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Yield of maize as treated with plant-based liquid fertilizers at varying concentrations and frequencies of application

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Abstract Azolla (*Azolla pinnata*), water lettuce (*Pistia stratiotes* L.), and banana peel (*Musa paradisiaca*) are known to contain nutrients that can serve as an environmentally friendly fertilizer. Result indicated that liquid organic fertilizer (LOF) made from leachate mix of azolla, water lettuce, and banana peel has the potential to serve as an alternative source of nutrients for maize production, in lieu of inorganic fertilizers. Grain number per row, tip filling, weight of 100 grains, and grain yield can be maximized by three applications of LOF at 2, 4, and 6 WAP with a 10% concentration, or two applications at 2 and 4 WAP with a 20% concentration, or a single application at 2 WAP with a 30% concentration.

Keywords: Foliar spray, Grain yield, Leachate, Macro nurients, Plant growth

Introduction

Maize (*Zea mays* L) is a grain crop that has an important role in Indonesia, both as food, feed, and industrial materials. As a source of food, corn has a fairly complete nutritional content (Sinay and Harijati, 2021). Besides containing these nutrients, corn also has relatively low fiber content (Lapui *et al*., 2021). The low crude fiber content will be more easily digested in the digestive tract. Corn is also utilized as a raw material for animal feed, with composition reaching 71.1% (Lasek *et al*., 2020). In the field of industry, corn is processed into oil, corn flour, sugar, and ethanol fuel (Zhang *et al*., 2021).

Since maize is a nutrient-hungry plant, inorganic fertilizers are typically the best option for satisfying plant nutrient needs since they are easily applied, have a measurable nutrient content, and are promptly and easily absorbed by plants (Dox *et al*., 2023). However, the cost of inorganic fertilizers is quite high, and if they are used excessively over time, they may harm the environment, reduce soil fertility, and negatively impact farmers' health (Syamsiyah *et al*., 2021).

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Due to these drawbacks, organic fertilizer is frequently used as a substitute for providing nutrients as it is eco-friendly and produced from readily accessible natural materials, making it a more cost-effective option. Moreover, the organic compounds found in organic fertilizers can enhance soil fertility and boost land productivity through physical, chemical, and biological means (Puspadewi *et al*., 2016). In addition to the benefits, organic fertilizers also come with limitations. The nutrients in organic fertilizers are less compared to inorganic fertilizer, which means they need to be applied in larger quantities and more frequently than inorganic fertilizers (Basysya *et al*., 2022).

Organic fertilizers must undergo decomposition and mineralization to effectively supply nutrients to plants. These fertilizers can be utilized in either solid or liquid forms. Typically, solid organic fertilizers are incorporated into the soil, whereas liquid organic fertilizers can be applied directly to the soil or sprayed onto the foliage. A significant benefit of foliar application is the enhanced absorption rate of both macro and micro nutrients compared to soil application (Sudarmaji *et al*., 2020).

Liquid organic fertilizer (LOF) can be produced using a range of organic substances; however, for corn plants, which demand substantial nutrients, it is essential that the selected materials possess elevated nutrient levels. Notable organic materials that are rich in nutrients include Azolla (*Azolla pinnata*), water lettuce (*Pistia stratiotes*), and banana peels (*Musa paradisiaca*).

Azolla has been found to possess a nutrient composition of 40.6% nitrogen (N), 0.47% phosphorus (P), 1.66% potassium (K), and 79.6% organic matter, as reported by Sharma *et al*. (2020). In contrast, water lettuce exhibits a nutrient profile of 2.5% N, 1.0% P, 3.2% K, and 85.0% organic matter, which is significant for plant health (Rattanawong *et al*., 2022). Additionally, banana peel is characterized by a nutrient content of 5.85% N, 0.10% P, 5.80% K, and 13.40% organic matter (Widyabudiningsih *et al*., 2021). Numerous studies have demonstrated that the utilization of azolla-based liquid organic fertilizers (LOF) can enhance both the growth and yield of rice crops (Mujiyo *et al*., 2015; Setiawati *et al*., 2019). Similarly, LOF derived from water lettuce has also been shown to promote the growth and yield of rice (Lestari *et al*., 2022). Furthermore, LOF produced from banana peel has been reported to improve the growth and yield of eggplant (Hariyono *et al*., 2021).

Although these three organic materials are known to be able to effectively meet the nutrient needs of various plants, their application in maize production has not been widely explored. Therefore, further investigation regarding the optimal concentration and frequency of application is still needed. The objective of this study was to evaluate the growth and yield of maize when treated with liquid organic fertilizers derived from Azolla, water lettuce, and banana peel extracts, each applied at varying concentrations and frequencies.

Materials and methods

The experiment was conducted from April to August 2024 at Rejang Lebong Regency, Bengkulu Province, Indonesia at elevation of 900 m asl. The average monthly rainfall in study area during the course of study was 233,75 mm with air temperature ranged from 24 °C to 34 °C. The field was previously used for chinese cabbage production.

A factorial experiment arranged on a randomized complete block design (RCBD) with 3 replications was used to allocate treatments consisting of liquid organic fertilizer concentrations (0, 10, 20, and 30 %) and frequeny of applications (single, double, and triple applicaitons) to the experimental plots. The plots had a size of 300 cm x 250 cm and spaced 70 cm apart.

Liquid organic fertilizer (LOF) was produced from the leachate obtained through the fermentation of Azolla, water lettuce, and banana peels, with each substrate undergoing a distinct fermentation process lasting 14 days. This fermentation process utilized a mixture of palm sugar, rice bran, and the EM4 bioactivator. To attain the desired concentrations of LOF, the leachates from the three different sources were combined and subsequently diluted with water. Before application, the diluted mixture of leachates was enhanced with 50 ml/L of Sapindus rarak water extract, which serves as a surfactant.

Maize hybrid seeds of Bisi-18 were sown in the prepared experimental plots with a spacing of 70 cm x 25 cm. The supply of plant nutrients was implemented by spraying plants with LOF on their leaves at concentrations and frequencies determined by the allocated treatment. For single application, the LOF was foliar spray at 2 weeks after planting (WAP) at rate of 300 ml per plot. For double application, the LOF was foliar spray at 2 and 4 WAP at rate of 300 and 600 ml per plot, respectively. For triple application, the LOF was foliar spray at 2, 4, and 6 WAP at rate of 300, 600, and 600 ml per plot, respectively. The control plot received Urea 100 kg/ha, Sp36 150 kg/ha, and KCl 100 kg/ha as basic fertilizer, along with Urea 100 kg/ha as additional fertilizer, applied twice at 4 MST and 6 MST. The harvest took place when the husk dried out and the kernel is firm and glossy, with a moisture content of approximately 35%.

Data were collected from the samples of five plants randomly selected from the middle two rows of plants in each plot. Observations were made on unhusked ear diameter, number of kernel rows, number of kernels per row, tip fullness, 100-kernel weight, and yield per hectare of plot. The data were statistically analyzed using analysis of variance at 5% and 1% significance levels.

Polynomial regression analysis was performed to determine the relationship between the applied LOF concentrations and the observed variables. Data analysis was performed using SAS 9.4 software in conjunction with Microsoft Excel.

Results

Nutrients status and uptake

Preliminary soil analysis results showed that the soil of tihe experimental field is Latosol with the following properties: total = N 0.52 %, available P = 8.61 ppm, exchangeable K= 0.41 me/100g, organic C = 4.22 %, and pH = 4.75. The application of LOF was intended to supply the nutrients needed by plants during their growth. The selected macronutrients that could be contributed by the plant materials used as the main ingredients of LOF, and it can be seen that banana peel had the highest contribution for all macronutrients (Table 1).

Table 1. Macro nutrients content of the plant materials that make up LOF

Source	N (%)	P (%)	K (%)
Azolla	1.26	0.54	1.16
Water lettuce	0.84	0.33	1.39
Banana peel	2.24	0.74	2.52
Total	4.34	1.61	5.07

The macronutrient uptake levels in leaf tissue recorded at the conclusion of the vegetative phase, derived from different concentrations and application frequencies (Table 2). Overall, it showed that plants tended to absorb a greater quantity of nutrients from liquid organic fertilizers (LOF) compared to those sourced from inorganic fertilizers. Furthermore, the extent of nutrient uptake by plant tissue in response to LOF application is influenced by both the concentration and the frequency of its application.

Performances of grain yield and yield components

The mean performances of grain yield and yield components are presented in Table 3. On average, the yields and yield components of crops treated with liquid organic fertilizer (LOF) were comparable to those receiving inorganic fertilizers. It was observed that as the concentration of LOF increased, both the yield and its components exhibited a tendency to decline. Similarly, an increase in the frequency of LOF applications was associated with a reduction in performance.

Table 2. Uptake of macronutrients by corn leaves when fertilized with LOF at various concentrations and application frequencies

Treatment	N (%)	P (%)	K (%)
Inorganic NPK (control)	1.12	0.22	1.52
LOF 10% at 2 WAP	1.26	0.25	1.60
LOF 10% at 2 and 4 WAP	2.10	0.45	1.65
LOF 10% at 2, 4, and 6 WAP	2.66	0.55	1.85
LOF 20% at 2 WAP	2.66	0.24	1.71
LOF 20% at 2 and 4 WAP	2.80	0.33	1.60
LOF 20% at 2, 4, and 6 WAP	1.68	0.28	1.82
LOF 30% at 2 WAP	2.66	0.59	1.80
LOF 30% at 2 and 4 WAP	1.96	0.63	1.71
LOF 30% at 2, 4, and 6 WAP	2.24	0.66	1.53

Table 3. Mean yield and yield components as fertilized with LOF at different concentrations and application frequencies

Treatment	EL (cm)	GRN	GNR	TF (%)	HED (mm)	G100 (g)	Y (t/ha)
Concentration (C)							
0	19.5	15.3	39.1	98.3	58.7	33.8	8.93
1	19.4	15.4	39.2	99.2	60.1	34.1	8.56
2	19.4	15.8	39.7	99.2	60.1	33.8	8.47
3	19.3	15.5	38.6	98.8	56.5	34.0	7.92
Frequency (F)							
1	19.5	15.7	39.1	99.1	60.2	34.2	8.53
2	19.2	15.5	39.7	99.2	61.0	34.2	8.37
3	19.4	15.6	38.8	98.8	55.6	33.4	8.06

Note: EL = ear length, GRN = grain row number, GNR = grain number/ row, TF = tip filling, HED = husked ear diameter, G100 = 100-grain weight, and Y = grain yield.

Analysis of variance

The results of the analysis of variance is presented in Table 4, which confirmed that the interaction between LOF concentration and its application significantly affected grain yield and its components. This influence was particularly pronounced for grain row number (GNR), tip filling (TF), 100-grain weight (G100), and overall grain yield (Y). However, this interaction did not show a significant effect on ear length (EL), grain row number (GRN), or husked ear diameter (HED).

Table 4. Analysis of variance for grain yield and its components when fertilized with different concentrations and application frequencies of LOF

Source	df	Mean square						
		EL	GRN	GNR	TF	HED	G100	Y
Blok	2	0.82	0.05	0.03	0.03	13.06	3.30	0.01
Concentration (C)	3	0.05	0.32	1.78	0.70*	6.45	0.13	0.59
Frequency (F)	2	0.22	0.08	1.85	0.46	19.47	1.87	0.29
C x F	6	1.33	0.60	12.15**	1.49**	18.51	17.69**	2.59**
Error	18	0.51	0.59	1.80	0.20	10.51	2.01	0.16

Note: EL = ear length, GRN = grain row number, GNR = grain number/ row, TF = tip filling, HED = husked ear diameter, G100 = 100-grain weight, and Y = grain yield

Further analysis of the relationship between grain number per row and the applied LOF concentration and frequency of application revealed that when 10% is applied, the maximum grain number per row is achieved through three applications, i.e., at 2, 4, and 6 WAP (Figure 1a). Different frequency of applications did not show a notable impact on the number of grains per row with a 20% application rate. In fact, with a concentration of 30%, the highest 100-grain weight is achieved with only single application at 2 WAP.

In terms of the weight of 100 grains (Figure 1b), the highest weight was achieved by applying the 10% concentration three times. With two applications at 2 and 4 WAP, the 20% concentration reached its maximum weight, but additional applications decreased in the 100-grain weight. In the same way, achieving the maximum weight of 100 grains only required one application of 30% at 2 WAP.

The relationship between the frequency of LOF application and tip filling at various concentrations is illustrated in Figure 1c, where tip filling, indicative of the unoccupied space on the cob, was maximized with three applications of the 10% concentration. On the other hand, the 20% concentration achieved its maximum filling rate with two applications at 2 and 4 WAP, with increased application frequency leading to a decline in filling rate. Additionally, a single application of 30% at 2 WAP resulted in the highest seed filling rate.

A similar trend was observed in grain yield (Figure 1d), where the 10% concentration required three applications to reach its maximum yield. The 20% concentration achieved its peak yield with two applications at 2 and 4 WAP, while the 30% concentration only necessitated a single application at 2 WAP to optimize tip filling.

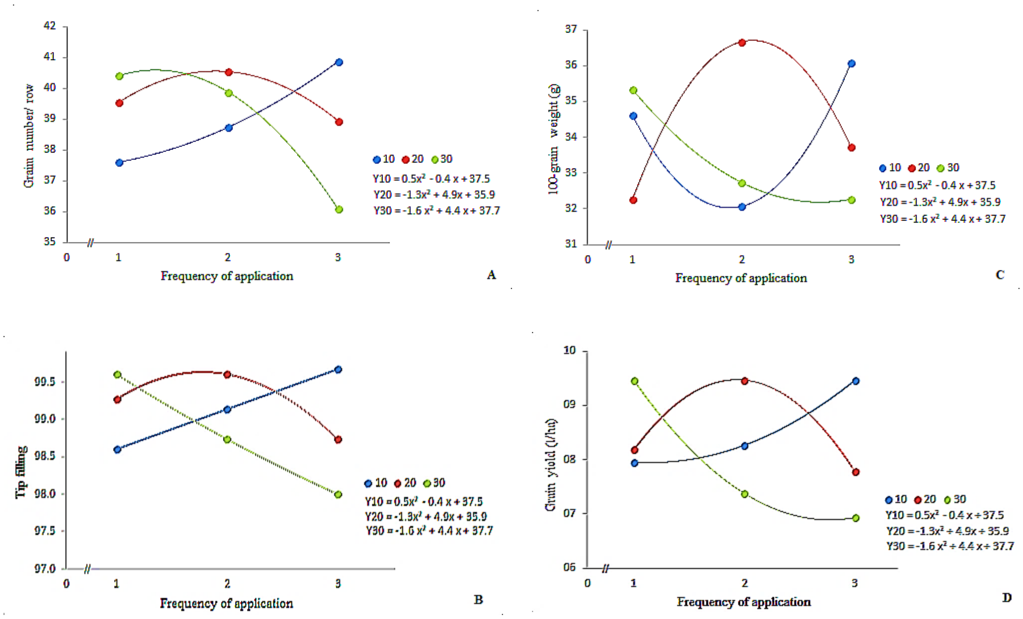

Figure 1. The polynomial regression showing the relationship between frequency of LOF applications at varying concentrations and grain yield as well as yield components

Discussion

Preliminary soil analysis results show that the land has adequate fertility for maize production. Referring to the standard soil fertility assessment by Sulaeman (2005), the land has high N, medium P, medium K, high C-organic content, and a relatively acidic pH. However, since maize is a crop that requires large amounts of macro-nutrients to support maximum growth and yield, the nutrients available in the soil may not meet the needs of the plants. Each corn plant requires 8.7 g N, 5.1 g P, and 4.0 g K (Du Plessis, 2003). Therefore, the use of fertilizers is an integral part of maize production.

The plant materials used as LOF constituents in this study showed relatively high macronutrient content, exceeding the nutrient content of LOF made from banana peels, orange peels, pineapple peels and cow urine (Syamsia, 2023), cow dung (Sutharsan and Rajendran, 2016), and sugarcane leaves (Phibunwatthanawong and Riddech, 2019). With regard to the uptake of nutrients in the leaf tissue, the application of LOF through the leaves resulted in higher levels than those observed with inorganic fertilizers applied through the soil.

However, it should be noted that the uptake levels varied among the treatments. The level of leaf nutrient uptake of LOF applied in this study was higher than that reported by Setyorini *et al*. (2023). In terms of the performances of yield and its components, it appears that there is equality between the supply of nutrients from inorganic fertilizer applied to the soil and the supply of nutrients from LOF applied to the leaves. The yield performance in this study was also higher than other studies reported by Idaryani *et al*. (2024).

The performed analysis of variance revealed that yield and yield components, except ear length, grain row number, and husked ear diameter, were found to be significantly affected by the LOF concentration and frequency of application. The grain number per row, tip filling, weight of 100 grains, and grain yield were 2, 4, and 6 WAP with a 10% concentration, two applications at 2 and 4 WAP with a 20% concentration, or a single application at 2 WAP with a 30% concentration. All these findings suggested that leachates from azolla, water lettuce, and banana peel had the potential to serve as an alternative source of nutrients for maize production in lieu of inorganic fertilizers.

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