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Weed-based liquid organic fertilizer increased growth and yields of organically grown sweet corn

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Abstract Results indicated that the use of weed-based liquid organic fertilizer (LOF) elevated sweet corn growth and yield. The use of weed-based LOF had a greater impact on generative growth than on vegetative growth of sweet corn. The best concentration of LOF for increasing plant height, fresh weight of unhusked ear, length of unhusked ear, and sweetness level of sweet corn were 57 %, 68 %, 72 %, and 76 %, respectively. These results are provided important information about how the use of weeds in LOF production for maximizing production of organic sweet corn.

Keywords: Liquid organic fertilizer; Organic vegetables; Sweet corn; Weed-based fertilizer

Introduction

Consumer demands to organic sweet corn is steadily increased in line with the growing need for organic crop. Organic sweet corn area harvested in United State increased from 6,239 acres in 2008 to 11,059 acres in 2019 (Kaiser and Ernst, 2021). Such increased was related to increasing consumer demands. In Indonesia, sweet corn per capita consumption steadily increased. According to Sabarella *et al*. (2022) annual per capita consumption of sweet corn was 1.335 kg (2017), 1.534 kg (2018), 2.034 kg (2019), 2.625 kg (2020), 1.782 kg (2021) and 2.272 kg (2022) with the annual rate of increase of 1.44 kg. Such increasing trends is followed by increased in organic sweet corn demands since Indonesian consumer demands for organic vegetables is among the top three people's choices for organic consumption (David and Alkausar, 2023). Vegetable growers must consistently offer enough organically cultivated sweet corn to comply growing customer demand for organic crops.

Research conducted by El-Bassel and El-Gazzar (2019) concluded that yield of organically grown tomatoes, eggplant, squash, lettuce, cabbage, and

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carrots, were better than those of non-organic. So did its vitamin C, β-carotene, vitamin E, phosphorous, and calcium. The uses of solid organic fertilizer, especially vermicompost, were reported to increase growth and yield of sweet corn (Emam *et al*., 2020) and sweetness of sweet corn (Talip and Villaver, 2022). However, Muktamar *et al.* (2017) concluded that the uses of vermicompost in sweet corn production must be combined with liquid organic fertilizer (LOF). This amendment compensates the solid organic fertilizer's gradual release, which could postpone early crop development and reduced crop yields.

Although there are many commercial LOFs available in the market, organic agriculture production system emphasized the utilization of local resources, including weeds around the production areas. Leaves of many weeds, including *Tithonia diversifolia*, *Amaranthus spinosus, Gliricidia sepium*, *Wedelia trilobata*, *Leucaena leucocephala*, *Chromolaena odorata, Colopogonium mucunoides, Chromolaena odorata*, *Ageratum conyzoides*, and *Eichhornia crassipes*, are several examples for nutrient sources in LOF production. Susilo *et al*. (2017) evaluated the effectiveness of several weed combinations of *T. diversifolia*, *T. procumben*, *A. conyzoides* as major component of LOF and concluded that egg-plants fertilized with this combination produced the highest fruit weight among other plant-based LOFs. Recently, Harbi *et al*. (2021) concluded that the used of LOF made from *E. crassipes* and *C. odorata* increased plant height, tiller number, leaf number and chlorophyll of elephant grass. With respect to nutrient composition in weed-based LOF, Muktamar *et al.* (2020) revealed that LOF of *T. diversifolia* and *A. conyzoides* combination produced the highest N, P, and Mg contents compared to other weed combinations. This combination has been reported to increase growth and yield of organically grown carrot and green onion, as well as the nutrient uptakes (Fahrurrozi *et al*., 2022). However, the effects of LOF composed of *T. diversifolia* and *A. conyzoides* combination on growth of sweet corn was less appraised. The purpose of this experiment was to ascertain the effects of weed-based LOF fertilizer on growth and yields of sweet corn cultivated under organic production system.

Materials and methods

This research was established at the Closed Agriculture Production System Research Station of Universitas Bengkulu, Indonesia from April to July 2021 (3°, 27’, 30.38” South Latitude and 102°. 36’, 51.33’’ East Longitude). The soil type of this is classified as Inceptisol, located at $^{+}/_{-}$ 1.050 m above sea level, and has been repeatedly served as organic vegetable production areas since 2011.

The experiment was arranged in complete randomized block design with three replicates. Treatments were consisted of five levels LOF concentrations (0, 25, 50, 75, and 100 %). Production of weed-based LOF was established as method proposed by Muktamar *et al.* (2020) by composting the mixture of dairy cattle's feces and urine, top soil, green leaves of *T. diversifolia* & *A. conyzoides*, and water. All composing LOF materials were fermented aerobically in a plastic container for five weeks. Laboratory analysis indicated that pH of this LOF was 7.36 pH, and contained 2.23 %, 0.03 %, 0.17 %, 0.035 %, 0.025 %, 0.51 ppm, and 2.63 ppm of N, P_2O_5, K_2O, Ca, Mg, Cu, and Zn, respectively.

Plowing and harrowing of the experimental site were executed at two weeks before planting. Upon analysis of composite soil samples from the experimental site, it was found that the pH of the soil was 5.03 and that the nutrients present were 0.22 % N, 5.24 ppm P, 0.35 me/100g K, and 2.44 % organic C. Moreover, 10 M kg ha^{-1} of vermicompost was homogenously amended into the experimental soil a one week before planting. This vermicompost contained as 2.15, 0.24, 0.55, and 25.6 g kg^{-1} of N, P, K, and organic C, respectively (Muktamar *et al.*, 2017). Experimental units of 15 soil beds (5 m-length x 1 m-width x 0.25m-height) were created at one week before planting. Each experimental unit was 0.75 m away within the replication and 1 m away between the replications.

Seeds of sweet corn (CAPS hybrid) were sown on April 5th, 2021 by placing it into 5 cm in depth, at the 0.25 m spacing within the row and 0.75 m between the rows to establish 30 plants per plot. Sweet corn was irrigated as necessary during the absence of precipitations. Manual weeding was conducted at 2, 4, and 6 weeks after planting. To strengthen plant stands, the soil surrounding the stem was lifted during the weeding. Sweet corns were sprayed once a week with the biofungicide Glio ® and the biopesticide Pestona ® to prevent disease outbreaks. Treatments' applications with volumes of 50, 100, 150, 200, 250, 300, and 350 mL $plant^{-1}$, were made 2, 3, 4, 5, 6, 7, and 8 weeks after planting, respectively.

Responses of sweet corns to treatments were evaluated in terms of plant height, leaf number, leaf greenness, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, fresh weight of husked ear, fresh weight of unhusked ear, diameter of husked ear, diameter of unhusked ear and level of sweetness. Before doing an analysis of variance using the Statistical Analysis System at $P \leq 0.05$, the data were subjected to a homogeneity test. Trends of significant treatment responses were evaluated by using orthogonal polynomial analysis (Gomez and Gomez, 1984).

Meteorology, Climatology, and the Geophysical Agency Bengkulu (ID WMO: 96255) provided the weather data for the experiment, which included monthly rainfall, daily relative humidity, and daily air temperatures.

Results

Soil and weather

In terms of soil pH, it was recorded at 5.03 at one week before planting. Soil pH increased as sweet corn grew to 5.32 at 4 weeks after planting and 5.42 at 10 weeks after planting.

The nearest meteorological station's weather reported that, from April to July 2021, the average monthly rainfall amounts were 250, 220, 138, and 251 mm, respectively. Meanwhile, the average daily relative humidity was 86.7, 88.6, 88.7, and 85.1%, and the average daily temperature was 24.7, 24.7, 24.7, and 23.8 °C. These air conditions were sufficient enough to support sweet corn growths. Air temperature averages during the growing season were likely adjusted to that is required for sweet corn growth and development.

Growth of sweet corn

The use of LOF significantly influenced plant height ($P \leq 0.0300$). However, it did not significantly influence leaf number ($P \leq 0.7400$), leaf greenness ($P \leq 0.0600$), shoot fresh weight ($P \leq 0.0550$). shoot dry weight ($P \leq 0.2000$), root fresh weight ($P \leq 0.3900$) and root dry weight ($P \leq 0.6900$). LOF concentration was significantly correlated with sweet corn height of (r=0.584) and had a quadratic equation of $y = -0.0051x^2 + 0.5835x + 188.12$ (Figure 1).

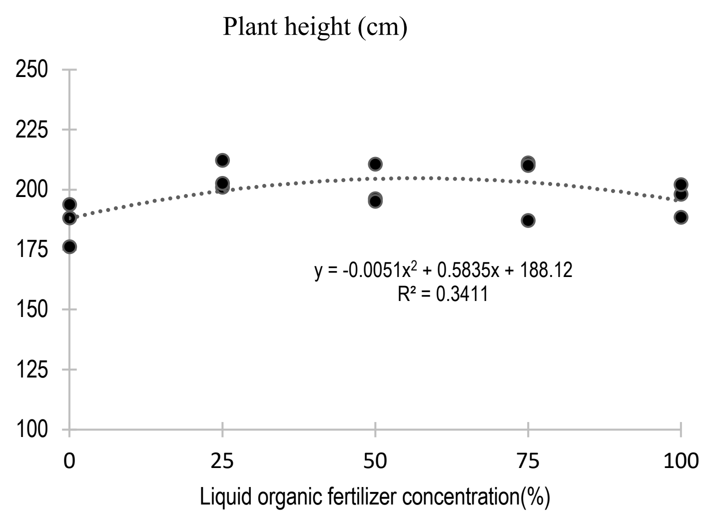

Figure 1. Relationship between LOF concentration and plant height of sweet corn

The effects of LOF concentrations on the growth variables are presented in Table 1. These results indicated that amendment of weed-based LOF had not significantly affected to vegetative growth of sweet corn, as reflected by its leaf number, leaf greenness, shoot dry weight, root fresh weight, and root dry weight of sweet corn. The averages of leaf number, leaf greenness, shoot dry weight, root fresh weight, and root dry weight were 24.25 cm, 35.99, 368.33 g, 77.76 g, 52.45 g, and 16.79 g, respectively.

Table 1. Effects of liquid organic fertilizer concentrations on leaf number, leaf greenness, shoot dry weight, root fresh weight, and root dry weight of sweet corn

Liquid Organic Fertilizer Concentrations (%)	Leaf number	Leaf greenness (SPAD index)	Shoot Fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
0	14.06	33.43	284.52	66.20	40.52	16.28
25	14.40	33.93	346.61	72.72	48.85	17.41
50	14.20	46.00	411.76	87.70	62.14	19.38
75	14.20	34.06	390.14	82.06	53.09	16.79
100	14.40	32.53	408.62	80.13	57.66	14.08
Standard Deviation	0.316	7.284	61.923	11.521	13.448	3.796

Yields of sweet corn

The use of LOF significantly influenced fresh weight of unhusked ear ($P \leq 0.0080$), length of unhusked ear ($P \leq 0.0020$), and level of sweetness ($P \leq 0.0200$) of sweet corn. However, treatment insignificantly affected fresh weight of husked ear ($P \leq 0.0900$), diameter of husked ear ($P \leq 0.1660$), diameter of unhusked ear ($P \leq 0.2900$), and length of husked ear ($P \leq 0.1800$). The effects of treatments are presented in Figure 2.

Result suggested that LOF concentration was significantly correlated with fresh weight of unhusked-ear sweet corn (r=0.815) and had a quadratic relationship of $y = -0.015x^2 + 2.0235x + 112.3$ (Figure 2-A). Meanwhile, length of unhusked ear was highly correlated with treatments (r=0.784) with a quadratic relationship of $y = -0.0006x^2 + 0.0863x + 16.164$ (Figure 2-B). Results also revealed that liquid organic concentration was significantly correlated with level of sweetness of sweet corn (r=0.747) and had a quadratic relationship of $y = -0.0003x^2 + 0.0465x + 13.486$ (Figure 2-C).

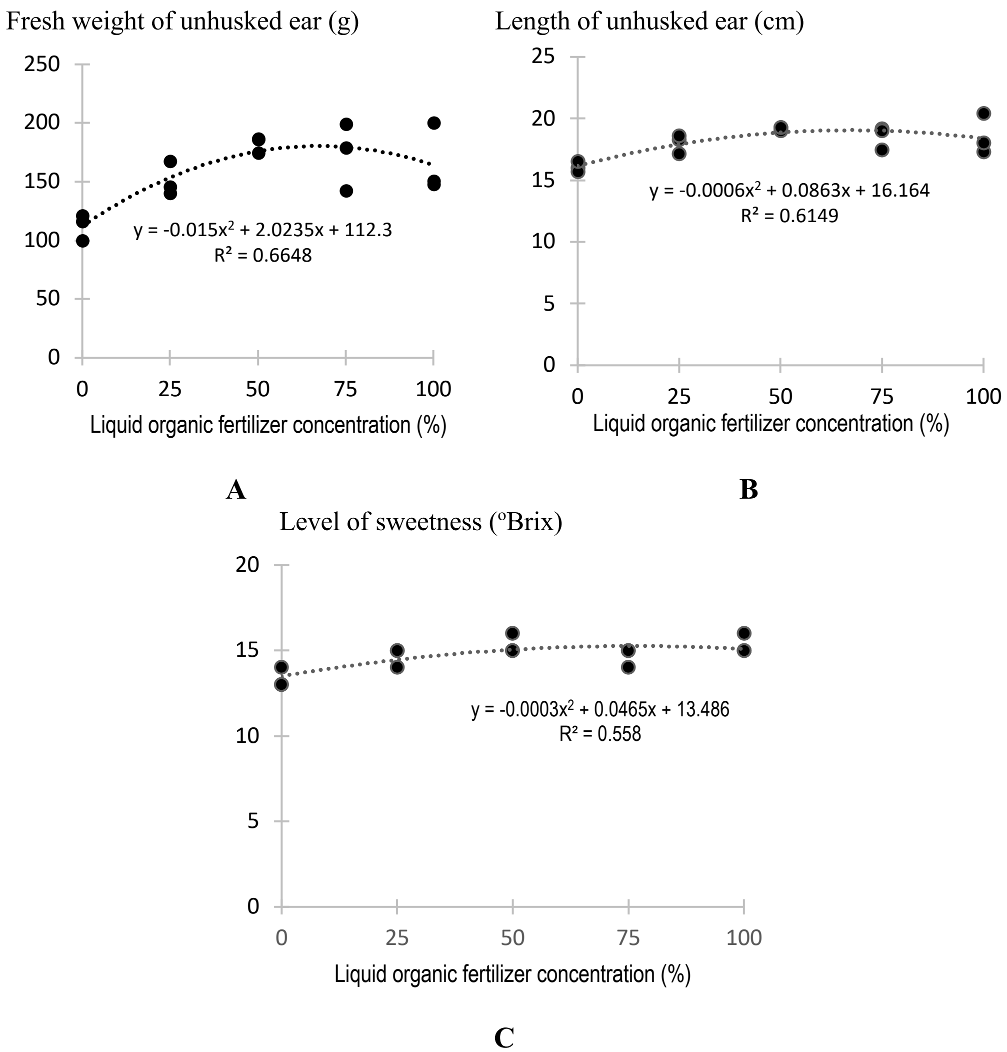

Figure 2. Relationship between LOF concentration and fresh weight of unhusked ear (A), length of unhusked ear (B) and level of sweetness (C)

The application of LOF was insignificantly affected fresh weight of husked ear, diameter of husked ear, diameter of unhusked ear, and length of husked ear of sweet corn, though the effects tended to positively increase such variables. The effects of LOF concentrations on those insignificant variables are presented in Table 2. The averages of fresh weight of husked ear, diameter of husked ear, diameter of unhusked ear, and length of husked ear of sweet corn were 267.92 g, 53.04 mm, 26.59 cm, and 42.01 mm, respectively.

Table 2. Effects of liquid organic fertilizer concentrations on fresh weight of husked ear, diameter of husked ear, length of husked ear, and diameter of unhusked ear of sweet corn

Liquid Organic Fertilizer Concentrations (%)	Fresh weight of husked ear (g)	Diameter of husked ear (mm)	Length of husked ear (cm)	Diameter of unhusked ear (mm)
0	199.85	47.98	25.12	39.17
25	253.62	53.36	26.04	42.21
50	295.23	54.80	27.62	42.52
75	297.14	53.66	27.06	42.16
100	293.76	55.42	27.09	43.99
Standard Deviation	56.29	3.93	1.53	2.68

Discussion

Results implied that optimum concentration of LOF to increase plant height was 57.02 %, which produced plant height of 238.19 cm. Previous research using the same concentration of LOF in this site indicated that treatments did not increase plant height with the average plant height of treated sweet corn was only 157.75 cm (Fahrurrozi *et al*., 2016). This implied that after six years of organically grown sweet corn, there was an increase plant height of organically grown sweet corn. Such increased might have resulted from changes in nutrient availability in the soil environment which eventually increased plant height. Continuous organic production systems might have slowly created residual effects to soil environments which benefit plant growth. Ros *et al.* (2006) concluded that long-term of soil composting, more than 12 years, increased levels of total-N, organic-C, and soil-microbial activities. Although during this experiment, soil nutrient was not measured, continuous practices of organic vegetable production in this experimental site in 2011 might have improve nutrient availability in which contributed to plant height increases. The roles of LOF also in enhancing height of sweet corn might be related to its ability to increase the contents of N and K plant tissues (Muktamar *et al*., 2021). Both N and K are essential for cell elongations and divisions, which increase plant height. Ciampitti *et al*. (2016) reported that stalk elongation was the cause of increases in sweet corn height. Nielsen (2019) stated that the elongation of sweet corn stalks starts around the V5 stage of development (collar of $5^{th.}$ leaf visible), which is mostly due to cell proliferation at the intercalary meristems along the internode bases. Pangaribuan *et al*. (2017); Aulya *et al*. (2018) and Maintang *et al.* (2021) concluded similar results that the use of LOF increased the height of sweet corn.

Nevertheless, residual effects of organic farming practices in this experimental site did not able to elevate other aspects of growth, including number of leaves, greenness of leaves, fresh and dry weight shoots and roots of sweet corn. Although leaf number must be proportionally to plant height, this result did not show such relationship. This implied that sweet corn produced the same number of leaves, but different in the length of the stem. Similarly, leaf greenness of sweet corn was insignificantly increased due to applications of LOF, yet it tended to produce greener leaves. Such results might have been resulted from residual effects of continuous application of vermicompost in this experimental site since 2011 and eventually have blurred the treatment effects on sweet corn growths. Both Ros *et al*. (2006) and Jackson *et al*. (2013) concluded that continuous application of composts increased soil nutrients and yields of sweet corn. According to Hou *et al*. (2020), a long-term application of organic fertilizer in organic production systems could accrue more essential nutrients and accumulate more specific microbes in the soil, which eventually supported sweet corn growth. The application of 10 M kg ha^{-1} of vermicompost before planting might have also diminished the treatment effects. Indeed, compared to previous research in this growing site evaluating the effect of similar LOF concentration produced fresh weight of shoot and root as much as 200 g and 24.3 g, respectively (Fahrurrozi *et al*., 2016), current shoot fresh weight (389.28 g) and root fresh weight (55.44 g) were very much higher than those of six years ago. A doubled increased of these variables compared to six years ago clearly indicated the existence of residual effects of continuous organic vegetable production practices.

Results from this organic production systems, it appeared that LOF with the concentration around 75 % was sufficient to increase fresh weight of unhusked ear (68 %), length of unhusked ear (72 %) and level of sweetness (76 %) of sweet corn. Results suggested that the optimum concentration of LOF to increase weight of unhusked ear was 67.4 %, which produced weight of 316.80 g. In addition, the optimum concentration of LOF to increase length of unhusked ear was 71.92 %, which produced length of 22.37 cm. Such concentration might have supported by the residual effects of experimental sites as well as annual application of vermicompost (10 M kg ha^{-1}) in increasing those variables. It was previously discussed that continuous application of composts increased soil nutrients and eventually increased sweet corn yields. Compared to six years ago, similar LOF concentration applied to sweet corn in this growing site, the average fresh weight and length of unhusked ears was only 165.5 g and 15.35 cm, respectively (Fahrurrozi *et al*., 2016). Prior research by Pangaribuan *et al*. (2019)

also revealed that the fresh weight, length of the unhusked ear, and sweetness level of sweet corn were all boosted by LOF application.

The optimum concentration of LOF to increase level of sweetness was 76 %, which produced level of sweetness of 16.84 ºBrix. Increased the sweetness level due to LOF application was also reported by Safiullah *et al.* (2018) and postulated that this increase was attributed to the ability of LOF to supply growth promoting substances (enzymes, hormones and growth regulators) that eventually increased the level of sweetness. Increased sweetness might also be related to LOF's ability to increase potassium (K) tissue contents of sweet corn (Muktamar *et al*., 2021). According to Prajapati and Modi (2012), K play roles in stimulating numerous enzymes involved in sugar production.

The use of LOF was insignificantly affected on fresh weight of husked ears, diameter of husked ears, diameter of unhusked ears, and length of husked ears of sweet corn, which were similar to the insignificant effects of LOF on numerous growth variables of sweet corn. The impacts of LOF on yield variables may be altered by the ongoing effects of vermicompost treatment at this experimental site in 2011. The treated sweet corn exhibited greater average fresh weight, diameter, length, and unhusked ear length when compared to the unfertilized sweet corn. As discussed earlier, continuous use of organic fertilizers may improve the rhizosphere's nutrition availability (Ros *et al.*, 2006; Jackson *et al.*, 2013; Hou *et al*., 2020). These findings differed with those of Pangaribuan *et al.* (2019), who found that applying LOF increased the fresh weight, diameter, and length of the husked ears of sweet corn as well as the husked ear diameter of the unhusked ear. Regardless of the insignificant effects of LOF on those variables, economic values of sweet corn were determined by the variables that were significantly affected by LOF, i.e. fresh weight of unhusked ear, length of unhusked ear, and sweetness level of sweet corn.

Nevertheless, results from this experiment comply to market standard, e.g., issued by Thailand Agricultural Standard (2011). According to this standard, the sweetness level shall not be less than 9 ºBrix, length of sweet corn ear without husk must be more than 20 cm (for Grade 1), length of sweet corn ear with husk must be more than 25 cm (for Grade 1). Results from this experiment indicated that level of sweetness, length of unhusked ear, and length of husked ear of sweet corn were 16.84 ºBrix, 22.37 cm and 26.59 cm, respectively, and classified above the market standards. This investigation revealed that growing sweet corn under organic production techniques has been demonstrated to be beneficial when LOF is used. In order to have better understanding of organic sweet corn production, long term evaluations must be accompanied with information on nutrient use efficiency of sweet corn. Sweet corn is classified as heavy N remover which requires N more than 168 kg ha-1

(Goldy, 2015). According to Congreves *et al*. (2021), nitrogen use efficiency (NUE) indices should take into account a broader diversity of soil N forms, the ways in which plants mediate their response to soil N status, N pools located below ground or in roots, and the timing of available N and plant N demand.

It is concluded that the use of LOF had more pronounced effects on the generative growth than that on vegetative growth of sweet corn. The optimum concentration of LOF to increase plant height, fresh weight of unhusked ear, length of unhusked ear, and sweetness level of sweet corn was 57 %, 68 %, 72 %, 76 %, respectively. Further research should be addressed on comprehensive evaluation of nutrient used efficiency by sweet corn under organic production systems.

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