Growth and yield of sweet corn (Zea mays L. Saccharata) as affected by incubation time of preparation for tithonia (Tithonia diversifolia) enriched liquid organic fertilizer

A R Puteri1, N Setyowati2*, Fahrurrozi2 and Z Muktamar3
1Agroecotechnology Study Program, Faculty of Agriculture, University of Bengkulu, Indonesia.
2Department of Crop Production, Faculty of Agriculture, University of Bengkulu, Indonesia.
3Department of Soil Science, Faculty of Agriculture, University of Bengkulu, Indonesia.

Corresponding author: nsetyowati@unib.ac.id

Abstract. The use of organic fertilizers could be an alternative for synthetic fertilizer because of its high price and limited availability. Organic fertilizer is commonly found in the form of solid or liquid organic fertilizer (LOF). Tithonia (Tithonia diversifolia), a broadleaf weed containing high N, P, and K, is often used to enrich LOF. However, the quality of LOF is highly dependent on the incubation time. This study aimed to examine the influence of LOF incubation time on sweet corn plant growth and yield. This experiment was conducted at the Experiment Station, Faculty of Agriculture, University of Bengkulu, from August to December 2019. The experiment used a completely randomized design (CRD), with five treatments and five replications. The treatments were LOF prepared for four, five, six, and seven weeks of incubation. No LOF was allocated as control. The result showed that the incubation time for LOF preparation had no significant effect on plant height, the number of leaves, stem diameter, ear weight, and ear length of sweet corn. It is suggested that the preparation of Tithonia enriched LOF be incubated for four weeks.

1. Introduction
Fertilization is to increase plant growth and yield. Fertilizer function is to improve soil fertility [1]. A serious problem in agricultural practice is dependence of farmers on synthetic fertilizers, which are expensive and not environmentally friendly when used excessively. An alternative to solve environmental damage, especially the declining soil fertility, is to use organic fertilizers.

Organic fertilizer can improve soil quality because, in addition to increasing soil pH, it can also reduce exchangeable-Al levels in the soil [2]. Two types of organic fertilizers are solid organic fertilizer (SOF) and liquid organic fertilizer (LOF). Liquid organic fertilizer contains essential nutrients for plant growth and is easily dissolved in the soil. The preparation of LOF takes place anaerobically or through organic material fermentation. Sources of organic material for LOF include plant residues, animal waste, and human waste, as well as utilizing local microorganisms such as vegetable and animal liquid waste [3].
Unlike synthetic fertilizers, LOF contains easily available plant nutrients and generally does not harm soil or crops, although it is frequently applied. On the other hand, solid organic fertilizer releases plant nutrients slowly, therefore, they are often not available when required. Only about 50% of N, P, K organic forms of SOF undergo a mineralization process [4]. On the other hand, LOF can overcome nutrient deficiency faster because it can provide nutrients more quickly than SOF [3]. Application of LOF increased chlorophyll content, plant vigor, plant resistance to drought, stimulated the growth of productive branches, and the formation of flowers [5].

Tithonia weed (*Tithonia diversifolia*) is commonly used as a source of LOF. Tithonia is a broad-leaf weed, grows fast, and contains high N. In East and South Africa, farmers applied tithonia biomass as fertilizer for sweet corn and vegetables [6]. Tithonia is easily decomposed in soil and provides high availability of N, P, and K for plants [7]. The results of Purwani [8] showed that Tithonia application increased total soil organic-C, available-N, $P_2O_5$, and $K_2O_3$ and yields of some horticultural commodities, including corn.

A factor determined the quality of LOF is the duration of fermentation time. Fermentation is a process of chemical change in an organic substrate through enzyme activity produced by microorganisms [9]. In the fermentation process, organic material decomposes and releases nutrients for plants. The duration of fermentation affects the nutrient content of LOF. During the fermentation process, solid organic materials decomposed, releasing simple form of elements or complex compounds. The nutrients, then, are available for plants. The organic matter decomposes in the present of microorganisms. The rate of decomposition is highly dependent on the microorganism activity. Microbial growth and reproduction depend on the duration and phase through which decomposing microbes go through. The duration of the fermentation determines how much the organic matter has been broken down to form LOF and the nutrients are ready for plant absorption.

The short duration of fermentation causes the limited opportunity for microbes to grow and develop, and reduces the substrate components decomposed. Conversely, the longer duration of the fermentation, the organisms may temporarily use nutrients to multiply themselves and the growth phase of microorganisms is faster. In some studies, LOF was aerobically prepared for five weeks [2, 10]. Duration for the fermentation process is expected to determine the nutrient content produced by the LOF.

Study on the duration of the LOF preparation using different sources has not been widely reported. In contrast, the content of released nutrient is highly dependent on the duration of incubation for LOF preparation. Therefore, it is necessary to study the duration of the incubation to obtain good quality LOF. This study aims to determine the growth and yield of sweet corn as affected by LOF prepared with different duration of incubation.

2. Experimental methods
The research was conducted from August to December 2019 at the Experimental Station Department of Crop Production, Faculty of Agriculture, Bengkulu University, Indonesia. The design of this experiment was a completely randomized design (CRD) with one factor and replicated five times. The factor was LOF prepared with different duration, consisted of $T_1$ : 4 weeks, $T_2$ : 5 weeks, $T_3$ : 6 weeks, $T_4$ : 7 weeks and $T_5$ : Control (treatment without LOF application).

2.1. Soil preparation
The soil sample was compositely collected from the depth of 0-20 cm. The soil was classified using Soil Taxonomy Classification as Ultisol with a pH of 4-5. The soil sample was, then, air-dried, ground, and sieved with 2 mm screen.

2.2 Liquid organic fertilizer preparation
The stater EM-4 solution was prepared by dissolution of ten ml of EM-4 + 1 kg granulated sugar in 10 L of water. The solution was stirred, and then let stand for 24 hours. Next, five kg of tithonia weeds was chopped and incorporated with 2.5 kg of topsoil, 5 kg of cow dung, 10 L of EM-4 starter solution.
and 10 L of coconut water in a plastic barrel. Water was poured into the barrel until solution volume reaching 100 L. The solution, then was stirred thoroughly.

The plastic barrel was then closed tightly and incubated for 4, 5, 6, and weeks (according to the treatment). Every three days, the LOF solution was stirred to provide adequate oxygen for fermentation. After the fermentation process was completed, then the LOF solution was filtered using gauze and ready for application [4].

2.3. Growing medium preparation
The soil sample for growing media was aerated for 2-3 days to remove toxic substance. Ten kg of soil sample was incorporated with 15 ton/ha vermicompost and put into the polybag. The mixture was prepared a week before planting. The polybags were randomly placed in the greenhouse with 25 cm distance among each other.

2.4. Planting
Two corn seeds were inserted in the soil media on each polybag. Thinning was completed one week after planting by cutting a plant and leaving a better growth plant.

2.5. LOF application
LOF was applied every week, started at one week after planting (WAP). Each plant received 50, 100, 150, 200, 250, 300 ml of LOF at week 1, 2, 3, 4, 5, and 6 respectively. Total volume of LOF for each plant was 1050 ml during its growing period. LOF was sprayed evenly through the leaves, and the remaining LOF was poured to the soil medium.

2.6. Irrigation and pest control
The corn was watered twice a day, in the morning and the late afternoon to keep the soil moist. The weed was manually controlled. So did the pest. The weed and part of the plant infected by pest was removed from the polybag.

2.7. Harvest and variable observed
The corn was harvested 75 days after planting. Variables observed included plant height, number of leaves, stem diameter, leaves greenness, plant fresh weight, plant dry weight, husk corn weight, cob weight and cob length. N, P, K content and pH in each LOF treatment as well as monthly rainfall were also observed.

2.8. Data analysis
Data were analyzed using analysis of variance (ANOVA) F-test at the 5% level. The significantly different variables were further tested by LSD (Least Significantly Different) at the 5%.

3. Results and discussion

3.1. Research overview
Rainfall in September, October, November and December 2019 was 1.9 mm; 1.3 mm; 2.0 mm and 4.5 mm respectively while the daily temperature was 26.17 ºC; 26.10 ºC; 26.93 ºC and 26.83 ºC with an average air humidity of 82.5%; 83.45%; 83.67%; and 86.16%. An environment condition with low rainfall, relatively high temperature and humidity, and acidic soil (low pH), is not favorable for the growth and development of sweet corn. Sweet corn requires rainfall, ranging from1200 to 1500 mm/year or 100 to 125 mm/month and a temperature between 23ºC - 27ºC [11] soil pH between 5.5 to 7.5, and the humidity between 50-80% [12].

In general, sweet corn requires urea fertilizer at a dose of 400 kg/ha, SP-36 100 kg/ha, and KCl 200 kg/ha. Sweet corn was planted at a plant spacing of 70 cm x 40 cm. Therefore, each plant received urea, SP36, and KCl as much as 5.6, 11.2 and 2.8 g/plant respectively or equal to 5.15 g N/plant, 1.01
g P2O5 / plant, and 3.36 g K/plant. Laboratory test showed the soil contained 0.24% total-N, 1.72 ppm P2O5, 0.19 me K2O/100g, 2.9% Organic-C, and soil pH of 4.76.

In this experiment, sweet corn was not fertilized with synthetic fertilizers; however, vermicompost was applied at a dose of 15 ton/ha or equivalent to 7.56 g N/plant, 5.54 g P/plant, and 5.37 g K/plant. Although the nutrient contribution from vermicompost to the growing medium was quite high, its availability for plants was slower compared to synthetic fertilizer.

3.2. Nutrient content of LOF at various duration of fermentation

The analysis showed, there were differences in the nutrient content of each duration of fermentation (Table 1). The total N content ranged from 0.75% - 1.04%; P between 0.51% - 0.58% and K between 0.58% - 0.66%.

| Duration of fermentation (weeks) | Nutrient content (%) | C/N ratio | pH    |
|---------------------------------|----------------------|-----------|-------|
| 4                               | 1.04                 | 0.58      | 0.60  | 9.05  | 6.12  |
| 5                               | 1.21                 | 0.56      | 0.66  | 1362  | 7.52  |
| 6                               | 0.92                 | 0.54      | 0.61  | 13.45 | 7.54  |
| 7                               | 0.75                 | 0.51      | 0.58  | 13.92 | 7.49  |

Source: Soil Science Laboratorium, Faculty of Agriculture, Bengkulu University 2019.

The nutrient content of N, P, and K decreased at 6 and 7 weeks of fermentation. LOF incubated for 4 and 5 weeks resulted in the higher nutrient content of N, P, and K than those of 6 and 7 weeks. The result may be associated with more intensive decomposition at 4-5 weeks where the decomposing microbial cells continue to grow. Yuwono [13] states that there is a continuous microbe activity in the fermentation process.

Fermentation is the process of breaking down carbohydrates and amino acids anaerobically. The fermentation process involves certain microbial activities in which these microorganisms adapt to their growing environment [14]. As microorganisms acclimatize to the environment, then the microorganism cells use carbon from the LOF source as an energy source to multiply themselves. The decomposition of organic matter for LOF was accelerated at five weeks duration of fermentation, which was indicated by the increasing content of N, P, and K. At this time, the cells of the decomposing microorganisms proliferate, reaching the maximum population. At five weeks of fermentation, the content of N, P, and K was 1.21%, 0.56%, and 0.66%, respectively, which was higher than that of 4 weeks of fermentation. This result may be related to lag phase of the activity of microorganisms.

The content of N, P, and K decreased at 6 and 7 weeks of fermentation. At this point, the microorganisms have reached a balance stage, where the number of microorganisms was about the same as the number of dead microorganisms. Thus, the activity of microorganisms was decreased. In addition, the release of secondary metabolite from tithonia weed brings about the toxic and inhibit the growth of decomposing microorganisms.

The source of organic material for LOF was tithonia weed. Tithonia contains allelopathic compounds, causing a negative effect on other plants. The allelopathic activity of tithonia leaves influenced by the time of decomposition, microorganisms' activity, and the absorption of the soil. Tithonia leaf extract at concentrations of 10 and 20 mg DME/ml inhibited seed germination and seed growth. The efficacy of tithonia allelopathic on cultivated plants' growth depends on the type of crops and the source of the extract [15–17].

The degree of acidity (pH) is another factor influencing the activity of organisms during the decomposition process. The value at pH shows the number of ionic concentrations (H+) in the
composting medium. As the ion content is higher, the organic fertilizer will be more acidic. Conversely, as the ion content is low, the organic fertilizer produced is alkaline. In the decomposition process of organic matter, microorganisms' activity increased pH [18]. The lowest pH of LOF in this experiment has resulted from 4 weeks of decomposition. The pH increased as the fermentation time increased.

The C/N ratio is the ratio of carbon (C) and nitrogen N, as indicator of the fermentation process. If the ratio is between 20-30%, the LOF is ready for application. Different C and N thus affect the quality of LOF [19]. When the C/N ratio is high, the LOF source has not completely decomposed. Organic matter with high C/N ratios take longer for the decomposition process compared to low C/N ratios. The quality of LOF is categorized as good as the C/N ratio is between 12-15. The results of this study showed the 4-week of fermentation resulted in a C/N ratio of 9.05 which was lower than the other treatments. All treatments had C/N ratio below 14 (Table 1).

Table 1 showed, longer fermentation resulted lower the N, P, and K content. Meriatna et al. [20] and Makkiyah [21] also reported that longer fermentation significantly decreased N, P, and K content of the LOF.

Another factor affect the decrease in N content at 6 weeks of fermentation was the possibility of the evaporation of N. Plant requires a significant amount of N, unfortunately the nutrient is easily lost through the leaching and evaporation process. The stirring during the preparation of LOF may cause the loss of N through the evaporation. According to Lingga and Marsono [22], urea is a hygroscopic fertilizer, easily dissolves in water and easily absorbed by plants. In the soil application, this fertilizer turns into volatile ammonia and carbon dioxide in short time.

3.3. Summary of analysis of variance
The analysis showed that the LOF had a significant effect on leaves greenness at 3, and 6 weeks after planting, as well as the plant dry weight (Table 2).

Table 2. Analysis of variance of variables observed in the experiment

| Variables                  | F-value (5%) | Coefficien Variation (%) |
|----------------------------|--------------|--------------------------|
| Plant height               | 0.48 ns      | 3.67                     |
| Number of leaves           | 2.71 ns      | 8.94                     |
| Stem diameter              | 0.95 ns      | 10.82                    |
| Leaves greenness (3 WAP)   | 3.80*        | 10.30                    |
| Leaves greenness (6 WAP)   | 3.26*        | 9.66                     |
| Plant fresh weight         | 2.76 ns      | 21.42                    |
| Plant dry weight           | 5.14 *       | 21.08                    |
| The weight of husked ear   | 1.40 ns      | 8.73                     |
| Cob length                 | 2.64 ns      | 3.60                     |
| Cob diameter               | 1.03 ns      | 3.81                     |
| Cob weight                 | 0.74 ns      | 7.63                     |

Note: * = significantly different at 5 % level, ns = non significantly different

3.4. Effect of LOF duration of fermentation on the growth of sweet corn
Table 3 showed the effect of LOF duration of fermentation on plant height, leaves number, stem diameter, leaves greenness, and plant weight.
Table 3. Effect of LOF duration of fermentation on the growth of sweet corn.

| Duration of fermentation (weeks) | PH (cm) | LN | SD (mm) | LG-3 | LG-6 | PFW (g) | PDW (g) |
|---------------------------------|--------|----|---------|------|------|--------|--------|
| 4                               | 158.25 | 10.80 | 15.40 | 29.70 a | 33.60 a | 110.30 | 25.40 a |
| 5                               | 159.19 | 11.90 | 16.10 | 29.00 a | 34.10 a | 108.20 | 23.20 ab |
| 6                               | 159.20 | 10.50 | 14.10 | 29.40 a | 34.40 a | 109.60 | 21.70 ab |
| 7                               | 155.92 | 10.30 | 15.30 | 28.70 a | 33.00 a | 108.70 | 18.00 bc |
| Control                         | 155.48 | 10.10 | 14.10 | 23.80 b | 28.20 b | 72.90  | 14.30 c  |

Note: PH= plant height, LN= leaves number, SD= stem diameter, LG= leaves greenness, PFW= plant fresh weight, PDW= plant dry weight. The numbers followed by the same letter in the same column are not significantly different at the DMRT test (5%).

The results of the experiment showed LOF duration of fermentation had a significant effect on leaf greenness at 3 and 6 weeks after planting and plant dry weight and had no significant effect on plant height, leaf number, stem diameter, and plant fresh weight. The average plant height, leaves number, stem diameter, and plant fresh weight ranged between 155.48 - 159.19 cm; 10.10 - 11.90; 14.10 -16.10 mm, and 72.90 - 108.7 g respectively (Table 3). The growth of sweet corn was lower than the potential of the sweet corn variety Bonanza, which has plant height of 220-250 cm and stem diameter of 20-30 mm. Thus, vermicompost applied as a base fertilizer has not met the nutrient requirement for sweet corn growth and development. The addition of LOF also did not increase the growth of sweet corn.

Although the nutrient content of LOF was sufficient for plant growth and development, however sweet corn plants have not fully utilized those nutrients. In this study, environmental factors might affect the nutrients availability for plants. Barus et al. [23] also reported LOF application had no significant effect on plant height, number of branches, flowering time, harvest time, number of pods per plot, and pod weight per plot.

High temperature during the study (27.9°C) with monthly rainfall between 1.3 - 4.5 mm/month (very low) also influenced the plant growth. Good performance of sweet corn requires rainfall between 1200 - 1500 mm/year or 100 - 125 mm/month and air temperatures between 23°C - 27°C [11]. Temperature is a uncontrollable factor which significantly affect plant growth [24]. Beside the environment, nutrient availability also affects plant growth and development.

Limited availability of nutrients brought about stunting of sweet corn plants. In this study, the application of a vermicompost at dose of 15 ton/ha provides sufficient N, P, and K for plant requirements. However, solid organic fertilizer releases plant nutrients slowly, causing they are not available, mainly at early stage of plant growth. Rakun et al. [25] reported that the best compost application was 40 days before planting. In this experiment vermicompost was applied seven days before planting. This might be the reason the nutrient from vermicompost was not readily available for sweet corn.

3.5. Leaves greenness
Liquid Organic Fertilizer prepared with different duration of fermentation increased leaf greenness (Table 3). The LOF contributes to increasing nutrients, mainly N for plant growth. The N content in LOF ranged from 0.75% - 1.21%. Nitrogen plays as an essential role in the formation of chlorophyll, a green leaf substance of all photosynthetic green plants. Photosynthesis is the mechanism of sunlight converting inorganic (CO₂ and H₂O) compounds into organic (carbohydrate) and O₂. Chlorophyll plays an essential role in the photosynthetic process by plants by absorbing and converting sunlight into chemical energy. Carbohydrates then are converted into photosynthesis products such as proteins, fats, nucleic acids, and other organic molecules [26,27].
3.6. Plant dry weight
The experiment showed that LOF increased plant dry weight (Table 3). The increase in dry weight was related to the increase in the maize plant’s leaf greenness. The greenness of the leaves is related to the amount of chlorophyll in the plant. Higher chlorophyll content will accelerate the photosynthesis process. The result of photosynthesis was a plant biomass as indicated by plant dry weight. Rohmawan [28] reported that the application of water hyacinth LOF at a concentration of 100% increased the plant dry weight of cucumber. The increase in the plant dry weight was associated with the absorption of nutrients that enable better assimilation process.

3.7. Sweet corn yield
Preparation of LOF with different duration of fermentation did not affect the length and weight of sweet corn (Table 4).

**Table 4.** The length and weight of sweet corn as affected by the duration of fermentation

| Duration of fermentation (weeks) | Cob length (cm) | Husk corn weight (g) | Cob weight (g) |
|---------------------------------|-----------------|----------------------|---------------|
| 4                               | 21.11           | 125.02               | 97.47         |
| 5                               | 20.78           | 115.48               | 94.24         |
| 6                               | 19.87           | 115.48               | 91.80         |
| 7                               | 20.05           | 113.42               | 92.77         |
| Control                         | 20.12           | 111.84               | 90.28         |

Note: the numbers followed by the same letter in the same column are not significantly different at the LSD test (5%).

The LOF application at different duration of fermentation had no significant effect on the yield of sweet corn. The non-significant yield of sweet corn was related to that the N, P, and P content of LOF might not be sufficient for the growth and development. Surtinah [29] reported that plant height and stem diameter were closely related to fruit weight. For the sweet corn production, N plays a significant role for the increase in the size and weight of cobs, P for the formation of flowers and seeds, while K for filling grains and forming carbohydrates.

![Figure 1. Average cob length at different duration of fermentation](image)
Beside LOF treatment, environment plays significant effect on plant growth and yield. In this study, the abiotic factors such as high soil acidity, high air temperature, and low rainfall significantly affect crop yield. Acid soil (low pH) affects the availability of nutrients availability. In addition, low soil pH also influences nutrients absorption, mainly P, due to the formation of Al and Fe phosphates, reducing the plant growth and yield [30]. Besides, the LOF application during the dry season with low rainfall and high air temperature might be ineffective due to the evaporation of the LOF. Study by [31] concluded that LOF evaporates faster than solid organic fertilizer. In this study, the environmental condition may cause the growth dan yield of sweet corn lower that its potential yield.

The plant genetic may also influence cob length as reported by Kartasapoetra [32] that the sweet corn cob length was more related to genetic factors. As shown in Figure 1 LOF prepared for 4 and 5 weeks of fermentation tended to have a higher average cob length than other treatments. The result indicates that the LOF's nutrient content prepared four and five weeks of fermentation contributed to the cob length.

4. Conclusion
The LOF prepared for four and five weeks of fermentation had significant higher content of N, P, and K than those of six and seven weeks. The LOF increased leaf greenness and plant dry weight of sweet corn, even though had no significant effect on other variables observed in this study.

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