasing on the potassium content from K-Morgan 804 ppm to 209-572 ppm. Those values are still in the range of the high concentration of K-available in the soil.

Table 1: Mineral content of organic materials

Organic materials	N-total (%)	P (%)	K (%)
White leadtree	5.41	0.32	1.87
Velvet bean	2.94	0.20	1.10
Snap bean	3.28	0.35	2.09
Elephant grass	2.50	0.25	2.58
Chicken manure	0.61	0.26	0.86
Cow manure	1.67	1.83	1.08
Rabbit manure	2.28	2.64	1.20
Goat manure	1.12	1.00	2.58
Bat manure	1.16	0.25	0.40

N-total: Nitrogen total, P: Phosphorus content, K: Potassium content

Table 2: Soil analysis result for before and after experiment

Soil sample	pH	C (%)	N (%)	C/N	P-Bray (mg P kg^{-1})	K (ppm)
Before experiment	5.4	7.26	0.55	13	13	804
After experiment						
100% SM+0 mL L^{-1} LOF (Control)	5.7	7.23	0.57	13	61	209
100% SM+10 mL L^{-1} LOF (L1)	6.0	7.96	0.60	13	75	573
100% SM+15 mL L^{-1} LOF (L2)	5.8	7.63	0.59	13	57	240
100% SM+20 mL L^{-1} LOF (L3)	5.7	7.63	0.59	13	81	252
75% SM+20 mL L^{-1} LOF (L4)	5.7	7.28	0.58	13	67	224
50% SM+20 mL L^{-1} LOF (L5)	5.8	7.36	0.56	13	70	249

C: Carbon organic, N: Nitrogen, C/N: Ratio of carbon organic/nitrogen, P-Bray: Phosphorus bray method, K: Potassium, SM: Solid horse manure, LOF: Liquid organic fertilizer

Table 3: Effect of liquid organic fertilizer on plant height and chlorophyll

Treatments	Plan height (cm)			Chlorophyll (mg g^{-1})
	2 WAP	4 WAP	6 WAP	
100% SM+0 mL L^{-1} LOF (Control)	9.20^{ns}	23.50^{b}	31.80^{ab}	4.15^{ns}
100% SM+10 mL L^{-1} LOF (L1)	9.30	20.10^{b}	29.70^{b}	4.47
100% SM+15 mL L^{-1} LOF (L2)	9.80	23.20^{b}	30.20^{b}	3.60
100% SM+20 mL L^{-1} LOF (L3)	9.20	19.40^{b}	26.40^{b}	3.72
75% SM+20 mL L^{-1} LOF (L4)	9.90	30.00^{a}	37.80^{a}	3.73
50% SM+20 mL L^{-1} LOF (L5)	10.00	24.70^{ab}	31.30^{ab}	3.97
CV (%)	7.41	15.21	12.93	19.57

SM: Horse solid manure, LOF: Liquid organic fertilizer, WAP: Weeks after planting, means presenting the same letter are not statistically different by DMRT at α = 5%, ns: Non significance, CV: Coefficient variance

Table 4: Effect of liquid organic fertilizer on tomato yield

Treatments	Fruit yield/plant (g/plant)	Number of fruits	Weight/fruit (g/fruit)
100% SM+0 mL L^{-1} LOF (Control)	282.20^{bc}	15.30^{ab}	18.20^{b}
100% SM+10 mL L^{-1} LOF (L1)	328.20^{bc}	13.50^{ab}	22.70^{ab}
100% SM+15 mL L^{-1} LOF (L2)	282.30^{bc}	13.80^{ab}	20.20^{b}
100% SM+20 mL L^{-1} LOF (L3)	218.70^{c}	11.00^{b}	19.30^{b}
75% SM+20 mL L^{-1} LOF (L4)	515.80^{a}	16.30^{ab}	35.80^{a}
50% SM+20 mL L^{-1} LOF (L5)	502.30^{ab}	23.50^{a}	23.70^{ab}
CV (%)	22.51	20.99	36.68

SM: Horse solid manure, LOF: Liquid organic fertilizer, means presenting the same letter are not statistically different by DMRT at α = 5%, ns: Non significance, CV: Coefficient variance

Table 5: Effect of liquid organic fertilizer on fruit quality

Treatments	Shelf life (days)	Fruit diameter (cm)	Length of fruit (cm)	Water content (%)	TSS (%)	Vitamin C (mg/100 g)	Texture (mm sec^{-1}/100 g)
100% SM+0 mL L^{-1} LOF	7^{ns}	2.6^{b}	3.2^{b}	94.9^{ns}	4.0^{ns}	16.0^{b}	4.0^{b}
100% SM+10 mL L^{-1} LOF	4	3.1^{ab}	3.8^{a}	95.4	3.9	24.8^{a}	4.8^{b}
100% SM+15 mL L^{-1} LOF	5	2.7^{b}	3.4^{b}	95.7	3.3	26.6^{a}	4.6^{b}
100% SM+20 mL L^{-1} LOF	6	3.4^{a}	3.8^{a}	95.1	3.6	21.3^{a}	5.1^{b}
75% SM+20 mL L^{-1} LOF	8	3.6^{a}	4.4^{a}	95.5	3.3	26.6^{a}	6.1^{a}
50% SM+20 mL L^{-1} LOF	6	3.5^{a}	4.1^{a}	95.2	3.4	28.4^{a}	6.0^{a}

SM: Horse solid manure, LOF: Liquid organic fertilizer, TSS: Total soluble solids, means presenting the same letter are not statistically different by DMRT at α = 5%, ns: Non significance

Effect of liquid organic fertilizer on plant height of tomato and chlorophyll content at 6 weeks after planting can be seen in Table 3. At 2 weeks after planting, there was no significant difference of plant height for each treatment. However, at 4 weeks after planting the application of liquid organic fertilizer with reducing the doses of solid horse manure gave a higher effect rather than 100% horse manure plus liquid organic fertilizer. Meanwhile, there was no significant difference between chlorophyll in all treatments.

Table 4 shows the effect of liquid organic fertilizer on fruit yield. Application 75% solid horse manure+20 mL L^{-1} liquid organic fertilizer obtained the highest fruit yield compared to other treatments. Meanwhile the lowest fruit yield was gained by 100% solid horse manure+20 mL L^{-1} liquid organic fertilizer treatments. The results showed that the application of liquid organic fertilizer with depletion of solid horse manure gave a better fruit yield compared to full doses. In addition, the average weight per fruit was significantly bigger than the control. Application 75% solid horse manure+20 mL L^{-1} liquid organic fertilizer increase the fruit yield up to 83% than control.

The fruit quality was described by shelf life, diameter and length of fruit, water content, total soluble solids (TSS), vitamin C and texture (Table 5). There was no significance different on shelf life, water content and total soluble solids. However, application liquid organic fertilizer doses 20 mL L^{-1} plus 50-75% solid manure increased fruit diameter, length of fruit, vitamin C and texture compared to control.

DISCUSSION

White leadtree (*Leucaena leucocephala)* extract had the highest concentration of nitrogen. Application of white leadtree extract was reported gave positive impact on Chinese

cabbage growth and yield[8] and increased the N-total soil and P-soil available[9]. White leadtree which mixed with other organic materials could have a better nutrient that gave a better impact to the plant growth[10,11]. The organic residue of *Leucaena leucocephala* contains 464 g kg^{-1} total carbon and 41 g kg^{-1} total nitrogen that was higher compared to other trees, such as *Centrosema pubescence*, *Gliricidia sepium*, *Pueraria phaseoloides*, *Azadirachta indica* and *Theobroma cacao*[12].

Rabbit manure consist of high amount of phosphorus. Rabbit manure is identified could increase soil nutrition, soil physical condition, soil microbial activity, improves soil aeration and retention of water[13]. Several studies reported that application of rabbit manure improved the biomass of corn (*Zea mays*), Chinese cabbage (*Brassica juncea* L.) and *kailan* (*Brassica oleracea* group Alboglabra)[14-16]. The combination of rabbit manure, rock phosphate, feldspar and bio-fertilizers enhance the tomato fruit yield by 30% compared to chemical fertilization[13].

Elephant grass (*Pennisetum purpureum*) is rich in nutrition[17] and known well as a forage crop for dairy farm and biofuel crops[18]. The composed of elephant grass with other organic materials bovinza and *Gliricidia sepium* improved the weight of *Eiseina foetida* up to 60%[18]. However, the information about using elephant grass as the source of liquid organic fertilizer for another crop is very limited.

Goat manure consist of high amount of potassium could improve the plant nitrogen uptake significantly[19]. Dry goat manure consist of 4.60 P g kg^{-1}, 17.8 cmol (+) kg^{-1} Ca^{2+}, 20.0 cmol (+) kg^{-1} Mg^{2+}, 38.7 cmol (+) kg^{-1} K^{+} and 38.40 cmol (+) kg^{-1} Na. The potassium concentration of goat manure is higher than poultry manure and cattle manure[20]. Application goat manure increased the yield of snap bean, rosella, spinach and sunflower[21-24].

In spite of the number of reports studied the effectiveness of those materials in increasing the crop growth and the yield, the information about the effectiveness of those materials, as liquid organic fertilizer sources was lacking. To understand the effect of liquid organic fertilizer from those materials, white leadtree *Leucaena leucocephala*, rabbit manure, elephant grass and goat manure, the evaluation experiment was carried out.

Overall, application of solid horse manure increased the soil pH. Horse manure increased bacterial diversity and the bacterial community composition and diversity involved the soil pH[25]. Manure increases soil pH because of the decomposition process that release organic compound and humic acid. Organic material increases soil pH and reduce aluminium toxicity that usually occur in acid soil conditions[26].

Manure increased soil P-availability through the addition of P-residue, increased P recovery and reduce the P-soil absorption that increase the soil P-availability and release of phosphorus by organic material during the decomposition. In addition, soil P-available improved because the manure made a complexion that minimize the immobilization process and replaced the phosphate (-) in the soil structure[27]. Horse solid manure contents 0.70 ppm N, 0.10 ppm P, 0.58 ppm K, 0.79 ppm Ca, 0.14 ppm Mg and 0.07 ppm S[28].

Application of liquid organic fertilizer without decreasing the dose of solid manure did not give a positive impact on the tomato yield. It seems that application of liquid organic fertilizer plus 100% solid manure gave an over-supply fertilization status. The situation can reduce the fruit yield. Oversupply of nitrogen reduces the tomato yield significantly[29]. In contrary, application of liquid organic fertilizer plus 50 and 75% solid manure improved the fruit yield significantly. The best treatment, 75% solid manure application+20 mL L^{-1} liquid organic fertilizer increased the fruit yield up to 83% from 282.2 g/plant to 515.8 g/plant. This finding similarly with other studies that reported the application of liquid organic fertilizer enhanced the fruit yield of tomato from 40%[4]. Increasing the tomato fruit yield in this trial because of the increasing of the fruit size that increased the tomato weight per fruit. The increasing of fruit diameter 38% from 2.6-3.6 cm, the length of fruit, 40% from 3.2-3.5 cm and the weight per fruit 97% from 18.2-35.8 g/fruit.

Furthermore, application of liquid organic fertilizer enhanced the vitamin C by 25-78% from 16 mg/100 g to 21.3-28.4 mg/100 g. The increasing of vitamin C occurred in all treatments with liquid organic fertilizer application. Antonious *et al.*[30] reported that the growth media involved the vitamin C content of tomatoes. Furthermore, the trial, 75% solid manure+20 mL L^{-1} liquid organic fertilizer involved the fruit texture softer than control that easily to digest. Even though, it was softer, but the shelf life of the fruits was not a significant difference. In conclusion, application liquid organic fertilizer made from white leadtree *Leucaena leucocephala*, rabbit manure, elephant grass and goat manure (2:2:1:1, v/v/v/v) not just increased the fruit yield but also the quality of organic tomato fruits.

CONCLUSION

White leadtree (*Leucaena leucocephala*), elephant grass (*Pennisetum purpureum)*, rabbit manure and goat manure are potential as main ingredients on creating liquid organic fertilizer. Application of liquid organic fertilizer made from green manures and manures increased the organic tomato

yield up to 83% and improved the quality, vitamin C, up to 78%. The liquid organic fertilizer formula is prospective to be developed and potential to be used as a supplementary fertilizer in organic farming system to increase the production and the quality as well.

SIGNIFICANCE STATEMENT

This study discover the new formula of liquid organic fertilizer made from manure and green manure that can be beneficial for organic tomato production. This study will help the researcher to uncover the critical areas of organic materials from West Java, Indonesia as liquid organic fertilizer sources that many researchers were not able to explore.

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