Ilmu Pertanian (Agricultural Science)

http://journal.ugm.ac.id/jip

Vol. 9 No. 1 April, 2024: 57–67 | DOI: doi.org/10.22146/ipas.85576

Sugarcane leaf litter biomass and its effects on increasing sugarcane drought stress tolerance and reducing CO_2 emissions

Donny Nugroho Kalbuadi, Siswanto, and Happy Widiastuti*

Indonesian Oil Palm Research Institute Unit Bogor
Jl. Taman Kencana No.1, Bogor 16128, West Java, Indonesia
*Corresponding author: happywidiastuti@yahoo.com

Article Info

Received : 11th June 2023
Revised : 15th February 2024
Accepted: 27th March 2024

Keywords:
Compost, drought stress, global warming, greenhouse gas, water retention capacity

Abstract

Burning biomass on sugarcane plantations can lead to pollution (CO_2 emissions) and degradation in soil properties. Adopting non-burning technology can increase the value of biomass by applying it directly to the soil, although this may result in nutrient immobilization, which can hinder optimal plant growth due to high lignin and cellulose content or high CN ratio. On the contrary, composting waste with a decomposer will boost plant nutrient availability and enhance other soil characteristics. This research was aimed to assess the effect of several types of sugarcane organic matter on improving soil characteristics, growth of sugarcane and the CO_2 emissions. The study was conducted using a Completely Randomized Factorial Design with two factors: type of organic matter (control, fresh litter and compost of sugarcane biomass) and level of drought stress (100, 75, 50 and 25%). Incubation occurred over 16 weeks, divided into two phases of 8 weeks each. The results showed that the application of organic materials in the form of compost could reduce water loss caused by environmental heat and sugarcane growing process. Furthermore, compost application improved soil chemical and biological properties by increasing soil pH, total nitrogen (N), total phosphate (P), total potassium (K), and the total microbial population, although differences were not significant compared to the control. Additionally, applying organic matter in the form of compost or litter helped suppress or reduce emissions, with compost treatment proving more effective than litter in reducing CO_2 emissions.

INTRODUCTION

In 2020, the area of sugarcane plantations in Indonesia was approximately 418,996 hectares. Assuming a yield of 75 tons per hectare, the post-harvest waste (litter) generated would be between 11 to 15 tons per hectare. This calculation results in a potential post-harvest waste volume of approximately 6 million tons across Indonesian sugarcane plantations. In sugarcane cultivation activities, from several stages of cultivation, there are stages contributing to greenhouse gas emissions, thereby triggering global warming and climate change. Mashoko et al. (2010) and Alvarez et al. (2018) stated that sugarcane cultivation process was the largest contributor to global warming and climate change, such as the process of burning sugarcane post-harvest waste. Burning sugarcane biomass (fresh litter) can also result in a decrease in soil fertility. According to Luo and Zhou (2006) and Yulianti et al. (2023), the practice of burning litter or sugarcane trash can accelerate the loss of soil organic matter. On the other hand, the practice of not burning sugarcane residue has several advantages, including: increasing soil nutrients, such as nitrogen (N), phosphate (P), potassium (K), calium (Ca), magnesium (Mg), and sulfur (S) due to mineralization (Batubara and Listyarini, 2017); minimizing water pollution and loss of nutrients due to surface runoff;

How to cite: Kalbuadi, D.N., Siswanto, and Widiastuti, H. (2024). Litter of leaf sugarcane biomass and their effects on increasing sugarcane drought stress tolerance and reducing CO_2 emissions. *Ilmu Pertanian (Agricultural Science)*, 9(1), pp. 57–67.

ISSN 0126-4214 (print) ISSN 2527-7162 (online)

preserving microbial habitats; and increasing soil organic matter content. Another problem caused by global warming and climate change in sugarcane cultivation is drought stress, where sugarcane production requires an optimal water supply according to the phase of the sugarcane crop. Excess or lack of water can lead to suboptimal growth and reduced productivity of sugarcane plants. The need for water in sugarcane plants is influenced by their growth phase (Mastur, 2016).

Two common methods of biomass management in sugarcane cultivation are burning and non-burning. In Indonesia, the practice of burning sugarcane residue has begun to be implemented, including in Lampung area, in accordance with Governor Regulation No. 33 of 2020 concerning crop management and sugarcane crop productivity. The management of biomass waste by burning is being abandoned due to adverse effects. Besides causing air pollution, burning biomass leads to increased CO_2 emissions and nutrient losses, such as nitrogen (N). Furthermore, burning sugarcane biomass reduces the diversity of PLFA (phospholipid fatty acids) and microbial diversity index, and it increases the ratio of Gram-negative to Gram-positive bacteria in response to greater substrate availability (Haynes and Graham, 2004).

The return of biomass has significant potential to improve the chemical, physical, and biological characteristics of the soil. However, sugarcane litter serves primarily as mulch if it is not composted, contributing solely to maintain soil moisture and temperature. On the other hand, composting sugarcane litter can produce simple compounds that can be utilized by sugarcane plants due to mineralization. It is important to manage sugarcane biomass effectively so that it does not only function as mulch. Research results also indicate that adding compost can improve the soil's water retention capacity (Pavel, 2011; Iqbal, 2018; Chacha et al., 2019). Water retention capacity can improve the drought tolerance of sugarcane. For this reason, the return of sugarcane biomass waste is aimed at conserving nutrients and water while reducing CO_2 emission which is expected to improve fertilizer and water efficiency. Additionally, this practice helps preserve soil health, which plays a role in increasing productivity and sustainability in sugarcane cultivation and maintaining air quality. This study was conducted to assess the potential of compost derived from sugarcane postharvest waste in improving soil characteristics, enhancing sugarcane growth, and reducing the CO_2 emission.

MATERIALS AND METHODS

Research location

This research was conducted in the Greenhouse of the Indonesian Oil Palm Research Institute (IOPRI) Unit in Bogor, using soil taken from the Ciomas IOPRI Unit Bogor Experimental Field. Soil property analysis was performed at the Microbiology and Chemistry Laboratory of IOPRI Unit Bogor. This research was conducted from November 2021 to April 2022.

Experimental design

The experimental design used in this study was a Completely Randomized Factorial Design with two (2) factors: type of organic matter and level of drought. Three types of organic matter were tested: without organic matter (control, B0); fresh litter (B1); and compost of sugarcane litter biomass (B2). The four levels of drought tested were field capacity (FC) of 100% (L1), 75% (L2), 50% (L3), and 25% (L4). The combination of treatments was made into three (3) replications. The application rates of fresh litter and compost derived from sugarcane litter were 15 tons/ha and 7.5 tons/ha, respectively. The polybags used had a dimension of 40 x 40 cm (length x width), each filled with 7 kg of soil. The soil and compost were thoroughly mixed until homogeneous and placed into polybags for use as sugarcane planting media, with each polybag containing one (1) sugarcane seed of the PS-881 variety. NPK fertilizer was applied twice during the experiment. The first application was conducted at 1 week after planting (WAP) with urea at 150 kg/ha, TSP at 350 kg/ha, and KCl at 50 kg/ha. The second application was performed at 4 WAP with urea at 300 kg/ha and KCl at 100 kg/ha.

The field capacity (FC) was determined by first drying 7 kg of soil. The dried soil was then placed into a black polybag with a diameter of 40 cm and watered until the first drop came out, at which point the amount of water added to reach this stage was recorded as the field capacity. After watering, the soil was allowed to stand for 24 hours. Subsequently, the water content (WC) was calculated by taking three separate 10 g soil samples. Each sample was dried in an oven at 60°C for 24 hours (Saputra et al., 2015). The amount of water added was calculated using Equation 1 and 2 as follows:

$$Wc\ (\%) = \frac{A - B}{A} \times 100\% \qquad (1)$$

$$FC\ C = C \times (FC - (FC \times WC)) \qquad (2)$$

Remarks:

A = Initial weight of the sample (g)

B = Final weight of the sample (g)

FC = Field Capacity (%)

WC = Water Content (%)

C = Desired field capacity

Watering according to treatment was conducted weekly. The variables observed in this study included water content, pH, organic carbon (C), nitrogen (N), phosphate (P), potassium (K), total microbial, and CO_2 flux at 2 months after planting (MAP). Plant observations included monthly measurement of plant height and the fresh weight of shoot and root at four (4) months after planting (MAP). Sugarcane was harvested after four-month incubation period. The observational data were analyzed using ANOVA followed by Duncan's test at a significance level of 5%.

CO_2 flux was measured once in 2 MAP in the morning between 8:00 AM and 10:00 AM using the closed chamber method (0.3 x 0.3 x 0.78 m) with the Li-830 portable Gas Analyzer (Figure 1). CO_2 measurements were carried out every second for a total of 2 minutes, resulting in 120 data points. Simultaneously, other variables such as soil temperature, air temperature, chamber's temperature and height were recorded during each measurement. Data from CO_2 emission measurements were then processed using Microsoft Excel by considering the volume of the chamber above ground level and the temperature of the chamber.

The CO_2 flux was calculated using the following equation (Madsen et al., 2009):

$$Fc = \frac{V}{A} \; \frac{P_0}{R(T_0 + 273.15)} \; \frac{dC}{dT} \qquad (3)$$

Remarks:

Fc = CO_2 flux ($\mu mol^{-1}.m^{-2}$ per second)

V = Chamber volume (m^3)

A = Chamber area (m^2)

P_0 = Initial atmospheric pressure

R = Gas constant (8.314 Pa m^3 K^{-1}. mol^{-1})

T_0 = Air temperature in the chamber

dC/dT = Changes in CO_2 concentration per unit time (mol ppm.m^{-2}.sec^{-1})

RESULTS AND DISCUSSION

Soil water losses in each type of organic matter application

The results of the research observations can be categorized into two phases: the first 8 weeks and the second 8 weeks of the study. During the first 8 weeks, water loss varied based on the treatment applied. Water loss rates for control, fresh litter, and compost treatments ranged between 0.98−1.23, 0.8−1.4, and 0.38−1.07 liters/week, respectively. Based on the results, it was found that the highest water loss occurred at week five when organic matter (compost and litter) was applied, and at week eight in the control group. Overall, water loss increased during the second 8 weeks of the study. Above all that, the control group experienced the highest water loss

Figure 1. LI-COR 830 gas analyzer

compared to other treatments. The water loss in the compost application ranged from approximately 1.22 to 1.52 liters/week. This value was significantly lower than the water loss observed with the addition of organic matter in the form of litter, which ranged from 1.59–1.79 liters/week. This value was not significantly different from that observed in the control treatment.

These results indicate that at 100% field capacity (Figure 2a), compost can reduce water loss compared to sugarcane organic matter given in the form of litter. Throughout both the first and last 8 weeks of incubation, application of compost led to suppressed water loss, as indicated by a lower water loss value compared to the control and application of organic matter in the form of litter. At 75% field capacity (Figure 2b), similar pattern emerged where the addition of compost was effective to suppress water loss during the first and second 8 weeks of incubation. It was indicated by a higher value of water loss compared to those observed with the control and application of organic matter in the form of litter. However, the observed water loss at a field capacity of 75% was consistently lower than the water loss observed at 100% field capacity throughout the entire 16-week observation period.

At 50% field capacity (Figure 2c), a comparable pattern to the observations at 75% to 100% field capacities was found, where the application of compost effectively suppressed water loss compared to the

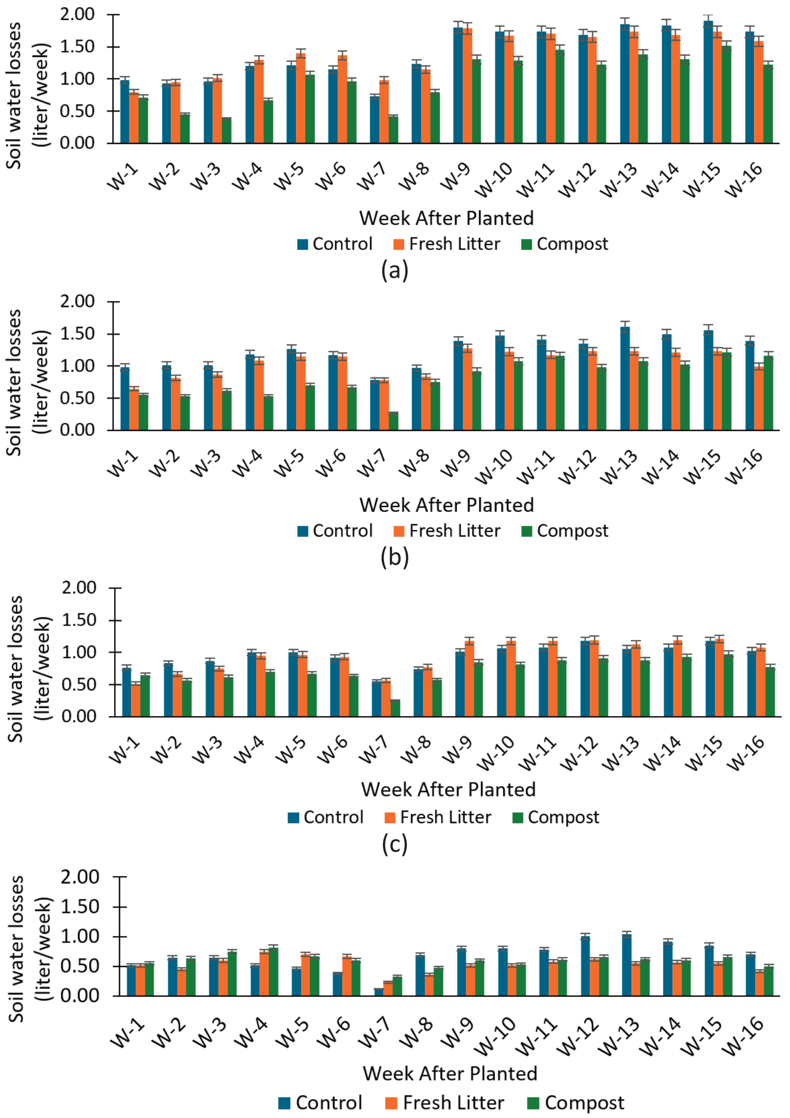

Figure 2. Soil water losses per week in each type organic matter application at 100% (a); 75% (b); 50% (c); and 25% (d) field capacity

control and litter treatments. However, during the second 8 weeks of incubation, the application of litter resulted in higher water loss compared to the control. This higher water loss may be attributed to the increased demand for water required by soil microbes during the decomposition process of the litter. Notably, the water loss observed at 50% field capacity was lower compared to 75% field capacity throughout the 16-week observation period.

At 25% field capacity (Figure 2d), an interesting observation was made. Applying compost during the first 8 weeks required additional watering to maintain soil moisture levels, resulting in water loss ranging from 0.33 to 0.82 liters per week, with the peak occurring around week 4. Organic matter in the form of litter and compost contributed to reducing water loss, with the highest water loss was found in the control treatment. These results indicate that the application of organic matter under conditions of low water content (dry conditions) can help reduce water loss, suggesting that organic matter increases the soil's ability to retain water. However, at 25% field capacity conditions, sugarcane in the control treatment experienced death. This is likely due to the insufficient water content in this treatment to meet the water needs of the plants.

The water loss data, grouped into two (2) phases, showed higher water loss in the last eight (8) weeks compared to the initial 8 weeks (Figure 3). This increase in water loss can be attributed to the difference in temperature within the greenhouse during the two phases (Figure 4). In the first 8-week phase, the greenhouse temperature was relatively lower, ranging from 29.5−31.0°C, whereas in the last 8-week phase, there was a significant increase in temperature, ranging from 30.2−34.0°C. Therefore, water loss increased during the last 8 weeks or 2 months of the study. This increase in water loss is not only influenced by the rise in temperature but also due to the greater water demand for sugarcane growth during the 3−4 months after planting (MAP). According to Yusara et al. (2019), sugarcane shows its highest water demand during the budding and stem elongation phases, accounting for 77% of the total water requirement. This aligns with the research of Silva et al. (2013), mentioning that low water content at 3−6 MAP will

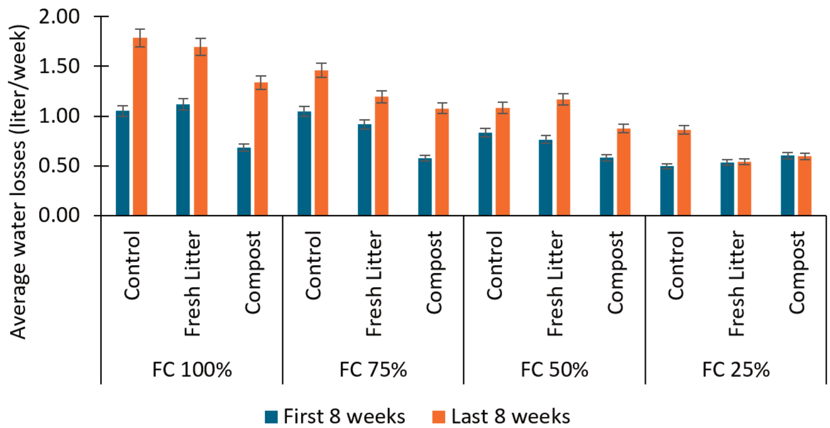

Figure 3. Soil water losses in two (2) time phase in each organic matter application at 100%, 75%, 50%, and 25% field capacity

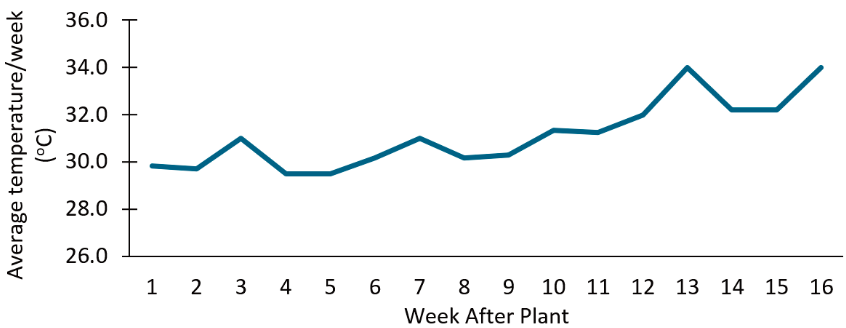

Figure 4. Average temperature per week in December 2021–April 2022

greatly affect the performance of sugarcane plant, especially its productivity.

Composting resulted in lower water loss compared to the fresh litter and control treatments. This difference underlines varied response of soil to the compost tratment compared to fresh litter or control treatments, indicating that compost application enhance soil's water retention capacity. The organic content in the soil plays a crucial role in influencing the soil's water holding capacity and the efficiency of fertilizer absorption by plants (Hariyono et al., 2020 and Iqbal, 2018). Organic matter presence increases the availability of water in the soil by creating pores (Hariyono et al. 2020; Abel et al. 2013; Bruun et al. 2014) and enhancing soil aggregation and structure (Nelissen et al. 2015).

Soil pH in each type of organic matter application

Soil pH is influenced by the addition of organic matter applied to the soil. Changes in soil pH were observed during the 1–4 MAP, as presented in Figure 5. The average soil pH prior to the control treatment was 4.31. From Figure 5, it is evident that composting was the most effective treatment for reducing soil acidity compared to the pre-treatment condition. This study also revealed that the application of the fresh litter was able to increase the soil pH, although not to the extent as observed with the compost treatment. According to Cai et al. (2018), organic fertilizer is effective in reducing soil acidity, as evidenced by the addition of compost and litter as organic matter that can decrease soil acidity. The increasing soil pH through

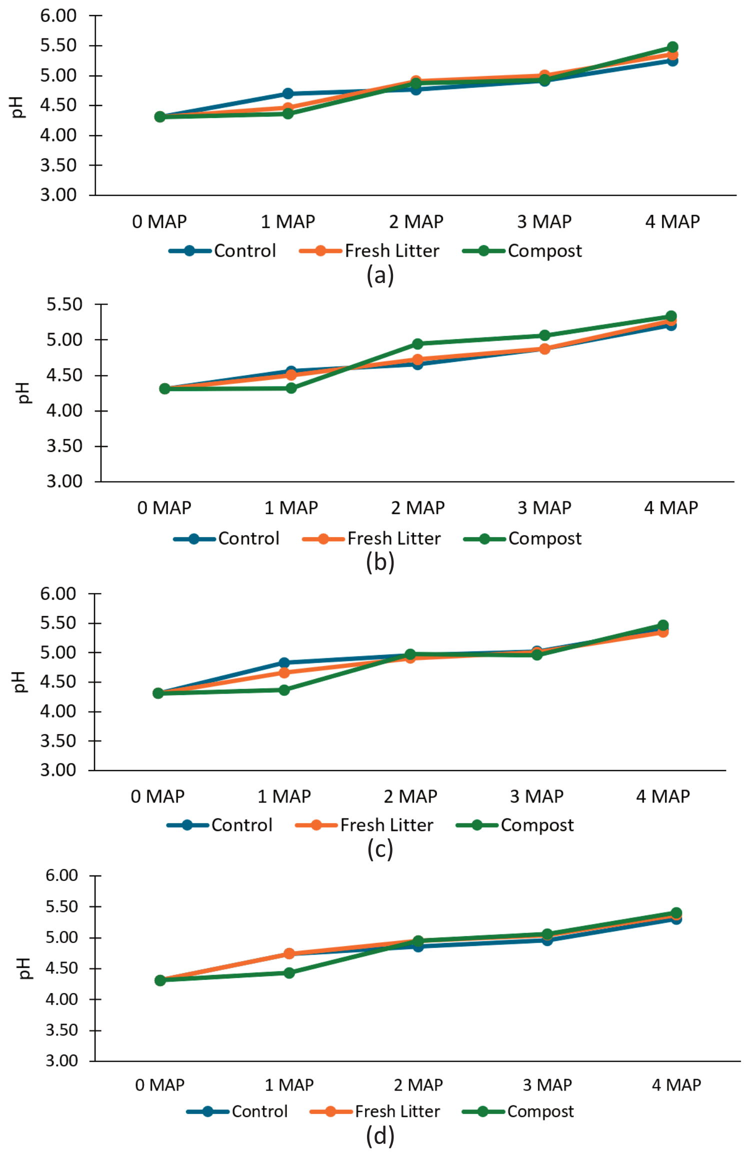

Figure 5. Soil pH in each organic matter application treatment at 100% (a); 75% (b); 50% (c); and 25% (d) field capacity

the application of organic material (compost) may be attributed to the organic material undergoing decomposition, which releases organic substances such as organic acids or basic cations, thereby increasing the soil pH (Siregar et al., 2017). This aligns with findings from Hamed (2014), who observed that content nutrients of soil organic matter correlates with mineralization processes that require organic matter to provide nutrients for soil. As a result of decomposition, organic acids can bind H^+ ions, which reduce acidity in the soil, leading to an increase in soil pH. An increase in pH also occurs in the control treatment because soil acidity is directly influenced by the concentration of hydrogen ions in the soil. Regular watering of the soil can intensify the process of acid dissolution, resulting in higher levels of hydrogen ions and thus making the soil more acidic (Nikiyuluw et al., 2018).

Soil properties

Soil analysis before treatment showed that the soil reaction was acidic (pH 4.31). The total organic C and nitrogen (N) was relatively low with 1.35% and 0.12%, respectively. The total number of microbes found in the soil was 3.2×10^6. In this study, the application of organic matter in the form of litter and compost is expected to improve soil properties, especially the physical and chemical properties of the soil.

The soil analysis conducted after treatment (Table 1) showed promising results, with a tendency to increase total nitrogen (N), total phosphate (P), and total potassium (K) nutrients compared to the control, although these increases were not statistically significant. It's important to note that increasing soil nutrients through the application of organic matter typically occurs over a relatively long period of time (Adugna, 2016; Liu et al., 2022). According to Iqbal (2018), the addition of organic matter such as compost plays a very important role in improving soil fertility. Organic matter in compost can enhance the availability of total nitrogen (N), total phosphate (P), and total potassium (K), and it can also contribute to the production of humic acids, which influence the soil's cation exchange capacity (CEC). Based on the results of the analysis, there was an increase in the total microbial population after the application of organic matter, especially compost. The highest total microbial population was found in compost treatment with various field capacity conditions. This shows that the presence of organic matter, especially compost, can be a source of energy for soil microbes, which are later expected to be able to support the soil nutrient cycle. According to Liu et al. (2022), the application of organic matter, especially compost, can increase or enrich the population of beneficial soil microbes while reducing the population of harmful soil microbes. The key factors that serve as the carrying capacity for shaping soil microbial community composition are electrical conductivity, total phosphorus, and soil organic matter.

Sugarcane plant height under each type of organic matter application

Plant growth at field capacity increased over time during the observations from 1–4 MAP, as shown in Figure 6. The highest growth was observed in plants at 100% field capacity (Figure 6a) with the application

Table 1. Soil chemistry properties after harvest (4 MAP)

Field capacity (%)	Organic matter	Total N (%)	Total P (%)	Total K (%)	Organic C (%)	Total Microbes (cfu/g)
100	Control	0.20	0.077	0.017	1.98	4.2×10^6
	Fresh Litter	0.21	0.111	0.017	2.00	6.0×10^6
	Compost	0.22	0.207	0.027	2.02	6.5×10^6
75	Control	0.15	0.064	0.017	1.61	2.5×10^6
	Fresh Litter	0.21	0.074	0.046	1.97	3.6×10^6
	Compost	0.20	0.069	0.017	2.00	3.8×10^6
50	Control	0.18	0.061	0.021	1.63	1.6×10^5
	Fresh Litter	0.19	0.077	0.027	1.64	1.8×10^5
	Compost	0.22	0.083	0.022	2.44	4.4×10^5
25	Control	0.20	0.061	0.012	1.81	3.9×10^4
	Fresh Litter	0.20	0.070	0.019	1.86	9.3×10^4
	Compost	0.20	0.087	0.020	1.93	1.9×10^5

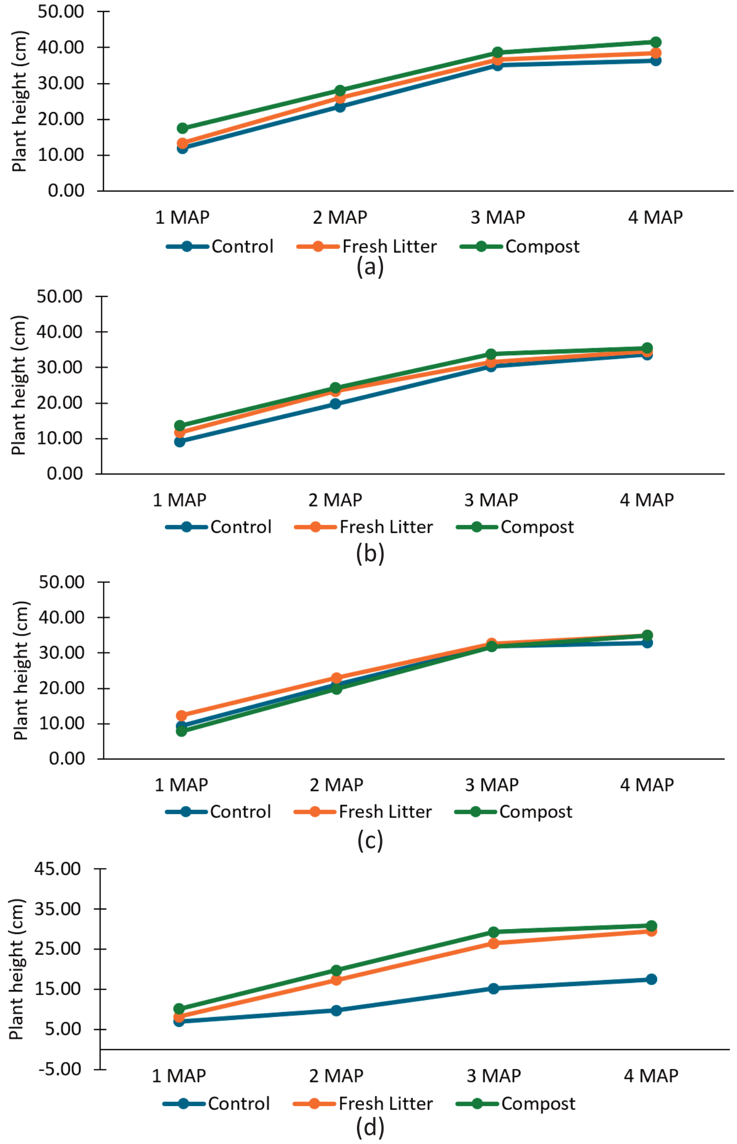

Figure 6. Height of sugarcane in each organic matter application at 100% (a); 75% (b); 50% (c); and 25% (d) field capacity

of compost, followed by the application of organic matter in the form of litter. At 4 MAP, plant height reached 41.5 cm with compost application, while in the control group, it was only 36.3 cm, representing 14.32% difference. This indicates that the growth rate of plant height with the application of compost was 0.35 cm/day, while without the application of organic matter (control), it was 0.30 cm/day.

The sugarcane plant height at 75% field capacity treatment did not differ significantly compared to the plants at 100% field capacity (Figure 6b). However, the control treatment at 75% FC showed a much lower plant height (33.7 cm) compared to 100% field capacity (36.3 cm). Based on these values, it is evident that the growth rate of sugarcane plant height with the application of organic matter was 0.30 cm per day, while without the application of organic matter (control), it was 0.28 cm per day.

At 50% field capacity (Figure 6c), the results were similar to those observed at 75% and 100% field capacity, with compost producing the highest growth of 35.0 cm, followed by the addition of litter at 34.9 cm. These results suggest that at 50% field capacity, the application of organic matter in the form of compost can promote optimal plant growth especially in terms of plant height. However, this value was not significantly different from that in the control and litter treatments. The optimal decomposition process of organic matter occurs at a water content range of 50–60%. This moisture level appears to be suitable for the decomposition process of litter.

At a very low field capacity of 25% (Figure 6d), the application of organic matter in the form of compost resulted in the highest sugarcane growth reaching 30.8 cm at 4 MAP, followed by the litter treatment at 29.5 cm. Contrary to that, the control treatment showed the lowest plant height growth at 17.5 cm. These results indicate that the application of organic matter, especially compost, significantly promotes plant growth.

Weight of plants and roots

In this study, an increase in plant and root weight in sugarcane was expected and observed at 4 MAP (Table 2). At various field capacities, composting was found to enhance plant and root weights, particularly at 100% field capacity where the compost treatment had the highest increases with 56.67 g and 21.00 g, respectively, representing a 29.8% and 34.0% increase compared to control treatment. At 75% field capacity, the increase in plant and root weight had a significant difference, ranging from 17.3−19.0 g compared to 100% field capacity. At 75% field capacity, the maximum plant weight was 37.7 g in the compost treatment, followed by 31.0 g in the litter treatment, and 26.3 g in the control treatment. Similar trends were observed for root weights at 75% field capacity with the highest record found in the compost treatment (37.7 g), followed by fresh litter (31.0 g), and control (26.3 g).

At 50% field capacity, the results were similar to those at 75% field capacity, with compost showing an increase in both plant and root weights (27.0 g and 10.3 g, respectively), followed by litter application (26.3 g and 9.0 g, respectively). These results suggest that at 50% field capacity, the application of compost leads to optimal growth. However, this value was not significantly different compared to the control and litter treatments. At 25% field capacity, it produced the lowest plant and root weight compared to other

Table 2. Fresh weight of shoot and root of sugarcane in each type organic matter application at 100%, 75%, 50%, and 25% field capacity

Field capacity (%)	Organic matter	Shoot Weight (g)	Root Weight (g)
	Control	43.67 b	15.67 ab
100	Fresh Litter	38.33 bc	16.00 ab
	Compost	56.67 a	21.00 a
	Control	26.33 cde	11.33 bc
75	Fresh Litter	31.00 bcd	11.33 bc
	Compost	37.67 bc	12.33 bc
	Control	24.67 cde	8.00 cd
50	Fresh Litter	26.33 cde	9.00 cd
	Compost	27.00 cde	10.33 bcd
	Control	9.67 e	4.50 d
25	Fresh Litter	15.67 e	4.67 d
	Compost	18.33 de	8.67 cd
Coefficient of Variance (%)		15.4	17.3

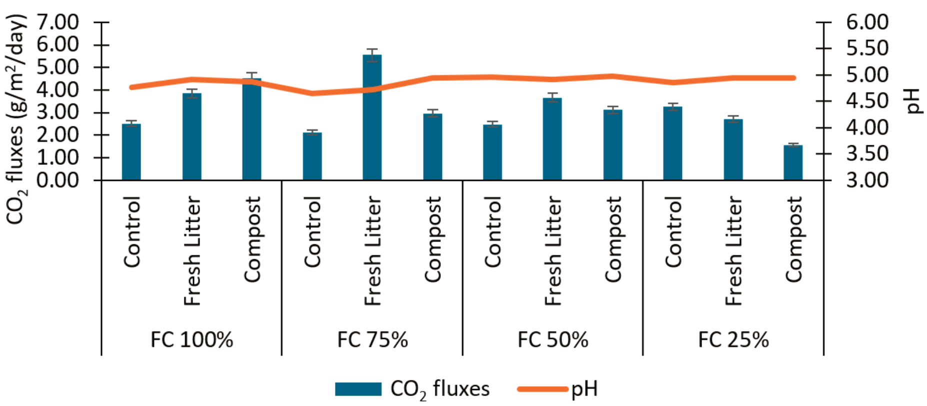

Figure 7. CO_2 emissions in each organic matter application at 100%, 75%, 50%, and 25% field capacity (2 MAP)

field capacities. However, the application of organic matter in the form of compost at 25% field capacity resulted in the highest plant and root weight, reaching 18.3 g and 8.7 g, respectively. The litter treatment yielded weights of 15.7 g for plants and 4.7 g for roots, while the control produced the lowest weights at 9.7 g for plants and 3 g for roots. These results indicate that the application of organic matter, especially compost, can help improve plant growth. These results align with the findings of Barakat et al. (2015) and Prasetyo et al. (2014), which reported that the use of urea and organic fertilizers increases plant and root weight compared to the control treatment. This is attributed to the general use of compost as a soil improvement material.

The CO_2 emission

At 100% field capacity, the highest CO_2 emission during 2 MAP (Figure 7) was in the application of compost. At 50%–75% field capacity, the highest emission was in the application of organic matter in the form of litter. The highest emission of litter treatment is due to the ongoing decomposition process. While at 25% field capacity, the highest emission was in the control treatment or without the addition of organic matter. These results indicate that in dry conditions, the application of organic matter in the form of compost or litter can suppress or reduce emissions, and compost treatment is much better than litter in reducing CO_2 emissions. The application of compost in soil has been shown to reduce greenhouse gas emission due to the soil's carbon storage capability (Ho et al., 2022). With compost, it is feasible to get an average organic matter absorption of 6.2 mg/ha over 22 years, or around 160 kg C year (Razza et al., 2018). In comparison to unburned sugarcane regions where CO_2 emission was 1.92 μmol m^{-2} s^{-1}, the burned sugarcane area exhibited average soil CO_2 emission of 37% greater at 2.63 μmol m^{-2} s^{-1} (Moitinho et al., 2021). The unburned sugarcane region had a higher soil moisture level (25.30%) compared to the burned sugarcane area (16.02%). Additionally, the temperature of the soil in the burned sugarcane region was higher, with values averaging 21.5°C, which was 2.4°C higher compared to 19.1°C in the unburned sugarcane area.

CONCLUSIONS

The application of organic matter in the form of compost can, in fact, play a significant role in reducing water loss and improving the chemical and biological properties of soil. This includes increasing soil pH, total nitrogen (N), total phosphate (P), total potassium (K), and the total microbial population, although these improvements may not always be statistically significant. Furthermore, the application of organic matter in the form of compost or litter can help suppress or reduce emissions. Specifically, compost treatment has been found to be much more effective than litter in reducing CO_2 emissions, with a rate of 2.97 g/m²/day. Future research should be conducted directly in sugarcane plantations over a duration of 3 to 5 years.

REFERENCES

Abel, S., Peters, A., Trinks, S., Schonsky, H., Facklam, M., and Wessolek, G. (2013). Impact of biochar and hydrochar addition on water retention and water repellency of sandy soil. *Geoderma,* 202–203, pp. 183–191.

Adugna, G. (2016). A review on impact of compost on soil properties, water use and crop productivity. *Acad. Res. J. Agri. Sci. Res.,* 4(3), pp. 93–104.

Alvarez, V., Rosas, F., Reyes, M., Murillo, J., De La Rosa, N., Arzaluz, M., Lara, J., and Cardoso, G. (2018). Sugarcane burning emissions: Characterization and emission factors. *Atmospheric Environment,* 193, pp. 262–272.

Barakat, M., El-Kosary, S., Borhan, T., and Abd-Al Nafea, M. (2015). Effect of hydrogel soil addition under different irrigation levels on grandnain bannana plants. *Journal of Horticultural Science and Ornamental Plants,* 7(1), pp. 18–28.

Batubara, R., and Listyarini, E. (2017). Kajian aplikasi seresah tebu dan urea terhadap ketersediaan nitrogen dalam tanah PT Perkebunan Nusantara X Jengkol, Kediri. *Jurnal Tanah dan Sumberdaya Lahan,* 4(1), pp. 411–419.

Bruun, E., Petersen, C., Hansen, E., Holm, J., and Hauggaard-Nielsen, H. (2014). Biochar amendment to coarse sandy subsoil improves root growth and increases water retention. *Soil Use and Management,* 30, pp. 109–118.

Cai, Z., Xu, M., Wang, B., Zhang, L., Wen, S., and Gao, S. (2018). Effectiveness of crop straws, and swine manure in ameliorating acidic red soils: a laboratory study. *Journal of Soils and Sediments,* 18(9), pp. 2893–2903.

Chacha, M., Andrew, B., and Vegi, M. (2019). Amandment of Soil Water Retention and Nutrients Holding Capacity by Using Sugarcane Bagasse. *Curr.*

Agri. Res., 7(2), pp. 224–235.

Hamed, M., Desoky, M., Ghallab, A., and Faragallah, M. (2014). Effect of Incubation Periods and Some Organic Materials On Phosphorus Forms In Calcareous Soils. *International Journal Of Technology Enhancements And Emerging Engineering Research,* 2(6), pp. 2347–4289.

Hariyono, B., Utomo, W., Utami, S., and Islami, T. (2020). Utilization of the trash biochar and waste of sugarcane to improve the quality of sandy soil and growth of sugarcane. *IOP Conf. Ser.: Earth Environ. Sci.*, 418, 012067.

Haynes, R., and Graham, M. (2004). Composition of the soil microbial community under sugarcane production as indicated by phospholipid fatty acid analysis. *Proc S Afr Sug Technol Ass,* 78.

Ho, T., Tra, T., Le, T., Nguyen, N., Tran, C., Nguyen, P., Vo, T., Thai, V., and Bui X. (2022). Compost to improve sustainable soil cultivation and crop productivity. *Case Studies in Chemical and Environmental Engineering*, 6, 100211.

Iqbal. (2018). Effect of Sugarcane Litter Compost on Soil Compaction. *International Journal of Agriculture System,* 6(1), 35–44.

Liu, X., Shi, Y., Kong, L., Tong, L., Cao, H., Zhou, H., and Lv, Y. (2022). Long-term application of bio-compost increased soil microbial community diversity and altered its composition and network. *Microorganisms,* 10, 462.

Luo, Y., and Zhou, X. (2006). Soil respiration and the environment, CHAPTER 3 - Processes of CO_2 Production in Soil. *Academic Press*, pp. 35–59.

Mashoko, L., Mbohwa, C., and Thomas, V. (2010). LCA of the South African sugar industry. *Journal of Environmental Planning and Management,* 53(6), pp. 793–807.

Mastur. (2016). Respon Fisiologis Tanaman Tebu Terhadap Kekeringan. *Buletin Tanaman Tembakau, Serat & Minyak Industri,* 8(2), pp. 98–111.

Moitinho, M., Ferraudo, A., Panosso, A., Bicalho, E., Teixeira, D., Barbosa, M., and La Scala, N. (2021). Effects of burned and unburned sugarcane harvesting systems on soil CO_2 emission and soil physical, chemical, and microbiological attributes. *CATENA,* 196, 104903.

Nelissen, V., Ruysschaert, G., Manka'Abusi, D., D'Hose, T., De Beuf, K., Al-Barri, B., Cornelis, W., and Boeckx, P. (2015). Impact of a woody biochar on properties of a sandy loam soil and spring barley during a two year field Experiment. *Europ. J. Agronomy,* 62, pp. 65–78.

Nikiyuluw, V., Soplanit, R., and Siregar, A. (2018). Efisiensi Pemberian Air dan Kompos Terhadap Mineralisasi NPK pada Tanah Regosol. *J. Budidaya Pertanian,* 14(2), pp. 105–112.

Prasetyo, A., Listyorini, E., and Utomo, W. (2014). Hubungan sifat fisik tanah, perakaran dan hasil ubi kayu tahun kedua pada Alfisol Jatikerto akibat pemberian pupuk organik dan anorganik. *Jurnal Tanah dan Sumberdaya Lahan,* 1(1), pp. 27–37.

Razza, F., D'Avino, L., L'Abate, G., and Lazzeri, L. (2018). The role of compost in bio-waste management and circular economy. *Designing sustainable technologies, Prod. & Pol.,* pp. 133–143.

Silva, D., Silva, B., Albuquerque, W., Borges, C., Sousa, D., and Neto, J. (2013). Crop coefficient, water requirements, yield and water use efficiency of sugarcane growth in Brazil. *Agricultural Water Management*, 128, pp. 102–109.

Siregar, P., Fauzi, and Supriadi. (2017). Pengaruh pemberian beberapa sumber bahan organik dan masa inkubasi terhadap beberapa aspek kimia kesuburan tanah ultisol. *Jurnal Agroekoteknologi FP USU,* 5(2), pp. 256–264.

Yulianti, T., Hidayah, N., Wijayanti, K., Sujak, S., Sunarto, D., Nurindah, N., Supriadi, S., and Subiyakto. (2023). Sugarcane-trash management for sustaining soil health and decreasing risk of soil-borne diseases, particularly in tropical regions. *Applied Ecology And Environmental Research,* 21(3), pp. 1837–1854.

Yusara, A., Handoko, and Budianto, B. (2019). Analisis kebutuhan air tanaman tebu berdasarkan model simulasi tanaman (studi kasus: Kabupaten Kediri, Jawa Timur). *Agromet*, 33(1), pp. 30–40.