Pertanika J. Trop. Agric. Sc. 42 (3): 1157 - 1166 (2019)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Liquid Organic Fertilizer from Plant Extracts Improves the Growth, Yield and Quality of Sweet Corn (*Zea mays* L. var. *saccharata*)

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ABSTRACT

The objective of this research was to study the effect of concentration and dose of liquid organic fertilizer (LOF) derived from an extract mixture derived from *lamtoro* leaves, banana humps, and coconut fibers on the growth, yield, quality, and nutrient uptake of sweet corn. Experiment 1 comprised six treatments, namely a control without LOF, recommended inorganic fertilizers, and LOF at a concentration of 15 ml l^{-1}, 30 ml l^{-1}, 45 ml l^{-1}, or 60 ml l^{-1}. Experiment 2 consisted of five treatments, namely recommended inorganic fertilizers, and LOF doses of 25 l ha^{-1}, 50 l ha^{-1}, 75 l ha^{-1} or 100 l ha^{-1}. Results showed that LOF consistently increased the growth, yield and quality of sweet corn. Application of LOF with a concentration of 60 ml l^{-1} or a dose of 100 l ha^{-1} showed the highest yield compared to other treatments. The quality of sweet corn increased markedly. It was concluded that LOF could be applied as an additional supplement to inorganic fertilizers used for sweet corn organic farming in the tropics.

Keywords: Banana hump, coconut fiber, leucaena extract, nutrient uptake, organic farming

ARTICLE INFO

Article history:
Received: 01 March 2019
Accepted: 10 June 2019
Published: 19 August 2019

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INTRODUCTION

The community prefers sweet corn (*Zea mays* L. var. *saccharata*) because of its relatively high sugar content. Organic sweet corn production needs can be improved by improving fertilization techniques. Fertilizers for sweet corn can be given in the solid or liquid form. Solid organic fertilizers tend to be taken up by the crop

ISSN: 1511-3701
e-ISSN: 2231-8542

relatively slowly (Hartz et al., 2000; Johnson et al., 2012). Another alternative in organic tropical agriculture is the use of liquid organic fertilizers (LOF), which are taken up more quickly by crops.

The application of fertilizer into the plants through leaves was successfully carried out on corn plants (Amanullah et al., 2014). Similarly, the application of LOF was carried out on various vegetable crops such as sweet corn (Fahrurrozi et al., 2016) and tomatoes (Zhai et al., 2009). Hartz et al. (2010) reported that the application of LOF could function the same as conventional fertilization with solid fertilizers. Furthermore, the researchers stated that nitrogen derived from liquid organic fertilizers was more readily available and the nitrification process took place faster.

One cultivation technique used to increase growth, yield, and quality of sweet corn grown organically are LOF made from the waste of plant materials available around the farmer's garden. There is still a lack of a scientific basis on the utilization of plant extracts as LOF. Plant wastes such as *lamtoro* (*Leucaena leucocephala*) leaves, banana humps, and coconut husks are widely available around farmers' gardens in tropical areas. *Lamtoro* leaves are often used as animal feed. *Lamtoro* leaves contain significant amounts of nitrogen, protein, vitamins, and minerals (Farinu et al., 1992; Meulen et al., 1979). Liquid organic fertilizer from the leaves of *lamtoro* is a source of nitrogenous nutrients for plants. Banana humps contain microbial decomposers of organic matter, such as *Bacillus* sp., *Aeromonas* sp. and *Aspergillus niger* (Suhastyo et al., 2013). These microbes are able to decompose organic matter. The main content of coconut fibers is cellulose, hemi-cellulose, and lignin (Arsyad et al., 2015). If the coconut fiber is soaked and fermented with water, the potassium contained in coconut fiber will dissolve in soaking water so that the liquid fertilizer coconut husk is high in potassium.

The purpose of this study was to determine the effect of concentration and dose of liquid organic fertilizer made from an extract mixture of *lamtoro* leaves, banana humps and coconut fibers on the growth, production, quality, and nutrient uptake of sweet corn plants.

MATERIALS AND METHODS

This research was carried out in Kota Sepang experimental station, Bandar Lampung, Indonesia. The study area was classified as having Ultisol soil. A field study was set up in RCBD (Randomized Complete Block Design) and replicated three times. The experiment consisted of two sub-experiments. Experiment 1 (April to June 2016) consisted of six treatments, namely an unfertilized control, recommended inorganic fertilizer, and application of LOF with a concentration of 15 ml l^{-1}, 30 ml l^{-1}, 45 ml l^{-1}, or 60 ml l^{-1}. Experiment 2 (April to June 2017) consisted of five treatments, namely recommended inorganic fertilizer, and an application of LOF with a dose of 25 l ha^{-1}, 50 l ha^{-1}, 75 l ha^{-1}, or 100 l ha^{-1}.

The research began with making plant extract LOF following a modified procedure developed by Astuti et al. (2014). *Lamtoro* leaves, banana humps, and coconut fibers were cut into small pieces and then separately put into containers, into which brown sugar and rice washing water were added and stirred evenly. Then EM-4 was added, after which the container was closed and then fermented for 21 days and filtered. Liquid organic fertilizer from *lamtoro* leaves, banana humps, and coconut fibers was then mixed in a ratio of 1: 1: 1. The nutrient content of the plant extracts (Table 1) was analyzed in Soil Laboratory, Faculty of Agriculture, University of Lampung.

Table 1
Content of fermented plant extract

Plant extract	N (ppm)	P (ppm)	K (ppm)
Lamtoro leaves	763.01	55.11	125.81
Banana humps	238.04	63.88	88.21
Coconut fiber	133.12	8.95	192.11

All plots were hand hoed before planting with sweet corn. The area of each plot was 3 m × 3 m, and the row spacing was 70 cm × 20 cm. The application of liquid fertilizer was carried out by spraying evenly on the upper and lower part of leaves. The application of LOF was carried out once a week from 2 to 7 weeks after planting (WAP). The inorganic recommended fertilizers were given included urea at 300 kg ha^{-1}, SP-36 at 150 kg ha^{-1}, and KCl at 100 kg ha^{-1}. Agronomic practices used in this study included watering, growing, control of weeds, pests, and diseases organically. Harvesting was conducted at 70 days after planting.

The parameters observed in this study were the number of leaves, stem diameter, plant height, leaf area index (LAI), SPAD value, the weight of husked ear, the weight of unhusked ear, ear length, ear diameter, shoot dry weight, ºBrix value, yield, and N, P and K nutrient uptake. Statistical analysis of the data was conducted using MINITAB v. 16.0 software. Analysis of variance and least significant difference (LSD) tests was used to test overall treatment effects and between-treatment differences and was conducted at the 5% probability level.

RESULTS AND DISCUSSION

Results

The LOF application affected the vegetative parameters of the plants. Leaf number and stem diameter were greater in LOF-applied plant than the control (Table 2). The results of the analysis of variance showed that the application of LOF increased the number of leaves and stem diameter. The number of leaves and stem diameter treated with concentrations of 15 ml l^{-1}, 30 ml l^{-1}, 45

Table 2
Effects of liquid organic fertilizer concentration on the number of leaves and stem diameter in experiment 1

LOF concentration	Number of leaves	Stem diameter (cm)
Control	11.33 c	1.60 c
Inorganic fertilizer	12.47 b	1.80 b
15 ml l^{-1}	12.80 ab	1.93 ab
30 ml l^{-1}	13.00 ab	1.89 ab
45 ml l^{-1}	13.20 a	2.02 a
60 ml l^{-1}	13.47 a	2.00 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

ml l^{-1}, and 60 ml l^{-1} were not significantly different. The lowest number of leaves and the lowest stem diameter were recorded in the control treatment (Table 2).

The LOF application increased plant height, leaf area index, and the greenness of the leaves (indicated by SPAD value) (Table 3). The plant height, LAI, and SPAD value were greater in LOF-applied plants than with the inorganic fertilizer treatment. Plant height and LAI increased with increasing doses of LOF until 75 l ha^{-1}; above these levels, there was no significant additional increase. The greenness level of leaves (SPAD value) in the 100 l ha^{-1} treatment was higher than in the other treatments, while doses of 50 l ha^{-1} and 75 l ha^{-1} were not significantly different from each other. The lowest plant height, LAI and SPAD value were recorded with the inorganic fertilizer treatment (Table 3).

LOF application also affected the generative parameters of plants. The results of the analysis of variance indicated that the LOF application increased the weight of unhusked ears and weight of husked ears (Tables 4 and 5). Weights of unhusked ears and weight of husked ears in the LOF treatment were significantly higher than the control treatment (Table 4). The lowest weights of unhusked ears, the weight of husked ears, ear length, and ear diameter were recorded in the control plants (Table 4).

The LOF application increased ear length (Tables 4 and 5). Ear lengths at concentrations of 30 ml l^{-1}, 45 ml l^{-1}, and 60 ml l^{-1} were not significantly different from the treatment of inorganic fertilizer (Table 4), while ear length between doses of 25 l ha^{-1} and inorganic fertilizer did not show any significant differences (Table 5). The ear length between doses of 50 l ha^{-1}, 75 l ha^{-1}, and 100 l ha^{-1} did not show any significant differences (Table 5).

Table 3
Effects of liquid organic fertilizers doses on plant height, LAI, and SPAD value in experiment 2

LOF dose	Plant height (cm)	LAI	SPAD value
Inorganic fertilizer	82.05 c	3.07 d	44.28 c
25 l ha^{-1}	83.31 b	3.64 c	44.91 c
50 l ha^{-1}	84.56 b	4.23 b	46.22 b
75 l ha^{-1}	93.80 a	5.33 a	46.97 b
100 l ha^{-1}	93.45 a	5.51 a	48.15 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

Table 4
Effects of liquid organic fertilizer concentration on the weight of husked ear, the weight of unhusked ear, ear length, and ear diameter in experiment 1

LOF concentration	Weight of unhusked ear (kg $plant^{-1}$)	Weight of husked ear (kg $plant^{-1}$)	Ear length (cm)	Ear diameter (cm)
Control	1.88 b	1.28 b	18.61 c	3.94 c
Inorganic fertilizer	2.33 a	1.77 a	21.03 ab	4.42 b
15 ml l^{-1}	2.35 a	1.78 a	20.15 b	4.40 b
30 ml l^{-1}	2.30 a	1.97 a	21.14 ab	4.55 ab
45 ml l^{-1}	2.63 a	2.08 a	21.85 a	4.71 a
60 ml l^{-1}	2.63 a	2.12 a	21.61 a	4.68 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

Table 5
Effects of liquid organic fertilizer doses on the weight of husked ear, the weight of unhusked ear, ear length, and ear diameter in experiment 2

LOF dose	Weight of unhusked ears (kg plant^{-1})	Weight of husked ears (kg plant^{-1})	Ear length(cm)	Ear diameter (cm)
Inorganic fertilizer	2.10 e	1.60 c	20.32 a	4.39 d
25 l ha^{-1}	2.30 d	1.73 c	20.19 a	4.43 c
50 l ha^{-1}	2.57 c	1.80 bc	18.45 b	4.50 b
75 l ha^{-1}	3.03 b	2.07 ab	18.12 b	4.58 a
100 l ha^{-1}	3.30 a	2.27 a	17.79 b	4.60 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

The application of LOF increased the ear diameter (Tables 4 and 5). The lowest ear diameter was recorded in control plants (Table 4). The diameter of the ear between concentrations of 30 ml l^{-1}, 45 ml l^{-1}, 60 ml l^{-1} (Table 4) as well as between doses of 75 l ha^{-1} and 100 l ha^{-1} (Table 5) were not significantly different.

The application of LOF consistently increased sweet corn yields (Tables 6 and 7). The yield of sweet corn at all LOF concentrations (Table 6) was not significantly different. The lowest yield was recorded in control treatment. The highest yield was obtained at a concentration of 60 ml l^{-1} (Table 6) and dosed 100 l ha^{-1} (Table

Table 6
Effects of liquid organic fertilizers concentration on shoot dry weight, ºBricks value, and yield in experiment 1

LOF concentration	Shoot dry weight (g plant^{-1})	ºBrix value	Yield (ton ha^{-1})
Control	14.19 a	15.22 c	8.28 b
Inorganic fertilizers	19.24 bc	15.76 b	11.59 a
15 ml l^{-1}	17.16 ab	15.85 ab	13.26 a
30 ml l^{-1}	18.97 bc	16.16 ab	13.24 a
45 ml l^{-1}	20.74 c	16.18 a	14.76 a
60 ml l^{-1}	21.31 c	16.22 a	14.94 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

Table 7
Effects of dose of liquid organic fertilizers doses on shoot dry weight, ºBricks value, and yield in experiment 2

LOF dose	Shoot dry weight (g plant^{-1})	ºBrix value	Yield (ton ha^{-1})
Inorganic fertilizers	16.25 d	11.05 b	15.15 c
25 l ha^{-1}	16.87 c	11.50 b	15.97 b
50 l ha^{-1}	17.07 b	11.56 b	16.21 b
75 l ha^{-1}	17.43 a	12.39 a	17.37 a
100 l ha^{-1}	17.33 a	12.56 a	17.81 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

7). The application of LOF increased the dry shoot weight (Tables 6 and 7). The lowest shoot dry weight was noted in control treatment (Table 6).

Application of LOF increased plant nutrient uptake (Table 8). Nutrient uptake of P and K in the LOF treatment were significantly higher than those treated with inorganic fertilizer. Also, nutrient uptake of N, P, and K between doses of 25 l ha^{-1} and 50 l ha^{-1} as well as between doses 75 l ha^{-1} and 100 l ha^{-1} did not show any significant differences (Table 8).

The LOF application increased the quality of sweet corn as indicated by sugar content (Tables 6 and 7) as indicated by ºBrix value. The lowest sugar content was recorded in control treatment (Table 6). The sugar content between all concentrations of LOF (Table 6) and between doses of 75 l ha^{-1} and 100 l ha^{-1} (Table 7) were not significantly different.

Table 8
Effects of liquid organic fertilizers doses on nutrient uptake in experiment 2

LOF concentration	N uptake (g $plant^{-1}$)	P uptake (g $plant^{-1}$)	K uptake (g $plant^{-1}$)
Inorganic fertilizers	7.70 b	1.97 c	2.51 c
25 l ha^{-1}	8.17 b	2.39 b	2.69 b
50 l ha^{-1}	8.57 b	2.51 b	2.93 ab
75 l ha^{-1}	9.80 ab	2.70 a	3.22 a
100 l ha^{-1}	10.10 a	2.72 a	3.47 a

In a column, values having common letter(s) do not differ significantly at $p \leq 0.05$ as per LSD

Discussion

Vegetative growth of plants is represented by the number of the parameters of leaves, stem diameter, and plant height. The highest number of leaves and stem diameter were seen concentrations of 45 ml^{-1} and 60 ml l^{-1} in experiment 1. At the beginning of growth, plants can absorb nutrients from LOF, which are used by plants to support growth. Nitrogen (Table 1) is needed for vegetative growth. Nitrogen is a key element for producing vegetative biomass on the early growth of maize (Massignam et al., 2009).

The fact that LOF increased the leaf area index might be due to an increase in the number of leaves (Table 3). Fageria et al. (2009) stated that foliar application required higher LAI for absorbing applied nutrient solution in sufficient amounts. Table 3 shows that the application of LOF at a dose of 100 l ha^{-1} gave a higher value of leaf greenness compared to the other treatments. According to Nugroho (2015) nitrogen, in addition to stimulating plant growth, also gives the green color of the leaves. The darker the green color of leaves on corn plants, the higher the amount of nitrogen absorbed by the plants.

The application of LOF gave positive results in terms of the generative growth of plants. The results showed that the concentration of 60 ml l^{-1} gave the best results in terms of the weight of unhusked ears and husked ears, and the treatment with a dose of 100 l ha^{-1} gave the highest ear diameter and the heaviest weight of the ears. It can be inferred that the higher the dose or concentration of LOF given, the higher the generative growth of plants. According to Zafar et al. (2013), enlargement of ear diameter is related to the availability of phosphorus; phosphorus greatly influences the formation of ears.

Liquid organic fertilizer application increased the yield of sweet corn. This means that the contribution of nutrients from LOF can be complementary to the recommended solid fertilizer. The results of this study are supported in various other LOF studies. Minardi et al. (2015) found that banana corm extract increased the available P in soil. Aini et al. (2017) stated that the treatment of banana humps had a significant effect on the growth and yield of soybean. Working with *Gleicheni linearis* plant extract, Aulya et al. (2018) showed that the application of 100 mg l^{-1} was the most effective concentration in increasing plant height and leaf area of maize compared to a control.

The results showed that the treatment of a dose of LOF 100 l ha^{-1} gave a high degree of N, P, and K nutrient uptake, and this was attributed to the adequate supply of nutrients from LOF. This means that the higher the dose of LOF application, the higher the nutrient uptake of N, P, and K; in contrast to Muktamar et al. (2016) showed that increase in rates of LOF significantly raised nitrogen uptake by sweet corn but did not raise phosphorus and potassium uptake. Mukuralinda et al. (2010) also showed high P nutrient uptake due to the application of organic fertilizer compared to control.

The application of N nutrients in plants has a direct role in the formation of amino acids, proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids (Mokhele et al., 2012), which are needed for the vegetative growth process of plants and increase the greenness of leaves. Leaf N nutrient uptake has a close relationship with the leaf greenness level, characterized by the SPAD value. Increasing nutrient uptake of P enhanced the metabolic processes in the plant to become more active. P is known as the forming element of ATP for energy sources. In addition to P, K also plays an important role in improving the quality of plant fruit. The application of liquid organic fertilizer containing an element of K from coconut fiber extract improved the quality of sweet corn, which is characterized by a higher Brix value. Jifon and Lester (2009) found that the application of K fertilizer through leaves increased the sugar content of muskmelon plants. Sweet taste in sweet corn involves potassium nutrients, which play a role in the activation of many enzymes that has a role in metabolic processes in plants. Enzymes that play a role in sugar synthesis are activated by K (Prajapati & Modi, 2012).

The research showed that in both experiments, between the all concentration of the LOF and inorganic recommended fertilizers (experiment 1) as well as between the doses of the LOF and inorganic recommended fertilizers (experiment 2) gave the same effect on all parameters of growth and yield of sweet corn. Sweet corn plants fertilized with LOF had the same growth and yield with those of recommended fertilizers. Therefore, it implied that LOF could be a complementary fertilizer. Many researchers have also succeeded in applying the foliar application of LOF to sweet corn (Muktamar et al., 2017) and corn (Aulya et al., 2018).

From this experiment, it can be recommended to utilize local plant resources around farmers such as *lamtoro* leaves, banana humps, and coconut fibers to be used as LOF. The high content of N, P, K nutrients in LOF (Table 1) means that the application of liquid organic fertilizer is sufficient to meet the needs of N, P, and K nutrients for sweet corn plants. The mixture of plant residues contained the basic nutrient requirements for plants. *Lamtoro* leaves have a high content of protein, carbohydrate, and nitrogen (Devi et al., 2013). Banana humps contained P and K (Bahtiar et al., 2016). *Azospirillum*, *Azotobacter*, *Bacillus* sp., *Aeromonas* sp., and *Aspergillus niger* and the other phosphate solubilizing bacteria were identified in banana humps (Minardi, et al., 2015; Suhastyo et al., 2013). Banana humps naturally had bioactive compounds to be used as plant growth regulators (Ulfa et al., 2013), namely auxin, gibberellin and cytokinin. Coconut fiber had a high P and K (Abad et al., 2002). It can be said that the application of LOF supplied nutrients, microbes, and hormones leading to better growth, yield and quality of sweet corn.

The use of liquid organic fertilizer from plant materials can be used as a complementary fertilization technology in developing organic agriculture. However, the nutrient content of plant extract is dependent on the type of organic waste used, the fermentation period, and the storage of plant extract. In its application, liquid organic fertilizer needs to be mixed with a surfactant to increase the efficiency of uptake by plant leaves. The application of liquid organic fertilizer is an inexpensive and effective technology in organic farming. Therefore, local-based liquid organic fertilizers that contain extracts of *lamtoro*, banana hump, and coconut fiber have the potential to support organic farming. Further research is still needed to determine the appropriate concentration and doses of liquid organic fertilizer for each horticultural and food crop.

CONCLUSIONS

Application of LOF with the concentration of 60 ml l^{-1} or dose 100 l ha^{-1} showed the best growth, yield, and quality of sweet corn compared to lower concentrations or lower doses. Application of LOF improved the agronomic quality of sweet corn. Sweet corn sprayed with LOF absorbed a higher amount of N, P, and K. It is recommended that LOF could be a complementary fertilization technology in sweet corn organic farming.

ACKNOWLEDGEMENT

This research was funded by the Research Grant 2017, Faculty of Agriculture, University of Lampung. The authors would like to thank to Rugayah and Y. C. Ginting for scientific discussions during manuscript preparation.

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