Original Research Article

Increasing Soil Total Nitrogen and the Performance of Sweet Corn after the Application of Vegetable Waste-Based Liquid Organic Fertilizer in Coastal Entisols

Comment [MD1]: This topic is informative but lengthy

ABSTRACT

Coastal Entiols generally have coarse-textured, low organic matter and total soil nitrogen (N), and low water holding capacity. The liquid organic fertilizer is expected to increase soil organic matter in soil. The study's objective was to determine the total soil organic carbon (TSOC) and TSN on coastal Entisols and the performance of sweet corn under the application of liquid organic fertilizer (LOF) produced from vegetable waste. The study used a completely randomized design (CRD) with the treatments of rates of LOF from vegetable waste consisting of 0, 100, 200, 300, 400, 500, and 600 ml l^{-1} with three replicates. The results indicated that applied LOF linearly increased TSOC and TSN. The addition of LOF at the rate of 600 ml l^{-1} improved TSOC and TSN by as much as 19.5% and 24.70%, respectively, compared to the control. The growth of sweet corn was insignificantly dependent on the LOF, except plant height. The optimum concentration of LOF was approximately 250 ml l^{-1} to reach the highest yield, indicated by unhusked ear diameter (5.57 mm), unhusked ear weight (319.75 g $plant^{-1}$), and husked ear weight (215.12 g $plant^{-1}$). The study is significant for the productivity improvement of coastal Enstisols.

Keywords: Coastal Entisols; Liquid organic fertilizer; Soil nitrogen;Sweet Corn

1. INTRODUCTION

Indonesia comprises thousands of islands with 106.000 km long coastlines. The coastal area has the potential for the expansion of agricultural land. Moreover, Bengkulu Province has a coastline of approximately 525 km. Most of the coastal area in this province has not been intensively used as a productive agricultural area. Entisols are an order of soil commonly found in coastal areas. The main constraints of this soil are low water holding capacity, loose structure, high water infiltration and evaporation, and low soil fertility indicated by low organic matter content and high salinity [1]. A study by [2] suggested that Entisols in the coastal area contain low organic matter and low fertility. According to [3] Entisols from Bandar Pinang have low total soil nitrogen (0.07-0.16%)

Low N content in Entisols might have been due to coarse texture, causing its leaching and low soil organic matter [4]. Denitrification, volatilization, harvest loss, and erosion also lead to the N loss from the soil. This nutrient is very mobile in the soil; therefore, adding organic matter is an approach to overcome the constraints of the soil. The application of organic matter to soil increases organic-C, nitrate, total N, available-P, exchangeable K, microbial biomass carbon (MBC), and soil pH [5, 6, 7,8]. A previous study also suggested that applying liquid organic fertilizer (LOF) improves soil chemical properties, including N, P, and K [9].Liquid organic fertilizer is superior to solid one since the nutrients are more readily available and easily absorbed by plants. Organic sources for LOF are abundant, such as household waste, industry, agricultural production, livestock, etc. [10,11,12,13]. Converting household waste into LOF is strategic to prevent environmental pollution.

The quality of LOF highly depends on its source. Liquid organic fertilizer from household waste contains organic-C 7.85% and N 0.33% [14]. Another study revealed that LOF from urban organic waste has organic matter 17.98-22.15%, N 0.03-0.08%, P 0.04-0.095, K 0.31-0.825, C-organic 0.79-1.22%, Mg 2.26-4.12 ppm, Ca 2.26-11.80 ppm, Cu 0.52-0.86 ppm, Zn 2.83-3.83 ppm, Fe 2.83-3.81 ppm, and humic acid 3.85-7% [15].

Liquid organic fertilizer is commonly used to improve plant performance. The application of LOF significantly increases the productivity of sweet corn [16], lettuce [17], and cucumber [18]. Applying LOF also increases the absorption of P, and K by plants [19]. Our objective was to compare total soil nitrogen under household waste-based liquid organic fertilizer application and determine the growth and yield of sweet corn response on the LOF in coastal Entisols.

2. MATERIAL AND METHODS

2.1. Soil Collection and Experimental Design

A study was carried out in the Greenhouse, Faculty of Agriculture, the University of Bengkulu from July to September 2021. The experiment used coastal Entisols from Beringin Raya Village, MuaraBangkahuluSubDistrict, the City of Bengkulu at an altitude of approximately 5 m above sea level. Composite soil samples were collected from 5 representative spots at 0-20 cm depth. The soil was air-dried, ground, and sieved with a 5 mm screen. A portion of the soil sample was screened with a 0.5 mm sieve and analyzed for total soil organic carbon (TSOC) using the Walky and Black Method and total soil nitrogen (TSN) using the Kjedahl Method. The soil contained 2.71% TSOC and 1.3% TSN. The experiment used a completely randomized design (CRD) with seven treatments of LOF concentrations (0, 100, 200, 300, 400, 500, and 600 ml/L). The treatments were replicated three times.

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2.2. Liquid Organic Fertilizer Preparation

The LOF was produced from vegetable wastes collected from urban markets, mainly cabbage wastes. The vegetable waste was cut into approximately 2-4 cm pieces to ensure it quickly decomposed. The organic substrate (675 kg) was placed in a 250-l plastic bio-decomposer with selected tiny holes around the decomposer for airflow. A faucet was inserted at the basal of the decomposer for dispensing the LOF. The decomposer was mixed with 1 liter EM4 and water to achieve 225 ml of total volume. The mixture was incubated for five weeks and stirred every week. After the incubation, the LOF was ready for application, indicated by odorless and brown. The original LOF was considered 100%. The LOF contained 5.74% N, 0.29% P, 0/48% K, 3.19% organic-C, and a pH of 5.1.

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2.3. Experimental Procedure

Growing media was prepared by weighing 10 kg of air-dried soil incorporated with basal fertilization, consisting of half of the recommended rate (75 kg urea/ha, 37.5 kg SP36/ha, and 25 kg KCl/ha), and put into the polybag. The polybags were randomly allocated in a 0.5 m wooden rack. Two seeds of sweet corn were inserted into the Furadantreated hole at the center of the polybag. Thinning was carried out a week after planting by leaving the healthier plant.

Each polybag received 1 liter of LOF in 6 applications at a volume of 100, 200, 200, 200, 200, and 100 ml at weeks 2, 3, 4, 5, 6, and 7, respectively. The plant was watered every day in the afternoon. Pest control used 500 g/l*Profenofos* active ingredient at a rate of 1 ml/l while weed was manually controlled. The plant was harvested 63 days after planting, indicated by yellowish ear, brownish ear hair, and fully filled seed. A representative soil sample was collected from each polybag, air-dried, sieved with a 0.5 mm screen, and analyzed for pH, TSOC, and TSN.

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2.4. Statistical Analysis

Data was subjected to analysis of variance (ANOVA) at a confidence level of 95%, and treatment means were separated using polynomial orthogonal.

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3. RESULTS AND DISCUSSION

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3.1. Analysis of Variance

Analysis of variance showed that applying LOF with different rates significantly affected TSN, TSOC, plant height, husked ear weight, unhusked ear weight, and husked ear diameter, as seen in Table 1. However, the LOF did not affect soil pH, leaf number, shoot fresh weight, shoot dry weight, and husked ear length.

Table 1. Analysis of variance

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Variable	F-calc	F-table 5%	Coefficient of Variance (%)
pH	$2,19^{ns}$	2,85	2,32
TSOC	5,85*	2,85	7,41
TSN	8,76*	2,85	6,53
Plant height	14,75*	2,85	5,39
Leaf number	$1,13^{ns}$	2,85	6,80
Shoot fresh weight	$2,31^{ns}$	2,85	24,15
Shoot dry weight	$2,71^{ns}$	2,85	23,37
Husked ear weight	17,38*	2,85	18,54
Unhusked ear weight	5,65*	2,85	12,35
Husked ear length	$2,08^{ns}$	2,85	7,93
Husked ear diameter	12,17*	2,85	13,01

Note: * = significantly different, ^{ns} = insignificantly different

3.2. The Effect of LOF on Soil pH, TSOC, and TSN

The study showed no significant effect of LOF on soil pH, as shown in Figure 1. This result differs from that reported by Muktamar et al. (2017), where LOF significantly increased soil pH. The difference might be related to the lower concentration of LOF than in the previous study. The highest concentration of LOF in this study was 600 ml l^{-1}, while the previous one was 100% (1000 ml l^{-1}), indicating a trend of rising soil pH in this study.

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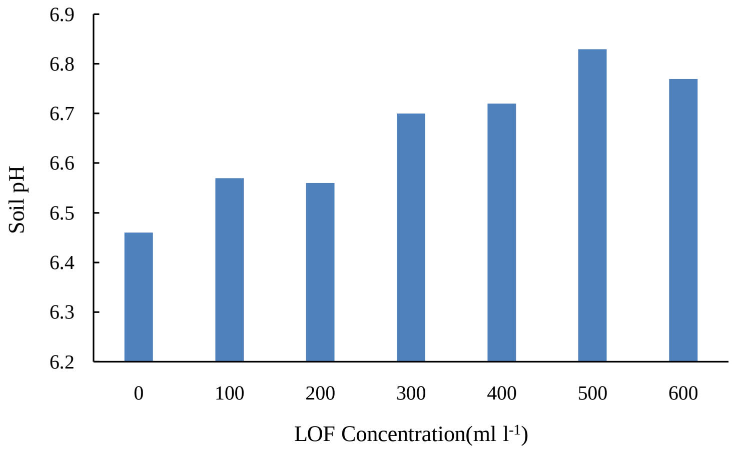

Figure 1. The effect of LOF on soil pH

Liquid organic fertilizer linearly increased TSOC with a regression equation of y = 0,0007x + 2,0481 and r^2 of 0.39 (Figure 2). The addition of LOF will directly increase carbon in the soil, as indicated by the concentration of C in the LOF is 3.19%. An increase in 1 ml l^{-1} of LOF raises TSOC by 7 ppm. The application of the highest concentration (600 ml l^{-1}) provides an increase of 2.4% TSOC compared to the control. This result is in line with that reported by [20], where the application of 50% from the original LOF on sandy soil had an organic C of 1.56%.

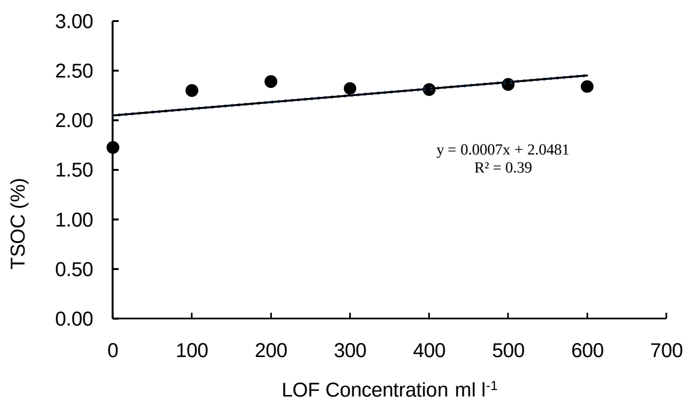

Figure 2. The effect of LOF on total soil organic carbon (TSOC)

The application of LOF also linearly enhances TSN following the equation of y= 0,00009x + 0,2186 with r^2 of 0.50, as shown in Figure 3. TSN increases by 0.9 ppm with a rising 1 ml l^{-1} LOF concentration. An addition of 600 ml l^{-1} exhibited a TSN of 0.27%. Nitrogen from LOF will eventually be available for plant growth, and the residual will accumulate in the soil. The nitrogen content of LOF is 5.74%, which directly contributes to

TSN. The increase in TSN is closely associated with the TSOC, where the increase in TSOC followed that in TSN. Carbon in organic matter will play as a primary energy source of microorganisms, leading to faster decomposition of organic matter and releasing protein and amino acids as well as simpler N inorganic forms such as N-NO_3 [21]. The result of a study by [9] discovered a similar result, where applying LOF at the rate of 100 mg l^{-1} on Inceptisols provides 0.27% TSN.

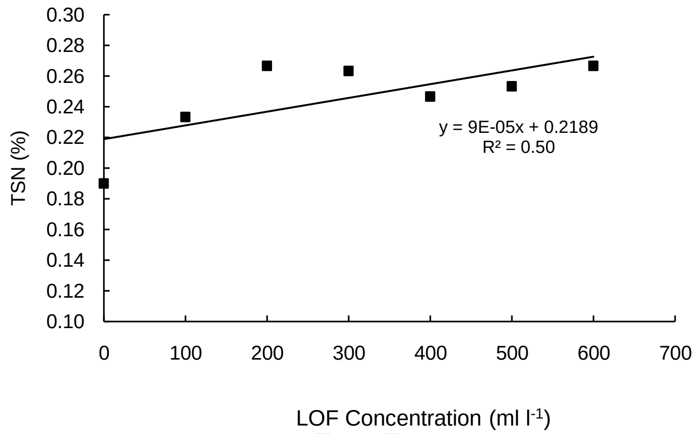

Figure 3. Total soil nitrogen (TSN) under different concentrations of LOF

3.3. The Influence of LOF on Sweet Corn Growth

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The study revealed that LOF affected the plant height of sweet corn. The relationship between LOF concentration and plant height follows the quadratic equation $y = -0.0003x^2 + 0.1015x + 173.2$ with r^2 of 0.60 (Figure 4). The optimum concentration of LOF is 169.2 ml l^{-1} with the plant height of 181.2 cm, indicating that the plant continues to increase up to the concentration of 169.2 ml l^{-1}, then decreasing afterward. A similar trend was discovered by [22], where applying LOF from mustard at a concentration of 3 ml l^{-1} reached the tallest corn while a higher concentration of 4-5 ml l^{-1} lowers the height of the corn. However, this result differs from that reported by [23], where applying LOF from pineapple waste does not affect sweet corn height and leaf area.

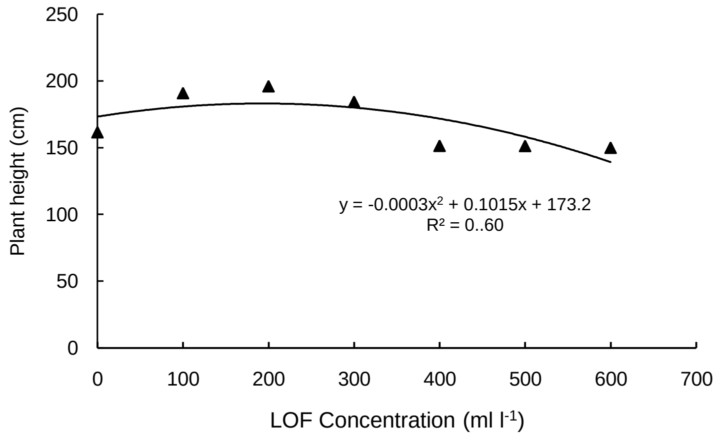

Figure 4. Sweet corn height as affected by the concentration of LOF

Unlike plant height, the application of LOF did not affect the number of leaves, shoot fresh weight, and shoot dry weight, even though there is an increased trend of those variables (Table 2). This result indicates that the application of LOF has not affected the growth of sweet corn. The insignificant effect might be attributed to the application method of the LOF. In our study, the LOF was applied sequentially at 2, 3, 4, 5, and 7 weeks after planting. This result indicates that in the early stage of sweet corn growth, mainly at weeks 3-4, the nutrients from LOF are insufficient for plant growth. A similar result was suggested by [24], where the number of sweet corn leaves is not different among concentrations of LOF from vegetable waste. Applying LOF up to 100 ppm, [25] did not find a significant effect on shoot fresh weight.

Table 2. The effect of LOF on the number of leaves and shoot weight of sweet corn

LOF Concentration (ml l^{-1})	Number of leaves	Shoot fresh weight (g)	Shoot dry weight (g)
0	10.00	256.00	180.80
100	10.55	367.00	266.83
200	10.55	398.00	279.37
300	11.22	366.67	270.60
400	10.00	225.33	160.43
500	10.11	239.00	163.63
600	10.33	238.67	172.50

The Effect of LOF on the Yield of Sweet Corn

The application of LOF did not influence the husked ear length, as seen in Figure 5, even though the concentration of 100 and 200 ml l^{-1} exhibited higher than others. On the other hand, unhusked ear diameter and ear weight significantly differed under different concentrations of LOF.

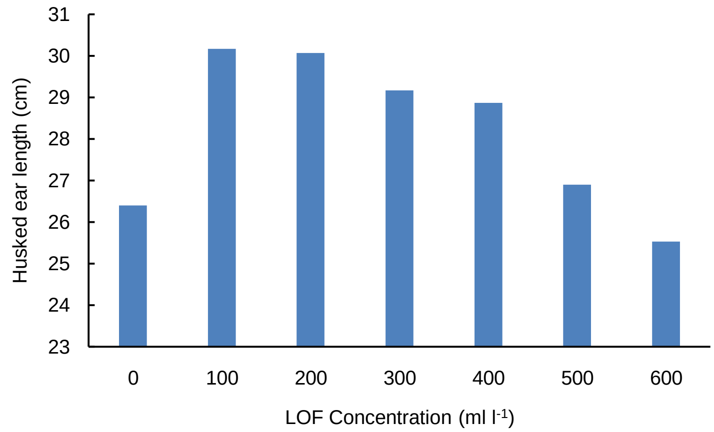

Figure 5. Husked ear length of sweet corn under different concentrations of LOF

The polynomial analysis shows that the effect of LOF on ear diameter and weight of sweet corn follows quadratic equations. The equation on unhusked ear diameter is y = -0,00003x^2 + 0,0145x + 3,8171, dan r^2 = 0,71 (Figure 6), unhusked ear weight is y = -0,0021x^2 + 1,0385x + 191,36 dan r^2 = 0,71 (Figure 7) while husked ear weight is y = -0,0013x^2 + 0,6257x + 139,83 dan r^2 = 0,71 (Figure 8).

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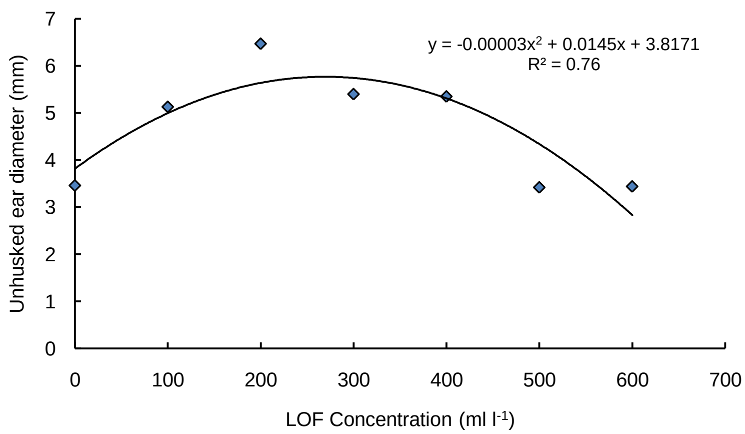

Figure 6. The effect of LOF on unhusked ear diameter of sweet corn

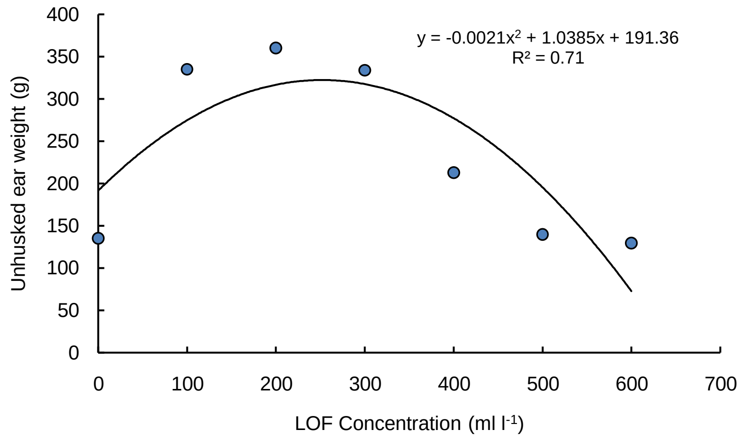

Figure 7. The effect of LOF on unhusked ear weight of sweet corn

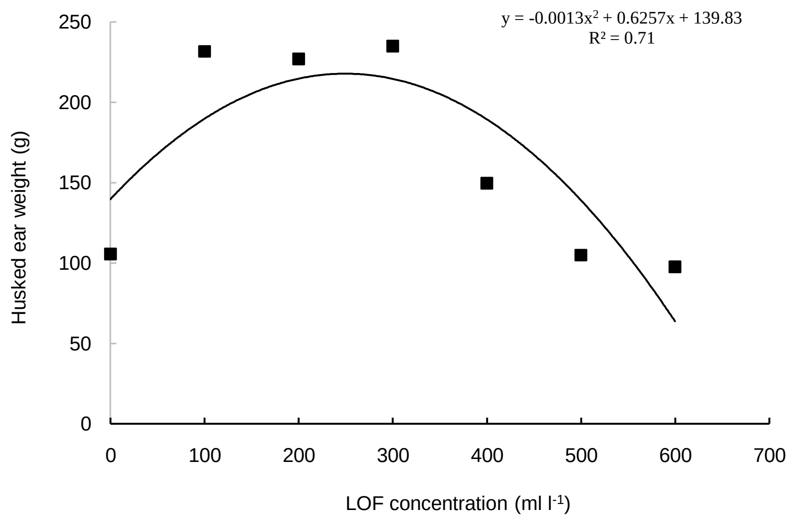

Figure 8. The effect of LOF on husked ear weight of sweet corn

In general, the LOF has no significant effect on the growth of sweet corn except for plant height. This result indicates that nutrient availability from LOF at a concentration of 600 ml l^{-1} has not been sufficient to assure the different growth of the sweet corn, probably due to successive application of LOF during the growth of sweet corn. A previous study also confirmed that LOF from dairy cattle up to the rate of 100 ppm also did not affect the growth of sweet corn [25].

However, the LOF has a substantial effect on the yield indicated by its unhusked ear diameter, unhusked and husked ear weights, following the quadratic equation with r^2 more than 0.71 for all variables. The quadratic equation indicates that increased LOF concentration will increase the yield variables to their optimum points. The optimum point for unhusked ear diameter is 241.67 ml l^{-1} of LOF to reach 5.57 mm, unhusked ear weight is 247.26 ml l^{-1} to obtain 319.75 g $plant^{-1}$, and husked ear weight is 240.65 ml l^{-1} to achieve 215.12 g $plant^{-1}$. Therefore, LOF is applied at a concentration of approximately 250 ml l^{-1} to reach the optimum yield of sweet corn.

Increasing the yield of sweet corn to the optimum point is attributed to the increase in nutrient availability from LOF as increased concentration. Even though there was no significant effect on sweet corn growth, nutrients were readily available during the seed filling of sweet corn. On the other hand, the yield decline after the optimum point of LOF concentration is might related to the imbalanced nutrient uptake of N, P, and K by sweet corn. The LOF used in this study has a much higher content of N (5.74%) than P (0.29%) and K (0.48%). The high N content at a higher LOF concentration may cause the lower uptake of P and K. An experiment by [26] suggested that applying the proper dose and balance to the other plant nutrients, mainly P and K is vital to ensure high fertilizer efficiency. A previous study by [27] concluded that there should be the interactive effect of N and K on leaf photosynthetic to reach maximal plant growth. excessive supply of N leads to K deficiency symptom.

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The high rate of LOF applied at weeks 6 and 7 might have caused the excessive absorption of N at which sweet corn already performs the generative period (tasseling). A study by [28] showed that an excessive supply of N can lower the corn yield. Earlier studies also revealed that LOF from vegetable waste with high concentration precisely had a negative effect on plants. [29] found that adding LOF from vegetable waste at a concentration of 8% provided the most significant fruit weight of chili papers. However, the variables decreased at higher concentrations (10%, 12%, and 14%). Another study by [30] showed that the fresh weight of mustard significantly decreased at the vegetable-based LOF concentration of 12% compared to 8%.

Comment [MD12]: Plant growth or yield?

4. CONCLUSION

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Applying LOF from vegetable waste to 600 ml l^{-1} continuously increased the TSOC and TSN of the soil used in the study. Liquid organic fertilizer up to the rate of 600 ml l^{-1} did not influence the growth of sweet corn. The optimum concentration of vegetable waste-based LOF for sweet corn yield is approximately 250 ml l^{-1}, after which the yield will be significantly lower due to the imbalanced nutrient absorption.

Comment [MD14]: But here we see LOF increased plant height

Comment [MD15]: The author(s) should declare conflict of interset after the conclusion

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