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Research Article

Growth and yield performance of maize at red-yellow podzolic acid soil after oil palm empty fruit bunches compost and rice husk charcoal application

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Abstract: On acid soils, maize growth cannot be optimal because of the high content of Al, Fe, Mg, and Zn, which has the potential to poison plants. Several nutrients such as P, Cu, and S are also available in small quantities for plants, thus inhibiting growth. This study aimed to determine the effectiveness of oil palm empty fruit bunches compost and rice husk charcoal in increasing the growth and yield of maize on red-yellow podzolic acid soils. Bonanza F1 varieties were planted and treated with (T1) 5 t ha^{-1} of oil palm empty fruit bunches compost; (T2) 10 t ha^{-1} of oil palm empty fruit bunches compost; (T3) 5 t ha^{-1} rice husk charcoal; (T4) 10 t ha^{-1} rice husk charcoal; and (T5) 5 t ha^{-1} of oil palm empty fruit bunches compost + 5 t ha^{-1} of rice husk charcoal, and control plants were not given any treatment. The results showed that all treatments had a better and significantly different effect than the control plants. The application of oil palm empty fruit bunches compost and rice husk charcoal could boost plants height (149.75% - 289.88%), stems diameter (124.10% - 204.62%), number of leaves (131.01% - 223.26%), plants fresh weight (204.14% - 342.25 %), plants dry weight (136.77% - 165.76%), weight of maize cobs (178.77% - 292.72%), weight of maize cobs without maize husks (158.27% - 233.03%), maize cobs length (112.44% - 147.14%), maize cobs diameter (117.16% - 187.79%), and the weight of 100 maize kernels (110.92% - 201.72%). Among all treatments, the T5 treatment (5 t ha^{-1} of oil palm empty fruit bunches compost + 5 t ha^{-1} rice husk charcoal) was the best because it consistently gave the highest yields on all observed variables.

Keywords: *Bonanza F1, cobs, degraded soil, nutrients, organic matter*

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Introduction

Maize is an agricultural commodity with high economic value in Indonesia generally used as food and animal feed. Maize is also one of Indonesia's primary export commodities (Timmer, 2019). Currently, it is cultivated in all regions in Indonesia from the lowlands to the highlands with monoculture and intercropping plant patterns (Suherman et al., 2019). Ominously, the problem of maize cultivation in Indonesia and other developing countries in Asia is the availability of fertile land (Sharma et al., 2017). The fertile soil is generally for rice, which is the staple food for most of the Asian people. Also, the conversion of fertile land to non-productive land is one of the problems in providing land for maize cultivation.

Sub-optimal land is a land that naturally has difficulties in its management, and has low soil fertility (Sharma et al., 2017). Therefore, it requires more effort to switch it as productive cultivation land. The characteristics of sub-optimal lands are varied widely, but based on their biophysical conditions, the sub-optimal area can be divided into five categories, namely acid dry land, tidal swampland, dry climate dry land, low swampland, and peatland (Wildayana, 2017; Sutapa et al., 2018). One of the suboptimal land characteristics found in Indonesia is a land with acid soils around 30% of the Indonesia land area. Acid soils are soils that contain relatively high concentrations of H^+ (Zhang et al., 2017). At a pH below three, H^+ is toxic, while pH under five will be Al toxicity (Lin et al., 2018), Fe and Mn cause root inhibitors by destroying the root cell structure and meristem (Hamim et al., 2018).

The low pH characteristic of acid soils also sources the deficiency of several nutrients such as N, P, Ca, and Mg (Baligar et al., 2001). This deficiency is partly because the Al element in the soil fixes P into the Al-P complex so that P becomes a form not available in the soil, which results in inhibition of root growth, nutrient and water absorption by plants (Shen et al., 2011). The application of phosphate fertilizer directly to acid mineral soils also does not solve the problem because most of the phosphate given is strongly adsorbed by soil colloids so that it is not available to plants (Baken et al., 2016; Zuo et al., 2016). Therefore, high liming and fertilization efforts are required to improve soil quality. The low soil productivity is also supported by low soil microbial activity (Lori et al., 2017).

Various attempts have been made to increase maize production on acid soils; yet, the problem has not been entirely resolved. One of the potential ways to increase maize growth in acid soils is by manipulating the rhizosphere through the application of organic matter and buffer materials. Natural materials and buffer materials can be obtained from agricultural waste such as oil palm empty fruit bunches compost and rice husks. Oil palm empty fruit bunches are generally processed as compost (Krishnan et al., 2017; Trisakti et al., 2017), and rice husks are processed into rice husk charcoal (Teo et al., 2016; Cheng et al., 2018). The use of agricultural waste will support the realization of sustainable agriculture and zero waste in agriculture. The application of compost around the plant's rhizosphere will increase the soil organic matter content, and increase the soil's ability to retain water (Adugna, 2016). Besides, the use of fertilizer is to stimulate soil microbial activity, which is beneficial for plants. Compost application can also improve soil structure and texture conditions so that O_2 diffusion or aeration can be better and grow the physiological quality plants (Agegnehu et al., 2017; Rabot et al., 2018). Furthermore, the form of rice husk charcoal was also reported to have a positive effect on soil conditions. Although rice husk charcoal does not contain high nutrients, charcoal can be an excellent habitat for soil microbes (McGee et al., 2019; Kallenbach et al., 2019). Charcoal is also known as one of the ingredients that can increase the pH value of the soil and increase the value of soil cation exchange capacity (Wang et al., 2017). This research aimed at finding the impact of the application of oil palm empty fruit bunches compost and rice husk charcoal on the maize growth and yield at the acidic soil.

Materials and Methods

Time and place of research

The research was conducted at the Borneo University of Tarakan experimental garden, Indonesia from December 2018 to February 2019.

Oil palm empty fruit bunches compost production

The empty fruit bunches of oil palm were chopped using a chopping machine and filtered using a sieve with a diameter of 1 cm^2. The cut results that have passed the filtering process were then put into the composter. The chopped material was then sprayed using a capable commercial microorganism (EM), which had been mixed using molasses with a ratio of 5:1 (v/v). The composting process was carried out for 35 days under anaerobic conditions. The nutrient content of oil palm empty fruit bunches compost used in this study were: N-total (1.9%); K (1.5%); P-total (0.5%); Ca (0.8%); Mg (0.09%); C-organic (51.2%); C/N ration (26.94%), and the pH value was 7.1.

Rice husk charcoal production

The rice husks were put into an iron plate with a diameter of 2 m^3. The iron plate was then heated using fire at the bottom. As long as the iron plate was heated, the rice husks were stirred using a wooden stirring so that the heat from the iron plate could spread evenly throughout the rice husks. The process was carried out for 30 minutes until all parts of the rice husk turned black. The method of making rice husk charcoal was carried out carefully to make the rice husk did not burn and did not turn into ash. The husks turned to charcoal were then sprayed with water to ensure that no embers were ignited. The rice husk charcoal produced was then cooled and dried in a greenhouse for seven days. The dried rice husk charcoal was later used in the field experiment.

Field experiment

The field experiment was done in the experimental garden of the Borneo University of Tarakan with a red-yellow podzolic soil type, and a pH of 4.5. The maize variety used in this experiment was Bonanza F1. The study was conducted following a randomized block design (RBD) with six treatments, each treatment was repeated four times, and each replication consisted of 4 tested plants. The procedures used in this study are presented in Table 1. Maize was planted on 70 × 40 cm beds, and each bed was planted four plants. The compost of empty palm oil bunches and rice husk charcoal were applied utilizing blasting with a distance of 5 cm from the plant. The application was carried out once in one week after planting.

Table 1. The treatment used in the study.

Code	Treatment
Control	No oil palm empty fruit bunches compost and rice husk charcoal
T1	5 t ha^{-1} of oil palm empty fruit bunches compost
T2	10 t ha^{-1} of oil palm empty fruit bunches compost
T3	5 t ha^{-1} of rice husk charcoal
T4	10 t ha^{-1} of rice husk charcoal
T5	5 t ha^{-1} of oil palm empty fruit bunches compost + 5 t ha^{-1} of rice husk charcoal

Harvesting and observation of research variables were conducted in 90 days after planting. The research variables observed included plants height (cm), stems diameter (cm), number of leaves, plants fresh weight (g), plants dry weight (g), the weight of maize cobs (g), the weight of maize cobs without maize husks (g), maize cobs length (g), maize cobs diameter (g), and the weight of 100 maize kernels (g).

Data analysis

Data were analyzed using analysis of variance (ANOVA), followed by Duncan's test at the 95% confidence level. The analysis was performed using the DSAASTAT version 1.021 program.

Results and Discussion

Maize growth performance

Based on observations, all treatments had a positive effect on plant height. The height of the treated plants from the first week to the seventh week was significantly different from the control plants (Table 2). However, the treatment that showed the best performance and consistently gave the highest plant height was T5 (5 t ha^{-1} of oil palm empty fruit bunches compost + 5 t ha^{-1} of rice husk charcoal). In the seventh week, the highest plant height was shown by T5 treatment (225.09 cm), followed by T2 (184.43 cm), T1 (140.77 cm), T4 (123.01 cm), and T3 (116.28 cm).

Table 2. The maize height.

Treatment	Average Plant Height (cm)						
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP
Control	3.31 d	10.85 e	15.24 e	30.25 e	35.60 e	62.72 e	77.65 e
T1	4.80 b	11.83 b	56.63 b	78.37 b	82.25 b	118.11 b	140.77b
T2	4.95 c	13.03 b	56.04 c	73.95 b	79.54 c	138.64 c	184.43c
T3	3.62 c	18.74 c	29.94 d	41.58 c	45.96 d	87.34 d	116.28d
T4	3.75 c	29.75 d	34.70 d	44.82 d	49.32 d	85.72 d	123.01d
T5	5.57 a	33.30 a	63.00 a	82.35 a	108.20a	161.20 a	225.09a

Note: The number followed by each different letter shows a significant difference in each line based on the DMRT test results with a 95% confidence level. WAP = week after planting.

When compared with control plants, then sequentially, T5 showed 289.88% higher plant high performance, followed by T2 (237.51%), T1 (181.29%), T4 (181.29%), T3 (158.42%), and T3 (149.75%). Based on the results of the observation, all treatments met better results and were significantly different from the control plants (Table 3). However, T5 treatment gave the best result. In the seventh week, the largest stem diameter was shown by T5 (3.99 cm), followed by T2 (3.81 cm), T1 (3.61 cm), T3 (2.56 cm), and T4 (2.42 cm). When compared with control plants, T5 gave 204.62% larger stem diameter, followed by T2 (195.38%), T1 (185.13%), T3 (131.28%), and T4 (124.10%). The observations showed that at the first week, the effect of application of rice husk charcoal was not seen; however, the application of oil palm empty fruit bunches compost exposed significantly different results from the control plants. In the second to seventh weeks, the plants treated with T5 (5 t/ha oil palm empty fruit bunches compost + 5 t ha^{-1} rice husk charcoal) gave the best performance (Table 4). At the end of observation, T5 disclosed the best performance with an average leaf count of 14.40, followed by T1 (11.80), T2 (11.75), T3 (8.50), and T4 (8.45). When compared with control plants, plants treated with T5 provided 223.26% more leaves, followed by T1 (182.95%), T2 (182.17%), T3 (131. 78%), and T4 (131.01%). The observations fresh and dry weight of the plants revealed that all treatments contributed a significant effect on dry and fresh weight of plants than control plants (Table 5). The highest fresh weight was shown by T5 treatment (440.31 g), followed by T2 (357.46 g), T1 (331.18 g), T4 (273.99 g), and T3 (262.63 g).

Table 3. The maize stem diameter.

Treatment	The Average Maize Stem Diameter (cm)						
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP
Control	0.13 d	0.43 b	0.43 e	0.43 c	0.44 d	1.50 c	1.95 d
T1	0.26 b	0.26 d	0.38 c	0.67 b	2.25 b	2.81 ab	3.61 c
T2	0.28 ab	0.28 cd	0.47 b	0.91 b	2.33 b	2.93 ab	3.81 c
T3	0.19 c	0.77 a	0.77 d	0.77 c	1.30 c	2.19 b	2.56 b
T4	0.14 d	0.14 e	0.22 d	0.22 c	1.33 c	1.69c	2.42 b
T5	0.30 a	0.30 c	0.84 a	1.21 a	2.73 a	3.45 a	3.99 a

Note: The number followed by each different letter shows a significant difference in each line based on the DMRT test results with a 95% confidence level. WAP = week after planting.

Table 4. The number of maize leaves.

Treatment	Average Number of Leaves						
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP
Control	2.00 c	2.35 d	3.35 e	3.40 e	4.40 e	6.40 e	6.45d
T1	2.85 c	4.15 d	5.45 d	7.50 d	8.40 d	10.40 d	11.80 c
T2	3.00 c	3.55 d	4.60 c	6.45 d	7.80 d	9.65 d	11.75 c
T3	2.00 b	2.50 c	3.70 b	4.50 c	5.50 c	7.60 c	8.50 b
T4	2.00 b	2.55 b	3.45b	4.60 b	5.50 b	7.60 b	8.45 b
T5	3.05 a	5.30 a	6.65 a	8.80 a	10.10 a	12.30 a	14.40 a

Note: The number followed by each different letter shows a significant difference in each line based on the DMRT test results with a 95% confidence level. WAP = week after planting.

Table 5. Maize fresh and dry weight

Treatment	Fresh Weight (g)	Dry Weight (g)
Control	128.65 d	116.57 f
T1	331.18 b	175.83 c
T2	357.46 b	183.30 b
T3	262.63 c	159.43 d
T4	273.99 c	135.73 e
T5	440.31 a	193.23 a

Note: The number followed by each different letter shows a significant difference in each line based on the DMRT test results with a 95% confidence level.

Plants treated with T5 produce the fresh weight 342.25% higher than control plants, followed by T2 (277.85%), T1 (257.43%), T4 (212.97%), and T3 (204.14%). Furthermore, T5 treatment also showed the best performance on the variable plant's dry weight around 193.23 g, followed by T2 (183.30 g), T1 (175.83 g), T3 (159.43 g), and T4 (135.73 g). Treated plants with T5 is yield a higher dry weight of 165.76% than control plants, followed by T2 (157.24%), T1 (150.84%), T3 (136.77%), and T4 (136.77%). Based on the overall results, the growth of control maize plants on all growth variables showed less than optimal performance. On the other hand, plants that were applied with oil palm empty fruit bunches compost and rice husk charcoal showed a better performance than the control plants. This phenomenon can be caused because the rhizosphere in control plants is less supportive of maize growth. One of the limiting factors for maize growth on acid soils is the limited nutrient availability (Pandit et al., 2018). One of them is the element P, which is bound by Al, Fe, Mg, and Zn so that plants cannot utilize P. Apart from low P elements, other elements in acid soils such as N, K, Ca, Mo, Mg, Cu, and S are also relatively small (Bravo et al., 2017). Application of oil palm empty fruit bunches compost and rice husk charcoal can improve the growth performance of maize plants, presumably because of the nutrient content of them (Yavari et al., 2016). In addition, application of these two materials can also support the development of microbes in the soil, which indirectly have a role in plant growth (Jindo et al., 2012). Oil palm empty fruit bunches compost contains N, P, K, and Mg, which are needed for plant growth. It releases nutrients slowly, which allows the plant to absorb the nutrients properly (Chiew and Shimada, 2013). Furthermore, it is an excellent organic material for microbial growth.

The abundance of microbes around the plant rhizosphere was reported to correlate with plant fertility (Meena et al., 2017). Some soil microbes can fix N from the environment and dissolve bound P (Arsita et al., 2020). N is one element that is very important for plant growth because it plays an essential role in forming amino acids (proteins), nucleic acids, nucleotides, and chlorophyll in plants (Leghari et al., 2016). Plants grown on soil with sufficient nutrients will supply greener phenotypes than plants growing on-farm with insufficient nutrients. Also, N contributes to an optimal growth plant because the availability of N stimulates plant height, leaves number, biomass, and other plant growth variable (Eickhout et al., 2006). The previous study conducted by Fahrunsyah et al. (2019) reported that the application of oil palm empty fruit bunches compost stimulated the growth of maize on an Ultisol. In that study, they reported that the increasing growth of maize was due to the nutritional support of oil palm empty fruit bunches compost applied. In another study conducted by Zhen et al. (2014), it was reported that the application of compost increased the number of nitrogen-fixing microbes in the soil. Lim et al. (2015) reported that the application of oil palm empty fruit bunches compost increased the pH value of the soil. Those studies support the results obtained in this study which reports that the plants treated with oil palm empty fruit bunches compost had a better growth performance. In addition, the use of rice husk charcoal is also reported to increase the growth of maize plants by Shashi et al. (2018). This increase occurred because of the improvement in the physical properties of the soil due to the application of rice husk charcoal.

Maize yield performance

All the treatments generally gave higher and significantly different values for maize cobs weight, maize cobs weight without the maize husks, maize cobs length, maize cobs diameter, and weight for 100 maize kernels than the control plants. Among all the treatments, T5 treatment provided consistent results and always produced the highest results on each observation variable (Table 6). The weight of maize cobs in T5 treatment gave 292.72% higher yield than control plants, followed by T2 (273.93%), T1 (255.03%), T4 (190.13%), and T3 (178.77%). In the observation of maize cobs without maize husks weight, T5 also gave 233.03% higher yield, followed by T2 (221.47%), T1 (202.37%), T3 (161.79%), and T4 (158.27%). Furthermore, on the variable maize cobs length observation, T5 treatment also gave the best results with maize cobs length of 147.14% longer than control plants, followed by T2 (140.28%), T1 (137.17%), T3 (128.34%), and T4 (112.44%). The measurement results of maize cob diameter also showed the same pattern that the T5 gave the largest maize cob diameter of 187.79%, followed by T2 (160.73%), T1 (148.18%), T3 (129.37%), and T4 (117.16%). The weight of 100 maize kernels of T5 treatment remained consistent with the best results of 201.72% which was higher than that of the control plants, followed by T2 (162.16%), T1 (146.55%), T3 (120.11%), and T4 (110.92). The overall yield performance of maze indicated that the application of oil palm empty fruit bunches compost and rice husk charcoal was effective in increasing the yield of maize grown on acid soils.

Table 6. Maize yield variables.

Treatment	Maize cobs weight (g)	Maize cobs Without maize husks Weight (g)	Maize cobs (cm)	Maize cobs diameter (cm)	Weight of 100 Maize Kernels (g)
Control	103.65 c	82.77 d	14.15 f	3.03 f	10.44 d
T1	264.34 a	167.50 c	19.41 c	4.49 c	15.30 b
T2	283.93 a	183.31 c	19.85 b	4.87 b	16.93 b
T3	185.30 b	133.91 b	18.16 d	3.92 d	12.54 c
T4	197.07 b	131.00 ab	15.91 e	3.55 e	11.58 cd
T5	303.40 a	192.88 a	20.82 a	5.69 a	21.06 a

Note: The number followed by each different letter shows a significant difference in each line based on the DMRT test results with a 95% confidence level.

One of the nutrients needed for the formation of maize cobs is P (Tokatlidis et al., 2015). However, in acid soils usually P is bound by other elements, making it unavailable to plants (Ch'ng et al., 2014). Research conducted by Hutapea et al. (2020) reported that application of empty fruit bunches compost palm oil could increase maize yields. The increase in yields was reported due to the fulfilment of the nutrients needed by maize in producing cobs. In control plants, yield performance was less than optimal because in acid soils the P elements were bound and not available to plants. However, in plants that were given the application of oil palm empty fruit bunches compost and rice husk charcoal, the growth was better because it was reported that oil palm empty fruit bunches compost and rice husk charcoal could support the development of P-solvent microbes in the soil (Phuong et al., 2020).

Apart from providing P in a form that can be used by plants, compost can also stimulate the growth of phosphate solubilizing microbes (Sembiring et al., 2020). Bacteria from the *Bacillus* and *Pseudomonas* groups, which generally can dissolve phosphate, are found in abundant amounts in various compost types (Bhatia et al., 2013). P is one of the essential elements that plants need in large quantities for the process of growth and production of seeds or fruit. The availability of P in the soil will stimulate root growth and the formation of a good root system (Zhihui et al., 2016; Zhang et al., 2016). Also, P can encourage flowering, ripen seeds/fruit, and increase the percentage of fruit formation in plants. Furthermore, it can strengthen the plant cell in increasing the plants' resistance from pest and pathogenic infections (Huber and Huber, 1996).

The combination of oil palm empty bunches compost and rice husk charcoal gave the best performance. Rice husk charcoal supplies a neutral pH with a value of ± 6.7. It generally has low nutritional, namely SiO_2 (52%), C (31%), K (0.3%), N (0.18%), F (0.08%), and calcium (0.14%). Additionally, rice husk charcoal provides various organic acids which are capable of releasing bound nutrients. The high silica in the rice husk charcoal subsidizes not only more resistant to pests and diseases due to tissue hardening but also plant metabolism to determine the quality of plant nutrition because charcoal is a good medium for microbes (McGee et al., 2019; Kallenbach et al., 2019). The provided charcoal in the soil can be a factor that supports the growth of beneficial soil microbes, in which the abundance of soil microbial populations has a positive correlation with increased plant growth and yield.

Conclusion

Adding oil palm empty fruit bunches compost with a dose of 5 t ha^{-1} and 10 t ha^{-1}, as well as rice husk charcoal with a dose of 5 t ha^{-1} and 10 t ha^{-1}, can increase the growth and yield of maize better in red-yellow podzolic acid soils than control plant. However, the combination of oil palm empty fruit bunches compost and rice husk charcoal with each dose of 5 t ha^{-1} showed the best and most stable performance in this research.

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