**TITLE**

Comparative effects of soil and foliar applications of tithonia-enriched liquid organic fertilizer on yields of sweet corn in closed agriculture production system

**ABSTRACT**

A closed agriculture production system, a practice of organic production, usually applies solid organic fertilizer for nutrient source. The slow-release characteristic of solid organic fertilizer endorsed the application of liquid organic fertilizer (LOF) through leaves to fulfill required nutrients. Experiments were conducted to compare LOF application methods and to determine optimum LOF concentrations for sweet corn. Two separated experiments were conducted from February to May and March to June 2015, respectively, arranged in factorial randomized complete block design with three replicates. The first factor was LOF application methods (soil and foliar) and the second factor was tithonia-enriched LOF concentration (0, 25, 50, 75, and 100 ppm). Observations focused on average weight of husked ear (g), length of unhusked ear (cm), weight of unhusked ear (g) and diameter of unhusked ear (cm). Results indicated that soil and foliar applications of LOF have the same effects on sweet corn yields. Concentrations of tithonia-enriched LOF did not increase weight of husked ear, length of unhusked ear, weight of unhusked ear, and diameter of unhusked ear of sweet corn. It is concluded that in a closed production system, LOF application through soil is as effective as foliar application in affecting sweet corn yields.

**KEYWORDS**

Sweet corn; Tithonia diversifolia; Liquid organic fertilizer; Foliar application; Soil application

**INTRODUCTION**

Sweet corn production in a closed production system is a practice of organic vegetable production, a system approach where the production was intentionally designed to promote biodiversity, biological cycles, and soil biological activities (Brust *et al*., 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 in organic vegetable production, including sweet corn (*Zea mays* L. var. Saccharata), must be complemented with the use of liquid organic fertilizer (LOF) in order to compensate delayed effects of solid organic fertilizer availability to cultivated crops. Slow availability takes place due to the fact that solid organic fertilizer takes longer time to mineralized than crop life-cycles. According to Foth and Ellis (1997) within 90 days after solid organic fertilizer application, there were only 50% of its N, P, and K got mineralized. Another report confirmed that most composts mineralized <10% of initial N content during four to six months after the application into the soil (Hartz *et al*., 2000). It is therefore recommended to combine soil and foliar applications of organic fertilizers to increase crop productivity and yield quality of sweet corn in a closed production system. Mukhlis and Lestari (2013), for example, combined the use of biofertilizer with NPK to increase growth of sweet corn. In addition, Maswar and Soelaeman (2106), combined the use of solid organic fertilizer with NPK to maintain sustainable yields of maize grain.

There have been growing interests to use tithonia’s green biomass for organic vegetable production (Drechsel and Reck, 1998; Jama *et al*., 2000; Nziguheba *et al*., 2002; Olabode *et al*., 2007) due to the relatively high nutrient concentrations found in its biomass. Jama *et al*. (2000) reported that green leaf biomass of tithonia contained 3.5% N, 0.37% P, and 4.1% K on a dry matter basis. In addition, Olabode *et al*. (2007) reported that organic matter, N, P, K, Ca, Mg, C, and C/N in *Tithonia diversifolia* were 24.04%, 1.76%, 0.82%, 3.92%, 3.07%, 0.005%, 14.00%, and 8:1, respectively. The use of tithonia plants as a source of LOF for organic vegetable production in humid tropical highland of Bengkulu, Indonesia has been introduced by Setyowati (2014) and Fahrurrozi *et al*. (2015, 2016).

The applications of LOF are generally conducted by directly spraying to leave surfaces. Foliar nutrients application is very effective to support growth and yield of maize plants under drought condition (Amanullah *et al*., 2014). According to Haytova (2013), effectiveness of foliar application of organic fertilizers was determined by crop species, fertilizer form, concentration, frequency, and the stage of plant growth. However, foliar applications often fail to meet the demand of nutrients at specific vegetative or generative stages of growth. Our reports confirmed that the use of LOF through foliar applications did not significantly improve yields of sweet corn (Fahrurrozi *et al*., 2015), carrots (Fahrurrozi *et al*., 2016). Less response of both sweet corn and carrots to LOF might be related to the fact that this crop has narrow leaf morphology, since foliar fertilization is more effective in broad leaves than narrow leaves (Hagin and Tucker, 1982). The use of local based LOF had been reported to successfully increase yields of broad-leaf vegetables such as in tomato (Zhai *et al*., 2009) and marrow (Kostova *et al*., 2014).

In organic sweet corn production which solid organic fertilizer mainly serves as a source of nutrient, direct application of LOF into the 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. According to Fernandez and 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 in highland of Rejang Lebong, Bengkulu, Indonesia. 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 1.050 m above sea level in Rejang Lebong highland (3°39'35.1" South Latitude and 102°34'23.6" East Longitude) in a Closed Agriculture Production System (CAPS) research station. 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 byproducts 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 experiments were conducted from February to May and March to June 2015, respectively, arranged in factorial completely randomized block design with three replicates. The first factor was application techniques of LOF (soil and foliar) and the second factor was five levels of LOF concentrations (0, 25, 50, 75, and 100 ppm). Homemade LOF was made of cattle’s feces, cattle’s urine, topsoil, green mass of *Tithonia diversifolia* (Hamsley) A. Gray, solution of 24-hour incubated 20 ml EM4 + 0.25 kg white sugar with weight ratio of 2:4:1:2:4. All these materials were together aerobically incubated in a blue plastic container to reach a volume of 200 L for five weeks.

Experimental plots were cultivated, harrowed and 15 soil beds of 5 m x 1 m in each block were constructed two weeks before planting. The experimental plots were separated by 0.5 m within the block and 1 m between the block. Experimental plots have been continuously planted with organic vegetables since 2011 where organic fertilizer (vermicompost) at rate of 30 ton ha-1 year-1 (two growing season year-1). No additional synthetic fertilizer had been applied to soil since 2011. Sweet-corn seeds (cv Talenta) were planted at a spacing of 0.7 m x 0.2 m. A week before planting, each soil bed was fertilized with 15 ton ha-1 of vermicompost. Manual controls of weeds were bi-weekly controlled throughout the growing season. At the time of weeding, soil around the stem was raised to prevent up-rooting.

Each plant received 25, 25, 50, 100, 150, 250, and 250 mL LOF, respectively at 2, 3, 4, 5, 6, 7, and 8 weeks after planting. Application was conducted during calm day and no rain using knapsack sprayer. Sweet-corns were harvested at 70 days after planting. Crop responses to treatments were measured by means of weight of husked ear (g), length of unhusked ear (cm), weight of unhusked ear (g), and diameter of unhusked ear (cm).

The effects of treatments were determined by analysis of variances. Means of treatments were compared using Least Significant Difference at 95% level of confidence.

**RESULTS AND DISCUSSION**

Results indicated that the use of tithonia-enriched LOF (concentrations, application methods and its interactions) have the same effects on weight of husked ear, length of unhusked ear, weight of unhusked ear, and diameter of unhusked ear of sweet corn (Table 1).

Results indicated that both soil and foliar applications of tithonia-enriched LOF had similar effects weight of husked ear, length of unhusked ear, weight of unhusked ear, and diameter of unhusked ear of sweet corn (Table 1). This finding was in accordance to those reported other researchers where both soil and foliar application of urea had the same effects on growth and yield of pineapple (Reddy *et al*., 1983), grape (Bratasevec *et al*., 2013), and soybean (Ashour and Thalooth, 1983). This result, however, was not similar to that reported by Khan *et al*. (2009), foliar application of urea significantly increased plant height, spike length, number of grains per spike, hundred grain weight, biological yield, grain yield and N uptake by wheat. Although foliar application provides practical aspects to comply 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 particular element (Fageria *et al*., 2009), foliar fertilizing could not substitute soil fertilization and served as supplement of soil applications (Kannan, 2010). It appeared that foliar feeding might only be effective when the availability of soil nutrients was less available or insufficient.

This finding suggested that application of tithonia-enriched LOF could be effectively applied through both soil and foliar applications. From the practical point of view, there is no point to have foliar application tithonia LOF for sweet corn production since it will cost farmers. Consequently, the complementary nutrient supply of tithonia-enriched LOF for sweet corn production could be directly sprayed to the soil, *i.e.* incorporated with irrigations, drips or sprinkle irrigation to save labor costs. Abbas and Ali (2011) suggested that foliar fertilization is usually practiced as supplement of soil fertilization. Previously, McCall (1980) concluded that effectiveness of foliar fertilizer application might be improved by proper management of spraying pressures, frequent applications with low dosages and application through drip or sprinkle irrigation. However, it will be very challenging for farmers to install drip or sprinkled irrigation systems for their organic sweet corn production in the farm to have successful LOF applications, where production costs should be optimally reduced.

It might be appeared that those above results were related to the fact that concentrations of tithonia-enriched LOF (25 to 100 ppm) did not increase weight of husked ear, length of unhusked ear, weight of unhusked ear, and diameter of unhusked ear of sweetcorn compared to without LOF (Table 1). It was possible that continuous applications of vermicompost since 2011 in the experiment plots at the rate of 30 ton ha-1 year-1 are 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-100g of C-organic, N-total, P205, and K, respectively. The residual effects of solid organic fertilizers might bring about such phenomenon. It is presumably that high content C-organic leveled the sweet corn yields, especially with additional 15 ton ha-1 of vermicompost applied in 2015. Ros *et al*. (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 et al. (2013) suggested that compost has a residual effect on the soil nutrient and sweet corn yield. The average weight of husked ear, length of unhusked ear, and diameter of unhusked ear of sweet corn from this experiment were 235.84 g, 16.90 cm and 4.56 cm. These features somehow comply to variety descriptions of Talenta sweet corn used where the weight of husked ear and diameter of unhusked ear were 221.20–336.70 g and 4.50–5.40 cm. However, the average length of unhusked ear of sweet corn from this experiment was lower that variety descriptions (*i.e*., 19.70–23.50 cm). 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. Since the effectiveness of crop responses to LOF is also determined by its concentration (Haytova, 2013), it appeared that LOF concentration used in this experiment was not sufficient enough to support growth and yields of sweet corn. In addition to apply tithonia-enriched LOF with higher concentration, manipulating the composition of green plant of *Tithonia diversifolia* (Hamsley) A. Gray and cattle’s feces would be one of possible way to have better effect of tithonia-enriched LOF that will further increase growth and yields of sweet-corn. Tithonia-enriched LOF used in this experiment contained 3.36%, 146 ppm, and 0.0325% of N, P, and K. Nitrogen content of this LOF somehow comply to the standard quality for organic fertilizer issued by Indonesian Standardization Board (SNI 19-7030-2004) where total N should be >0.4%, but not the case of P and K which must be >0.10% (P2O5) and >0.20% (K2O). This low content of P (146 ppm) and K (0.0325%) might have presumably limited LOF effects on sweet corn growth and sweet corn yields. However, increasing LOF concentration might be carefully implemented, since research conducted by Sopha and Uhan (2013) suggested that higher concentration of LOF could delay nutrient uptake by plant, *i.e*., Chinese mustard (*Brassica juncea* L.).

Another reason might be related to the absence of surfactant during the application of tithonia-enriched LOF. The use of surfactant was designed to improve liquid foliar fertilizing (Holloway and Stock, 1990) and hence improve crop yields, for example in muskmelon (Lester *et al*., 2006). The use of leaf surfactant during LOF applications will increase its penetrations into leaf cells through leaf stomata and hydrophilic pores present on the leaf cuticles (Fernandez and 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.

The solubility of tithonia-enriched LOF must be another aspect needed to be closely paid attention. According to McCall (1980) fertilizer used for foliar application must be soluble in water and did not have burning effect to targeted leaves. In addition, less effective of foliar application might also take place when excessive solution is applied and rain falls shortly after application. 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. Hagin and Tucker (1982) concluded that foliar fertilization is more effective in broad leaves than narrow leaves. Dela-Pena *et al*. (2013) specifically concluded that tithonia-based organic fertilizer was effective to increase yield of leafy vegetables, such as pechay plant (*Brassica rapa* L.). Other reports also confirmed that the use of local based LOF successfully increased yields of broad-leaf vegetables such as tomato (Zhai *et al*., 2009). So did the effects of foliar application of micro nutrient did not increased the yields of broccoli (Yildrim *et al*., 2014) and potato (Qadri *et al*., 2015).

**CONCLUSIONS 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. It is also concluded that concentrations of tithonia-enriched liquid organic fertilizer did not influence sweet corn yields. Further studies need to be established to distinguish the residual effects of solid organic fertilizers and additional liquid organic fertilizer on sweet corn yields in closed agriculture production system.

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Table 1. Means values of weight of husked ear, length of unhusked ear, weight of unhusked ear, and diameter of unhusked ear of sweet corn as affected by application techniques and concentrations of **tithonia-enriched liquid organic fertilizer**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 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 |

*Note: Treatment means (of two experiments) in the same column followed with the same letter are not significantly different according to Least Significant Difference at 5%*