



Comparative Effects of Soil and Foliar Applications of Tithonia-Enriched Liquid Organic Fertilizer on Yields of Sweet Corn in Closed Agriculture Production System

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ABSTRACT

Solid organic fertilizer is commonly applied for organic vegetable production in a closed agriculture production system as nutrient source. However, its availability is considered slow to sweet corn, and thus it is important to make additional nutrients supply as liquid organic fertilizer (LOF) through leaves. The experiments were conducted to compare effects of LOF application methods and to determine optimum LOF concentrations for sweet corn. Two separated factorial experiments, arranged in randomized complete block design with three replicates, were conducted from February to May and March to June 2015, respectively. The first factor was LOF application methods (soil and foliar) and the second factor was LOF concentration (0, 25, 50, 75, and 100 ppm). The observations focused on average weight of husked ear, length, weight and diameter un-husked ears. The results indicated that the effectiveness of soil application of LOF was 99.625 % as effective as foliar application in influencing sweet corn yields. Concentrations of LOF did not increase all observed variables, but yield attributes were within the range of variety description. It is concluded that in a closed production system, LOF application through soil is as effective as foliar application in affecting sweet corn yields.

INTRODUCTION

A closed production system is considered as organic agricultural practice with integral approaches to maintain the sustainability of biodiversity, biological cycles and soil biological activities (Brust, Egel, & Maynard, 2003). From agronomical point of views, vegetables produced in organic system must benefit other crops in a long run and maintain land resources sustainability. The use of solid organic fertilizer for organic sweet corn (*Zea mays* L. var. *Saccharata*) production must be complemented with the use of liquid organic fertilizer (LOF) to compensate slow released behavior of solid organic fertilizer availability to cultivated crops. It has been documented that solid organic fertilizer was not available to cultivated crops since it could take more than 12 weeks to complete its mineralization (Foth & Ellis, 1997). Other report also confirmed that after 16 to 24 weeks after compost application, there was only less than 10% of nitrogen content

get mineralized (Hartz, Mitchell, & Giannini, 2000). Mukhlis & Lestari (2013), for example, combined the use of biofertilizer with NPK to increase growth of sweet corn. Maswar & Soelaeman (2016) combined the use of solid organic fertilizer with NPK to maintain sustainable yields of maize grain. In addition, Khairuddin, Isa, Zakaria, & Rani (2018) also concluded that the increased of maize yields were attributed to combination application of organic fertilizers with synthetic fertilizer. In organic sweet corn production, it appeared that the application of solid organic fertilizer must be combined with liquid organic fertilizer as foliar application to increase sweet corn yields. Mukhtar, Sudjarmiko, Chozin, Setyowati, & Fahrurrozi (2017) concluded that the application of liquid organic fertilizer in a closed production system served as complementary nutrient supply of solid organic fertilizer.

There have been growing interests to use tithonia green biomass, a wild Mexican sunflower

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(*Tithonia diversifolia* (Hemsl.) A. Gray), as source of organic fertilizer for vegetable production since this plant has high nutrient content (Drechsel & Reck, 1997; Nziguheba, Merckx, Palm, & Mutuo, 2002). *Tithonia* plant contained 3.5% N, 0.37% P, and 4.1% K, respectively (Jama et al., 2000), while Olabode, Sola, Akanbi, Adesina, & Babajide (2007) concluded that organic matter, N, P, K, Ca, Mg, C, and C/N in *Tithonia* leaves were 24.04%, 1.76%, 0.82%, 3.92%, 3.07%, 0.005%, 14.00%, and 8:1, respectively. Recently, Fahrurrozi et al. (2017) reported that *Tithonia* leaves contained 6.55% N-total, 0.87% of P, 3.94 mg/100 g of K, 7.50 Me/100 g of Ca, 5.67 Me/100 g of Mg and 40.01% of organic C.

The applications of LOF are generally conducted by directly spraying to leave surfaces. According to Amanullah et al. (2014), maize growth and yield under drought condition were effectively increased by nutrient application through leaves. Nonetheless, Haytova (2013) proposed that the effectiveness of foliar application of organic fertilizers was determined by type of crops, form of fertilizer, concentration of fertilizer, application's frequency and phase of plant growth. However, yield of sweet corn (Fahrurrozi, Mukhtar, Setyowati, Sudjatmiko, & Chozin, 2016) did not increase with foliar application of LOF. These were presumably attributed to leaf morphology of these crops which have narrow leaf type. On the other hand, yields of broad leaves plants, including tomato (Zhai et al., 2009) and marrow (Kostova, Haytova, & Mechandjiev, 2014), had positive response foliar application of LOF.

According to Fernandez & Eichert (2009) crop responses to foliar fertilizations are often inconsistent and not replicable elsewhere. Such reason endorses a more comprehensive finding on the use of tithonia-enriched LOF for sweet corn production in closed agriculture production systems. It appeared that direct application of LOF into soil would be an alternative to support the less availability of solid organic fertilizer. This is very important since improved fertilizer and soil management could maintain highly productive sweet corn yield. This experiment aimed to compare the methods of LOF applications and to determine the optimum concentrations of tithonia-enriched LOF on yields of sweet corn in closed agriculture production system.

MATERIALS AND METHODS

Experiments were conducted at 1,054 m above sea level at 3°27'30.38" South Latitude and

102°36'51.33" East Longitude in a Closed Agriculture Production System (CAPS) research station, Air Duku Village, Sub-district of Selupu Rejang, Municipality of Rejang Lebong, Province of Bengkulu, Indonesia. CAPS is a model for integration of organic farming and dairy cattle farm to produce organic vegetables with the restriction of external synthetic agrochemical inputs. In this model, cattle waste and organic farming by products were used to produce solid and liquid organic fertilizers to support growth and yields of vegetable crops. The cropping systems in CAPS were monoculture, multiple as well as in crop rotations that are alternately established in the same agricultural land. Overall objectives of CAPS are to improve the efficiency of agrochemical inputs and to maintain the sustainability of agricultural land.

Two separated factorial experiments were conducted from February to May and March to June 2015, respectively, arranged in a complete randomized block design with three replicates. The first factor was liquid organic fertilizer (LOF) application techniques (soil and foliar) and the second factor was LOF concentrations (0, 25, 50, 75, and 100 ppm). Local-based LOF was produced by aerobically incubating the mixtures of 10 kg cattle's feces, 20 l cattle's urine, 5 kg of topsoil, 10 kg of *Tithonia diversifolia* (Hemsley) A. Gray, 20 ml EM-4, 0.25 kg white sugar with additional water to reach a volume of 200 l, in the blue plastic container for four weeks. All material composed LOF were collected from surrounding CAPS station. *Tithonia diversifolia* (Hemsl.) A Gray, a shrub in the family *Asteraceae*, is widely grown along feeder roads, waterways and farm boundaries as well as on cultivated farmlands in this experimental site. In addition, C cattle feces and urine, as well as top soil, were collected from CAPS station. LOF was produced as proposed by (Mukhtar et al., 2016). Laboratory analysis indicated that LOF used in this experiment contained 3.36%, 146 ppm, and 0.0325% of N, P, and K, respectively.

Two weeks before planting, experimental plots of Inceptisol were cultivated, uniformly harrowed and 15 soil beds of 5 m x 1 m in each block were raised. Soil beds were distanced 0.5 m within the block and 1 m between the blocks. Experimental site has been continuously planted with organic vegetables since 2011 and fertilized with vermicompost at rate of 30 t/ha/year (two growing-seasons per year). Seed of sweet corn (cv. Talenta) was sown in the soil bed at 0.7 m x 0.2 m spacing. A week before planting, each

soil bed was fertilized with 15 t/ha of vermicompost. Weeds were manually removed every other week controlled throughout the growing season.

Treatment applications were conducted from 08.00 to 10.00 hours at no wind and rain using knapsack sprayer. At 2, 3, 4, 5, 6, 7, and 8 weeks after planting, every single plant was sprayed with 25, 25, 50, 100, 150, 250, and 250 ml LOF, respectively. Harvesting of sweet corn was conducted at 70 days after planting. Treatment effects were observed by measuring (1) weight of husked ear (g), (2) length of un-husked ear (cm), (3) weight of un-husked ear (g), and (4) diameter of un-husked ear (cm). Data of each variable from two sets of experiments were pooled together, averaged and subjected to analysis of variances. Means of treatments were compared

using Least Significant Difference at $P < 0.05$.

RESULTS AND DISCUSSION

Results from this experiments indicated that application methods of liquid organic fertilizer (LOF), LOF concentrations and interaction between application method and LOF concentration did not significantly affect weight of husked ear, length of un-husked ear, weight of un-husked ear, and diameter of un-husked ear of sweet corn (Table 1).

Both soil and foliar applications of tithonia-enriched LOF had similar effects on all observed variables (Table 1). Foliar application of LOF was conducted by spraying it on the surface of the leaves, while soil application was executed by placing LOF into the soil around the plants.

Table 1. Effects of application techniques and concentrations of tithonia-enriched liquid organic fertilizer on yields of sweet corn

Treatments	Weight of husked ear (g)	Length of unhusked ear (cm)	Weight of unhusked ear (g)	Diameter of unhusked ear (cm)
Application Techniques (A)				
Soil	235.17 a	17.09 a	171.05 a	4.58 a
Foliar	236.51 a	16.79 a	176.34 a	4.54 a
Prob. F > 5 %	0.9181	0.3247	0.52	0.57
Concentrations (B)				
0 ppm	220.43 a	16.63 a	165.50 a	4.50 a
25 ppm	232.28 a	17.10 a	171.52 a	4.53 a
50 ppm	225.52 a	16.88 a	168.75 a	4.57 a
75 ppm	270.63 a	17.45 a	187.75 a	4.71 a
100 ppm	230.33 a	16.64 a	174.97 a	4.48 a
Prob. F > 5 %	0.1516	0.4227	0.4872	0.4041
Interactions (AxB)				
Soil x 0 ppm	226.77 a	16.85 a	171.70 a	44.74 a
Soil x 25 ppm	212.67 a	17.12 a	159.47 a	45.99 a
Soil x 50 ppm	211.70 a	16.80 a	156.00 a	45.25 a
Soil x 75 ppm	305.73 a	17.73 a	196.67 a	47.19 a
Soil x 100 ppm	218.96 a	16.97 a	171.43 a	45.92 a
Foliar x 0 ppm	214.10 a	16.41 a	159.30 a	45.29 a
Foliar x 25 ppm	251.90 a	17.09 a	183.57 a	44.64 a
Foliar x 50 ppm	239.33 a	16.96 a	181.50 a	46.15 a
Foliar x 75 ppm	235.53 a	17.16 a	178.83 a	47.02 a
Foliar x 100 ppm	241.70 a	16.31 a	178.50 a	43.70 a
Prob. F > 5 %	0.0914	0.8901	0.3365	0.7029

Remarks: Treatment means (of two experiments) in the same column followed by the same letter are not significantly different according to Least Significant Difference at $P < 5\%$

Since both techniques used the same volume of LOF, any spilled over LOF from the leaf surfaces will hit soil surface around the base of the stem and eventually available for sweet corn. This might explain why soil and foliar application of LOF have the same effects on yields of sweet corn.

A research conducted by Ling & Silberbush (2002) concluded that both soil and foliar application of nitrogen–phosphorus–potassium (NPK) fertilizers applied to maize (*Zea mays* L.) had similar effects on crop growth and yields. In addition, soil and foliar application of urea had the same effects on growth and yield of grape (Brataševic, Sivilotti, & Vodopivec, 2013). The research findings, however, was not similar with that reported by Khan, Memon, Imtiaz, & Aslam (2009), where nitrogen application through leaves in wheat significantly increased plant height, spike length, number of grains per spike, weight of hundred grain, biological yield, grain yield and N uptake.

Fertilizer through leaves provides practical aspects to fulfill the advancement of soluble fertilizer and machinery technologies and to reduce the risks of physiological diseases of plants caused by deficiency or scarcity of a specific element (Fageria, Filho, Moreira, & Guimarães, 2009). Nonetheless, foliar fertilizing could not substitute soil fertilization and served as supplement of soil applications (Kannan, 2010). Harbi, Ghoneim, Modaihsh, & Mahjoub (2013) reported that foliar application of phosphor was only effective when no soil application of phosphor was applied. This experiments were conducted under organic environment where the sites have been continuously fertilized with vermicompost at rate of 30 t/ha/year (two growing-season per year) for organic vegetable productions since 2011. The residual effects of organic fertilizer might have decreased the effectiveness of foliar application. It appeared that foliar feeding might only be effective when soil nutrient was less available or insufficient. This was in line with research conducted by Mukhtar, Sudjarmiko, Chozin, Setyowati, & Fahrurrozi (2017) who concluded that the use of LOF must be accompanied by the use of solid organic fertilizer in order to increase growth and yield of sweet corn.

This research results suggested that under organic production system, the application of tithonia-enriched LOF could be effectively applied through both soil and foliar applications. Should

it considered, foliar application is the standard method for applying liquid fertilizer in organic sweet corn production, the results, however, found that the effectiveness of soil application of LOF was 99.43% as effective as foliar application in influencing the weight of husked ears (235.17 g vs 236.52 g) and 97.00% for weight of un-husked ears (171.05 g vs 176.34 g). In addition, the effectiveness of soil application of LOF to influence length of un-husked ears and diameter of un-husked ears were 101.19 % (17.09 cm vs 16.79 cm) and 100.88 % (4.58 cm vs 4.54 cm), respectively. Therefore, it was suggested that the effectiveness of soil application in influencing sweet corn yields was, in average, 99.625 % as effective as foliar application.

From the practical point of view, there is no point to have foliar application tithonia LOF for organic sweet corn production since it will cost farmers, due to fuel, equipment, and labor costs, and there may not be sufficient time to apply sufficient amount of the needed nutrient. Consequently, complementary tithonia-enriched LOF supply for sweet corn production could be directly sprayed to the soil and incorporated with sprinkled irrigation to save labor costs. Abbas & Ali (2011) suggested that foliar fertilization is usually practiced as supplement of soil fertilization. The effectiveness of LOF application for organically grown sweet corn might be improved by proper management of spraying and frequent applications with low dosages and application through sprinkled irrigation.

This experiment revealed that concentration of LOF did not significantly affect weight of husked ear, length of un-husked ear, weight of un-husked ear, and diameter of un-husked ear of sweet corn (Table 1). Although it was not significant, features observed variables were in accordance to variety descriptions of sweet corn variety. Average weight, length and diameter of husked ears of sweet corn from this experiment were 235.84 g, 16.90 cm and 4.56 cm, meanwhile its variety description on husked ear's weight and un-husked ear's diameter of sweet corn of Talenta variety were 221.20 – 336.70 g and 4.50 – 5.40 cm, respectively. However, the average length of un-husked ear of sweet corn from this experiment was slightly lower than variety descriptions (*i.e.*, 19.70 – 23.50 cm). Insignificant effects of LOF concentrations (25 to 100 ppm) on weight of husked ear, length of un-husked ear, weight of un-husked ear, and diameter of un-husked ear of sweet corn might have been resulted from

continuous applications of vermicompost at 30 t/ha/year to the experimental site since 2011 and be sufficient enough to support sweet corn growth and yields.

Soil analysis before planting indicated that experiment site had 6.14%, 0.32%, 58.38 ppm, and 3.6 me/100 g of soil organic C, total N, P_2O_5 , and K, respectively. Based on the soil classification systems issued by Pusat Penelitian Tanah (1983), these values were classified to be very high for organic C, medium for nitrogen, low for phosphorus and potassium. The residual effects of solid organic fertilizers might have brought about such phenomenon. It is presumably that high content soil organic C leveled the sweet corn yields, especially with additional 15 t/ha of vermicompost applied in 2015. Ros, Klammer, Knapp, Aichberger, & Insam (2006) found that long-term compost treatments (over a period of 12 years) increased organic-C and total-N levels in soils and had positive effects on the soil biota. Research conducted by Jackson, Brinton, Handley, Hutchinson, & Hutton (2013) suggested that compost applications had residual effect on nutrient availability in the soil and yield of sweet corn. With respect to nutrient uptakes of sweet corn, although how many nutrient uptakes by sweet corn, research conducted by Mukhtamar et al. (2016) in the same cultural practice environment concluded that nitrogen, phosphorus and potassium uptakes by Talenta sweet corn were 650 mg/plant, 48 mg/plant and 884 mg/plant, respectively. They also reported that nitrogen, phosphorus and potassium contents in this sweet corn were 1.84%, 0.15% and 2.48, respectively. The magnitude of nutrient uptakes and contents in sweet corn was presumably sufficient enough to support growth and development. Research conducted by Marlina et al. (2017) reported that fertilizing sweet corn with 5 t/ha organic fertilizer brought about nitrogen, phosphorus and potassium uptakes as much as 16.28 mg/plant, 3 mg/plant and 12.08 mg/plant, and produced weight husked ears of 333.68 g/plant. This number was higher than results from this experiment with average of husked ears ranged from 220.43 to 270.63 g/plant, which was still within the range of its variety description.

The insignificant effects of LOF concentrations on weight of husked ear, length of un-husked ear, weight of un-husked ear, and diameter of un-husked ear of sweet corn could not be assumed resulted from poor nitrogen contents of LOF used in these

experiments. Laboratory analysis of LOF used in this experiment indicated that nitrogen, phosphorus and potassium contents were 3.36%, 146 ppm, and 0.0325%, of N, P, K, respectively. Nitrogen content of this LOF complied with Indonesian Standardization Board (SNI 19-7030-2004) for organic fertilizer where total N should be $> 0.4\%$. However, this was not true for the case of P and K which must be $> 0.10\%$ (P_2O_5) and $> 0.20\%$ (K_2O), respectively. Low content of phosphorus (146 ppm) and potassium (0.0325%) in LOF and phosphorus (58.38 ppm), and potassium (3.6 me/100 g) in soil might have been responsible to leveling yields of sweet corn. According to Marschner (2012), phosphorous is one macro nutrient and plays important roles as macro-molecular structures in nucleic acids by inducing early growth and development as well as to maintain high yields and quality of many crops. The magnitude of this nutrient in plant tissues was also determined by its availability in rhizosphere. In addition, although potassium does not form any vital organic compound in plants, the presence of potassium is essential for plant growth and development through its effects on enzyme activities (Uchida, 2000), especially in increasing disease resistance, strengthening cell walls and improving the quality of many fruits. Failure to maintain sufficient potassium in rhizosphere of organic crop production system brought about poor water use efficiency, greater pest problems, decreased harvest quality and eventually reduced yields (Mikkelsen, 2007).

Regardless the residual effects of solid organic fertilizers on sweet corn yields, there some explanations might reveal such insignificant effect of LOF concentrations on sweet corn yields. In line with Haytova (2013) who concluded that LOF concentration and volume determined the effectiveness of its application in crop production, it appeared that all treatments in this experiment did not adequate to increase growth and yield of sweet corn. Increasing the quality of tithonia-enriched LOF should be considered in order to have better nutrient contents, for example, by manipulating the composition of green plant of *Tithonia diversifolia* and cattle's feces could be formulated to have better effect of tithonia-enriched LOF in increasing sweet corn growth and yields. However, increasing LOF concentration might be carefully implemented, since higher concentration could delay nutrient uptakes by plant (Sopha & Uhan, 2013). The quality of LOF

could be also improved by evaluating better green biomass or better animal feces as nutrient sources in production of LOF. Another thing that might be done is to increase of volume of LOF applications to sweet corns. These experiments used a volume of 850 ml LOF per plant during the course of vegetative growth. Increasing the volume of LOF application to organic sweet corn production up to 1000 or 1250 ml/plant might be evaluated in a future research.

The effects of tithonia-enriched LOF on sweet corn yield could have been better if its application was incorporated with the use of surfactant liquid to improve effectiveness of foliar fertilizing, for example in muskmelon (Lester, Jifon, & Makus, 2006) and onion (Safikhani, Chaichi & Mohammadi, 2018). Haleema, Rab, & Hussain (2018) used a surfactant at the rate of 0.5 cc / 100 ml of water was added for better retention of foliar application in tomato production. Such increase was attributed to increase LOF penetrations through leaf stomata and cuticles reaching leaf cells (Fernandez & Eichert, 2009). It is therefore very important to find suitable organic surfactants for organically grown sweet corn by using green mass available in surrounding production site. Other reason might explain the low effectiveness of tithonia-enriched LOF on sweet corn yields might be related to the narrow-leaf structure of sweet corn. Dela Pena, Bartolome, & Banwa (2013) and Fahrurrozi et al. (2016) suggested that foliar fertilization in narrow leaves was less effective than in broad leaves. Zhai et al. (2009) also reported that local based LOF increased yields of tomato and ground nut (Muchli, Ningsih, & Purba, 2019).

CONCLUSION AND SUGGESTION

In a closed agriculture production system, soil application of tithonia-enriched liquid organic fertilizer is as effective as foliar application in promoting sweet corn yields. The effectiveness of soil application was 99.625% as effective as foliar application in influencing sweet corn yields. In addition, although concentrations of tithonia-enriched liquid organic fertilizer did not increase yield components of sweet corn, yields attributed to weight of husked ear, length of unhusked ear, weight of un-husked ear, and diameter of un-husked ear of sweet were relatively within the description of sweet corn variety used in this experiment. Further studies need to be established to distinguish the residual effects of solid organic fertilizers and additional liquid organic fertilizer on nutrient uptakes and yields of sweet corn in closed agriculture production system.

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