Application of ameliorants for of ex-tin mining soil improvement and increasing corn (Zea mays) yield

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Abstract. Ex-tin mining land is a degraded land with low soil fertility and poor soil physical properties. The research aimed to find the best ameliorant for the improvement of ex-tin mining soil and corn yield. This experiment, conducted in Bangka Belitung Province, Indonesia, used a Randomized Block Design with 7 treatments and 4 replications: control, 20 t ha⁻¹ biochar, 20 t ha⁻¹ cattle manure, 20 t ha⁻¹ mucuna compost, 10 t ha⁻¹ biochar+10 t ha⁻¹ cattle manure, 10 t ha⁻¹ biochar+10 t ha⁻¹ mucuna compost, and 10 t ha⁻¹ cattle manure+10 t ha⁻¹ mucuna compost. The corn variety used was Sukmaraga. The application of ameliorant significantly increased soil chemical properties (pH, potential and available P, potential and exch-K, exch-Ca, exch-Mg, exch-Na, and base saturation) and growth and yield of corn. The corn yield from the 20 t ha⁻¹ biochar treatment was higher than that of the control, but was not significantly different from the other treatments. The single application of 20 t ha⁻¹ biochar and the application of 10 t ha⁻¹ biochar in combination with either 10 t ha⁻¹ cattle manure or 10 t ha⁻¹ mucuna compost resulted in the best soil chemical improvement and crop yields.

1. Introduction

Ex-mining land is a sub-optimal land that has the potential to be developed as agricultural land. However, not all ex-mining land can be used directly as agricultural land because there are various inhibiting and limiting factors that depend on the mining processes [1-2]. Ex-tin mining land is one of the potential lands that can be directly used as agricultural land. However, the use of ex tin-mining land for agriculture faces some limiting factors, such as irregular landscapes of varying sizes [3], decreased biodiversity including soil microbes [4], micro-climate change, low soil acidity, low soil nutrients and poor water holding capacity [5]. Improvement of the quality of ex tin-mining land, therefore must be done to overcome the existing limiting factors in supporting growth and yields of crops, by applying appropriate technologies. Among the soil chemical constraints, the availability of nutrients is the most problem that needs to be appropriately handled by applying chemical fertilizers accompanied by the addition of organic matter through the application of ameliorants. Depend on the kind of composition, ameliorants can increase soil fertility through improving chemical, physical, and biological properties. Commonly the material source of any ameliorant is required in large quantities. For this reason, it is important to use an ameliorant that can be produced from sources that are largely
available and easily obtained in the studied area. Biochar from empty oil palm fruit bunches (EFB), cattle manure, mucuna compost are three of the ameliorants that can easily produce in the studied area. According to some previous studies, biochar is beneficial in improving pH, levels of N and P, CEC, exchangeable bases, nutrient uptake, water use efficiency and ultimately crop yields [6-8] and also can reduce greenhouse gas emissions [9]. The raw materials of biochar are easily available at a low cost [10]. The application of cattle manure is also regarded as a key in mined land rehabilitation because it can quickly provide the nutrient needs both macro and micro nutrients. Also, according to [5], cattle manure can improve soil physical properties such as permeability, porosity, and water-holding capacity. Mucuna compost is green compost which contains 2.42% N and 1.97% K or the equivalent of 51.6 kg Urea and 39.4 kg KCl in 1 t of dry mucuna biomass, higher than other green composts from Guatemala, vetiver and Flemingia [11]. Also, the use of mucuna compost becomes more prospective because mucuna is grown quickly, resistant to shade, can compete with weeds and produces relatively large amounts of forage (high biomass production) [12-13].

Several studies on the application of ameliorants that have been carried out state that the use of biochar combined with cattle manure (1:1) has a significant effect on increasing the growth and yield of chilies in ex tin mining land [14]. A single application of biochar or in combination with mucuna forage has the potential to increase soil ammonium levels [15], soil fertility and papaya growth [16]. This study is one of the efforts to reclaim ex-tin mining land in Bangka Belitung and specifically aims to find the best combination of biochar with several ameliorants for the improvement of the soil characteristic of the ex-tin mining land for producing corn.

2. Materials and methods
The research was conducted from February-August 2020 in the ex-tin mining Land in Bukit Kijang Village, Central Bangka, Bangka Belitung Islands with the coordinate position S = 02°14’07.5” and E = 106°11’41.5”.

2.1. Materials
The materials used in this research were: 1) biochar from empty oil palm bunches (EFB), 2) cattle manure, 3) compost mucuna, 4) Sukmaraga corn variety, 5) inorganic fertilizers, 6) pesticides, and 7) chemicals for laboratory analysis. The tools used are: 1) pH-meter, 2) spectrophotometry, 3) atomic absorption spectrometer (AAS), 4) Kontiki equipment, and 5) field equipment.

2.2. Methods
This research composed of 3 (three) steps, as follows:

2.2.1. Production and characterization of chemical properties of biochar, cattle manure, and mucuna compost. This research stage aims to determine the chemical characteristics of ameliorant with different types of raw materials and the production process. The process of biochar production from EFB was done using the Kontiki method started with making a cone-shaped hole in the ground with the hole surface diameter of 1.5 m and the hole depth of 0.8 m followed by the pyrolysis process of air-dried chopped EFB at 300-500°C for 3 hours. Cattle manure used in this study was from cow dung, produce by BPTP Kepulauan Bangka Belitung through air drying the cow dung for three weeks without the addition of any decomposer. Mucuna compost was prepared by an anaerobic composting method of mucuna forages for two weeks by using an M-Dec bio decomposer. The ameliorants were analyzed for their chemical properties i.e. pH, organic-C, total Nitrogen, C/N, potential phosphorus, potential potassium, available phosphorus, exchangeable bases (exch-Ca, exch-Mg, exch-K, exch-Na), CEC and base saturation using standard methods according to the technical guidelines for chemical analysis of soil, plants, water, and fertilizers [17].

2.2.2. Test of application of different rates and types of ameliorant on corn planting at experimental plots. This study used a randomized block design with 7 treatments combination of rates and types of corn varieties.
ameliorant and 4 replications, so that the total experimental unit was 28 (table 1). In addition to the treatments, every treatment was added by fertilizers following the recommendation rate (Urea-SP36-KCl 350-250-250 kg ha\(^{-1}\)) of BPPT Kepulauan Bangka Belitung. One experimental unit is sized 4x4 m\(^2\) with a plant space of 75x20 cm. The ameliorants at any rate and combination were applied in plant beds of 30 cm depth at seven days before planting.

**Table 1.** Treatment of rates and types of ameliorants.

| No | Code of treatments | Description |
|----|--------------------|-------------|
| 1  | Control            | Without ameliorants |
| 2  | Bio                | 20 t ha\(^{-1}\) Biochar |
| 3  | PK                 | 20 t ha\(^{-1}\) Cattle manure |
| 4  | KM                 | 20 t ha\(^{-1}\) Mucuna compost |
| 5  | Bio+PK             | 10 t ha\(^{-1}\) Biochar + 10 t ha\(^{-1}\) Cattle manure |
| 6  | Bio+KM             | 10 t ha\(^{-1}\) Biochar + 10 t ha\(^{-1}\) Mucuna compost |
| 7  | PK+KM              | 10 t ha\(^{-1}\) Mucuna compost + 10 t ha\(^{-1}\) Cattle manure |

The observed parameters were:
(a) The chemical properties of soil: pH, organic-C, total Nitrogen, C/N, potential phosphorus, potential potassium, available phosphorus, exchangeable bases (exch-Ca, exch-Mg, exch-K, exch-Na), CEC and base saturation of the initial soil, incubated soil and the soil after corn harvesting. The measurements were carried out using the standard method that referred to the technical guidelines for chemical analysis of soil, plants, water, and fertilizers [17].
(b) Plant growth parameters: plant height, stem diameter, number of leaf at 14, 28, 42 and 75 days after planting (DAP); leaf length and width at 75 DAP; biomass weight (plants, roots, ears), root length, ear length, ear circumference, number of rows of grains per ear, number of grains of corn per ear, the weight of grains per ear, the weight of 1,000 grains and yield at 110 DAP.

2.2.3. **Statistical analysis.** To determine the effect of treatments, the data were statistically analyzed with the Analysis of Variance (ANOVA) and followed by a mean test using Duncan's Multiple Range Test (DMRT) at 95% confidence interval.

3. **Results and discussion**

3.1. **Chemical properties of biochar, cattle manure and mucuna compost**

The chemical characteristic of three ameliorants used in this study is presented in table 2. The table shows that among the three ameliorants biochar has the highest pH, high C/N, potential and exchangeable K and total bases. The high pH of biochar is certainly related to the high content of bases reflecting the high ash content [18-19]. Cattle manure has the highest potential P, exchangeable Mg, and exchangeable Na but has the lowest C/N ratio (<25). Mucuna compost has the highest organic-C, total N, exchangeable Ca and CEC. This is because Mucuna plants can fix nitrogen from the air [20] resulting in a high content of N in the mucuna forage, ranging from 5.4%-5.5% [21].

Overall, table 2 shows that concerning the nutrient contents, biochar seems to have the highest potential in improving nutrient availability, except for N. The high content of nutrients in the biochar is originated from the EFB that is known to have high ash content [22].
Multiple Range Test (DMRT) at sampled from the depth of 3.2.2. The growth of corn without any amendment in the study location very low to low potential P;

The data in Table 3 resemble most data from previous studies of similar land condition neighboring the study location [3,14,23,24]. This result indicates that the soil would not sufficiently support the growth of corn without any amendment.

Table 3. Chemical properties of the initial soil.

| No | Parameter          | Unit   | 0-20 cm | Criteria   | 20-40 cm | Criteria   |
|----|--------------------|--------|---------|------------|----------|------------|
| 1  | pH                 | 5.3    | Acidic  | 5.4        | Acidic   |            |
| 2  | Organic-C         | %      | 0.58    | Very low   | 0.40     | Very low   |
| 3  | Total N           | %      | 0.06    | Very low   | 0.04     | Very low   |
| 4  | C/N               |         | 9.7     | low        | 10.0     | low        |
| 5  | Potential P       | mg 100 g⁻¹ | 18.4 | low      | 9.6   | Very low   |
| 6  | Potential K       | mg 100 g⁻¹ | 2.7   | Very low  | 3.0    | Very low   |
| 7  | Available P       | mg kg⁻¹  | 115.0 | Very high | 57.7   | Very high  |
| 8  | Exch-Ca           | cmolc kg⁻¹ | 0.56 | Very low | 0.59   | Very low   |
| 9  | Exch-Mg           | cmolc kg⁻¹ | 0.26 | Very low | 0.29   | Very low   |
| 10 | Exch-K            | cmolc kg⁻¹ | 0.05 | Very low | 0.06   | Very low   |
| 11 | Exch-Na           | cmolc kg⁻¹ | 0.09 | Very low | 0.07   | Very low   |
| 12 | Number of exchangeable bases | cmolc kg⁻¹ | 0.96 | 1.01 | -  | |
| 13 | CEC                | cmolc kg⁻¹ | 2.57 | Very low | 2.50   | Very low   |
| 14 | Base saturation   | %      | 37.35   | low       | 40.46   | low        |

3.2.2. The effect of ameliorant on the incubated soil’s chemical properties. Properties of the soils sampled from the depth of 0-20 cm and 20-40 cm at each experimental plot at seven days after the addition of ameliorants (incubated soil) are presented in table 4. This table as well shows Duncan's Multiple Range Test (DMRT) at a 95% confidence interval.
The effect of ameliorants on the soil chemical properties after incubation.

| Parameters       | Unit | Control | Bio | PK | KM | Bio+PK | Bio+KM | PK+KM |
|------------------|------|---------|-----|----|----|--------|--------|-------|
| **pH**           |      | 5.7c    | 6.9a | 5.7c | 5.6c | 6.1bc  | 6.5ab  | 5.9c  |
| Organic-C        | %    | 0.78a  | 0.83a | 0.92a | 0.84a | 0.71a  | 0.68a  | 0.86a |
| Total N          | %    | 0.07a  | 0.07a | 0.07a | 0.07a | 0.06a  | 0.06a  | 0.07a |
| C/N              |      | 11.8a  | 12.2a | 12.7a | 12.4a | 11.3a  | 11.29a | 11.88a|
| Potential P      | mg/100g | 21.5c | 33.4a | 30.9ab | 23.4bc | 26.2abc | 22.4bc | 30.1abc|
| Potential K      | mg/100g | 3.6d | 58.9a | 9.6cd | 13.3cd | 18.4bc | 29.2b  | 9.8cd |
| Available P      | mg/kg  | 129.5c | 196.7a | 180.7ab | 142.5bc | 156.9abc | 139.0b  | 174.8abc|
| Exch-Ca          | cmolc/kg | 0.89a | 1.30a | 1.05a | 0.84a | 0.94a  | 0.94a  | 0.94a |
| Exch-Mg          | cmolc/kg | 0.31c | 0.59a | 0.47ab | 0.35bc | 0.43bc | 0.47ab | 0.48ab |
| Exch-K           | cmolc/kg | 0.07d | 1.13a | 0.18cd | 0.26cd | 0.35bc | 0.55b  | 0.19cd |
| Exch-Na          | cmolc/kg | 0.07c | 0.13b | 0.19a | 0.10bc | 0.13b  | 0.09bc | 0.14ab |
| CEC              | cmolc/kg | 2.78a | 3.61a | 3.53a | 3.27a | 2.93a  | 2.81a  | 3.03a |
| Base Saturation  | %     | 50.83c | 80.98a | 54.10c | 49.03c | 63.29bc | 72.98ab | 56.93c |

| **Parameters**   | **Unit** | **Depth 0-20 cm** | **Depth 20-40 cm** |
|------------------|----------|------------------|-------------------|
| **pH**           |          | 5.5a  | 6.3a  | 5.6a  | 5.4a  | 5.9a  | 6.1a  | 6.0a  |
| Organic-C        | %        | 0.72a  | 0.65a | 0.76a | 0.59a | 0.63a | 0.47a | 0.64a |
| Total N          | %        | 0.07a  | 0.06a | 0.07a | 0.05a | 0.06a | 0.05a | 0.06a |
| C/N              |          | 10.9a  | 11.1a | 11.5a | 11.0a | 11.4a | 9.9a  | 10.6a |
| Potential P      | mg/100g  | 9.8a  | 12.0a | 15.1a | 10.8a | 13.0a | 8.9a  | 11.2a |
| Potential K      | mg/100g  | 3.3c  | 27.6a | 7.8bc | 5.1bc | 10.6bc | 12.0b | 4.7bc |
| Available P      | mg/kg    | 61.5a | 69.8a | 97.8a | 57.7a | 74.4a | 52.5a | 64.4a |
| Exch-Ca          | cmolc/kg | 0.79a | 0.77a | 0.92a | 0.64a | 0.79a | 0.77a | 1.40a |
| Exch-Mg          | cmolc/kg | 0.25a | 0.33a | 0.38a | 0.23a | 0.31a | 0.28a | 0.26a |
| Exch-K           | cmolc/kg | 0.06c | 0.54a | 0.15bc | 0.10bc | 0.20bc | 0.23b | 0.09bc |
| Exch-Na          | cmolc/kg | 0.09b | 0.11b | 0.18a | 0.09b | 0.08b | 0.08b | 0.11b |
| CEC              | cmolc/kg | 2.65a | 2.72a | 2.97a | 2.76a | 2.56a | 2.20a | 2.53a |
| Base saturation  | %        | 46.75a | 65.05a | 54.74a | 40.74a | 53.48a | 61.86a | 62.10a |

Note: The numbers with the same letter in the same line do not differ at the 5% DMRT level.

The first parameter to discuss here is pH. Table 4 shows that all treatments have a significant effect on the increasing of soil pH at 0-20 cm soil depth. This fact is attributed to the application of the ameliorants that were thoroughly incorporated only into the 30 cm upper layer of the soil and the incubation period did not enough for the bases cations of the ameliorants to leach down. Among the treatments, the 20 t ha⁻¹ biochar (Bio) treatment resulted in the highest pH increase of the soil after seven days of incubation from acidic to neutral by 1.6 pH units. However, this treatment did not significantly differ from the 10 t ha⁻¹ biochar + 10 t ha⁻¹ mucuna compost (Bio+KM) for the 0-20 cm. All these findings are in line with several previous research results which state that some biochars have an alkaline pH (of mostly >8.5) that depend on the raw material and the pyrolysis process [25-27].

The next parameters to discuss are the soil organic-C, N, P, and K. Table 4 shows that all treatments have a significant effect on the increase soil potential and available P and a very significant effect on the soil potential and exchangeable K, but not on the soil organic-C and total N. Among the treatments, the Bio treatment resulted in the highest potential and available P, potential and exchangeable K of the soil after seven days of incubation. The increments were from very low to moderate for the depth of 0-20 cm P potential, by 81.7 ppm for P available at the 0-20 cm, from very low to high and to moderate for potential K of each the depth respectively, and from very low to very high and to moderate for exchangeable K of each the depth respectively. These all increments are true for all samples with the exception as is mentioned above. The increment in the incubated soil was in case the Bio treatment caused by the increase in pH of the incubated soil to 6.9 (neutral) which
eventually has caused an increment in the availability of nutrients in the soil, especially P, due to reduced Al and Fe cation activities in the soil [28–29] and on the same time, the biochar and the combining ameliorants acted as the source of additional P as well. The increase in the potential K and exchangeable-K content in the biochar amelioration was very high that is certainly due to additional K contained in the biochar that counts to 8.90% and 354.24 cmolc kg\(^{-1}\) respectively for the potential K and exchangeable K (table 2). Explanations on the increase of soil K status after EFB biochar amelioration were also previous reports stated that it was due to the potassium content in EFB is very high compared to other macro and micro nutrients [22,25].

Table 4 furthermore shows that all treatments have a significant effect on the soil exchangeable Mg and exchangeable Na as well as that resulting in the increase of both for the depth of 0-20 cm for Mg and both depth for Na, but have not significant effect on the soil exchangeable Ca. Among the treatments, the biotreatment resulted in the highest exchangeable Mg of the soil at after seven days incubation from very low to low by 0.330 cmolc kg\(^{-1}\) for the exchangeable Mg. However, this treatment did not significantly differ from PK, Bio+KM, PK+KM. On the other hand, the PK treatment resulted in the highest exchangeable Na of the soil after seven days of incubation from very low to low for both the 0-20 and 20-40 depths and but not significantly differ from PK+KM in the case of 0-20 cm depth. The significant increase of Na is attributable to the high content of Na in the cattle manure that is 58.74 cmolc kg\(^{-1}\), which is 9.7-14.8 higher than that of mucuna compost (6.03 cmolc kg\(^{-1}\)) and biochar (3.97 cmolc kg\(^{-1}\)).

The base saturation increase is also detected in table 4 for the biotreatment but has no significantly difference from the Bio+KM treatment. The treatments increased the soil base saturation from low to very high in the case of the 0-20 cm depth with an increment of 43.6%. This is because the number of exchangeable bases in the biochar is considerably higher than that of the two other ameliorants combined with the effect of the higher pH of the biochar in that a high or an increase in soil pH will increase the availability of the base nutrients (Ca, Mg, K, and Na) [30].

In general, the effect of all treatments regardless of the type of the ameliorant combination is more significant for the depth of 0-20 cm as monitored by analyzing the soil samples taken from each plot just seven days after the addition of the ameliorants. This fact reflecting strongly that ameliorants as solid particles and their released substances did not yet move downward into more depth. Over all the best effect was found for pH, P, K, base saturation and these all were found to strongly attribute to be the best effect of the biochar.

3.2.3. The effect of ameliorants on soil chemical properties after corn harvesting. Properties of the soils sampled from the depth of 0-20 cm and 20-40 cm at each experimental plot on the day after corn harvesting are presented in table 5. This table as well shows Duncan's Multiple Range Test (DMRT) at a 95% confidence interval.

In general, the comparison of table 4 and 5, the data pattern of both are comparable in that the treatments had a significant effect on soil chemical properties are found to be consistent. In the case of pH the table 5 shows that all treatments have a very significant effect on the soil pH is that resulting in the increase of pH of the 0-20 depth and significant effect of the 20-40 depth from the initial soil pH. Among the treatments, the biotreatment showed the highest pH of the soil at after corn harvesting in which the pH was found around neutral for the 0-20 cm depth and slightly acidic for the 20-40 cm depth. This treatment significantly differed from other treatments except for Bio+KM for the 20-40 cm depth. Further comparison of table 4 and 5 show that a slight decrease in soil pH has occurred that was due to a normal mechanism of the secretion of root exudate resulting in acidification.

Concerning the soil organic-C, N, P, and K table 5 shows that all treatments have a very significant effect on the increase of soil potential and exchangeable K of both depths, but have no significant effect on the soil organic-C, total N, potential P and available P. Among the treatments, the Bio treatment resulted in the highest potential and exchangeable K of the soil after corn harvesting. The increments from the initial soil values were from very low to low for both depths in that is lower than the increment from that of the initial soil to that of the incubated soil. This difference was due to


nutrient uptake by the plant. In this case corn requires more K than P, N and other macro nutrients as shown by the fact that the highest K content was found in the corn plant tissue compared to other nutrients (30).

As a continuation concerning the possible process taken place during the 7 days initial interaction between the ameliorants and the soil bulk, the data presented in table 5 representing the soil chemical characteristics after the period of corn plantation shows that all treatments showed a very significant effect on the soil exchangeable cations. However, unlike for the first seven days incubation period, the data after the period of corn plantation shows that the effects of the treatments are found for exchangeable Ca and exchangeable Mg and not for the Na. The values of these two elements were found to be higher than that of the initial soil for the depth of 0-20 cm for Ca and for both depths for Mg. Among the treatments, the Bio treatment resulted in the highest exchangeable Ca and exchangeable Mg of the soil after corn harvesting by 0.93 cmolc kg⁻¹ increment for the exchangeable Ca despite it was still in very low range and from very low to low for the exchangeable Mg. However, the Bio treatment did not significantly differ from Bio+PK and Bio+KM of exchangeable Mg at 20-40 cm depth.

Table 5. The effect of ameliorants on soil chemical properties after corn harvesting.

| Parameters | Unit | Control | Bio | PK | KM | Bio+PK | Bio+KM | PK+KM |
|------------|------|---------|-----|----|----|--------|--------|-------|
| pH         |      | 5.5d    | 6.6a| 6.0bc| 5.8cd| 6.2b   | 6.2b   | 5.8cd |
| Organic-C  | %    | 0.85a   | 0.78a| 0.82a| 0.90a| 0.70a  | 0.64a  | 0.76a |
| Total N    | %    | 0.07a   | 0.07a| 0.07a| 0.07a| 0.06a  | 0.06a  | 0.07a |
| C/N        |      | 12.6a   | 12.0a| 12.1a| 12.9a| 11.7a  | 11.1a  | 11.7a |
| Potential P| mg 100 g⁻¹| 24.1a | 27.1a| 25.6a| 24.1a| 27.0a  | 22.1a  | 23.5a |
| Potential K| mg 100 g⁻¹| 3.5c   | 16.8a| 5.5c | 5.5c | 9.0b   | 8.8b   | 4.0c  |
| Available P| mg kg⁻¹| 162.7a | 168.0a| 228.2a| 162.1a| 197.1a | 136.6a | 140.6a|
| Exch-Ca    | cmolc kg⁻¹| 0.95d | 1.49a| 1.15bc| 1.01cd| 1.23b  | 1.06bcd | 0.97cd|
| Exch-Mg    | cmolc kg⁻¹| 0.24d | 0.71a| 0.45b | 0.32cd| 0.50b  | 0.42bc | 0.31cd|
| Exch-K     | cmolc kg⁻¹| 0.06c | 0.33a| 0.10c | 0.10c | 0.17b  | 0.17b  | 0.07c |
| Exch-Na    | cmolc kg⁻¹| 0.20a | 0.20a| 0.22a | 0.24a | 0.23a  | 0.19a  | 0.20a |
| CEC        | cmolc kg⁻¹| 3.22a | 3.33a| 3.18a| 3.18a| 2.97a  | 2.67a  | 2.91a |
| Base saturation | % | 46.49d | 81.89a| 61.00bc| 53.32cd| 72.23ab| 69.68b| 53.24cd|

Table 5 also shows the increase of base saturation in the soil after corn harvesting from the initial values. The Bio treatment has no significantly different from the Bio+KM treatment at the soil depth of 0-20 cm and Bio+PK and Bio+KM treatments at the soil depth of 20-40 cm. The treatments increased the soil base saturation from low to very high in the case of the 0-20 cm depth and from low

Note: The numbers followed by the same letter on the same line do not differ at the 5% DMRT level.
to high in the case of the 20-40 cm depth. On other hand, all treatments have not signficant effect on the soil CEC.

In general, the pH, macro nutrients, exchangeable base, CEC and base saturation content of the soil after harvesting corn at a depth of 20-40 cm are lower than those of 0-20 cm depth. This is consistent with the soil nutrient content pattern of the soil after seven days of incubation (table 4). The soil after corn harvesting at depth of 20-40 cm has a higher nutrient content than those in incubation soil of the same depth, except for the potential K and exch-K. The increase of nutrients in the soil after harvesting compared to the incubation soil for the 20-40 cm depth is due to the leaching of nutrients from the 0-20 cm layer to the 20-40 cm layer. In a-sand-texture soil that has been given ameliorants, nutrient leaching can still occur from a depth of 0-20, moving from the root layer to the lower layer [5,31].

According to the soil data after corn harvesting at a depth of 0-20 cm and 20-40 cm as shown in table 5, the addition of the ameliorant increased the nutrient holdings and hence reduced nutrient leaching. The soil nutrient conditions after harvesting at a depth of 0-20 cm still have the same nutrient status as of the incubated soil, despite that they have undergone nutrient uptake by plants, except for the potential K and exch-K which has significantly decreased due to the luxury uptake by corn plants.

Treatment of 20 t ha\(^{-1}\) biochar singly or the treatment of the combination of 10 t ha\(^{-1}\) biochar with 10 t ha\(^{-1}\) cattle manure (Bio+PK) and a composition of 10 t ha\(^{-1}\) biochar with 10 t ha\(^{-1}\) mucuna compost (Bio+KM) have increased the nutrient retention and therefore have enabled the soils to have the best chemical properties as detected at after corn harvesting. This is because of the capability of biochar in retaining the nutrients by several mechanisms [31-32].

3.3. The effect of ameliorants on growth and yield of corn plant

3.3.1. Growth. The effect of ameliorant on the growth response of corn are presented in table 6 and 7. The results of the average vegetative and generative growth parameters of plants showed that ameliorant application increased the height, leaf number and diameter of corn plants compared to treatment without ameliorant (control). This is consistent with the results of the analysis of soil chemical properties where ameliorant treatments provide improved soil chemical properties compared to the control (table 4 and 5). Based on the results of statistical analysis, the application of ameliorants had a significant effect on plant height and number of leaves and did not affect stem diameter, leaf width, and leaf length (table 6 and 7).

| Parameters           | Day after planting | Control | Bio | PK | KM | Bio+PK | Bio+KM | PK+KM |
|----------------------|--------------------|---------|-----|----|----|--------|--------|-------|
| Plant height (cm)    | 14                 | 29a     | 33a | 32a| 34a| 34a    | 33a    | 35a   |
|                      | 28                 | 70a     | 71a | 79a| 81a| 79a    | 80a    | 77a   |
|                      | 42                 | 198c    | 206bc| 220ab| 214ab| 222a   | 216ab  | 220b  |
| Leaf number (sheet)  | 14                 | 4.9bc   | 4.7c | 5.1abc| 5.2abc| 5.2abc | 5.4ab  | 5.6a  |
|                      | 28                 | 7.4b    | 7.9ab| 8.40a| 8.4a| 8.6a   | 8.5a   | 8.4a  |
|                      | 42                 | 11.8a   | 12.4a| 12.4a| 11.8a| 12.0a  | 11.7a  | 12.8a |
| Stem diameter (mm)   | 14                 | 2.2a    | 2.5a | 2.6a| 2.7a| 2.7a   | 2.8a   | 2.6a  |
|                      | 28                 | 15.8a   | 17.5a| 18.6a| 19.9a| 20.6a  | 19.7a  | 19.9a |
|                      | 42                 | 19.0a   | 21.0a| 20.8a| 19.8a| 20.6a  | 20.9a  | 19.7a |

Note: The numbers followed by the same letter on the same line do not differ at the 5% DMRT level.
In the generative growth phase, the application of ameliorant had a significant effect on the number of leaves aged 14 and 28 days after planting (table 7) compared to the control. The Bio+PK treatment had the highest significant effect on plant height at 42 days after planting and the number of corn leaves aged 14 and 28 days after planting (table 6) compared to the control. The Bio+PK treatment had the highest significant effect on plant height at 42 days after planting compared to the Control and Bio treatments but was not significantly different from the PK, KM, Bio+KM and PK+KM treatments. The highest number of leaves growth at 14 days after planting was found in the PK+KM treatment compared to Control and Bio treatments but not significantly different from the PK, KM, Bio+PK and Bio+KM treatments. In plants of 28 days after planting, the highest leaf number growth was obtained for the Bio+PK treatment compared to the Control and was not significantly different from other treatments.

In the generative growth phase, the application of ameliorant had a significant effect on the number of leaves at 75 days after planting (table 7). The highest number of leaves was obtained for Bio treatment compared to the Control and was not significantly different from other treatments. This finding is consistent with the results of an analysis of the incubated soil of the Bio treatment that had a neutral pH content; very high K potential and exch-K; moderate potential P; very high available P and base saturation at 0-20 cm depth (table 4). Data of the root length (table 8) shows that the root length of the corn is below 30 cm as more nutrient uptake occurs in the top layer (0-20 cm).

### 3.3.2 Yield of corn. The effects of ameliorant application on yield parameters can be seen in table 8. The harvest parameters show that ameliorant application can increase biomass, root length and harvest quality of corn compared to control. The control treatment had the lowest value of the yield parameters because the soil that was not treated with ameliorant had the lowest nutrient content and resulted in stunted plant growth compared to other treatments (tables 6 and 7).

**Table 7. The effect of ameliorants on the growth of corn in the generative phase.**

| Parameters            | Control | Bio  | PK    | KM    | Bio+PK | Bio+KM | PK+KM |
|-----------------------|---------|------|-------|-------|--------|--------|-------|
| Plant height (cm)     | 208a    | 222a | 218a  | 214a  | 221a   | 222a   | 220a  |
| Leaf number (sheet)   | 11.7b   | 12.9a| 12.9a | 12.4ab| 12.9a  | 12.7a  | 12.9a |
| Stem diameter (mm)    | 20.6a   | 21.6a| 21.4a | 21.5a | 22.2a  | 22.4a  | 21.6a |
| Leaf width (cm)       | 7.8a    | 8.4a | 8.5a  | 8.0a  | 8.5a   | 8.2a   | 8.6a  |
| Leaf length (cm)      | 84.0a   | 94.9a| 93.4a | 86.4a | 96.2a  | 91.2a  | 96.2a |

Note: The numbers followed by the same letter on the same line do not differ at the 5% DMRT level.

**Table 8. The effect of ameliorants on yield of corn.**

| Parameters                          | Control | Bio | PK | KM | Bio+PK | Bio+KM | PK+KM |
|-------------------------------------|---------|-----|----|----|--------|--------|-------|
| Plant biomass (t ha⁻¹)              | 6.8d    | 13.6a| 10.0c| 11.4bc| 12.4ab | 10.4c  | 11.0bc|
| Ear biomass/plant (g)               | 128.8a  | 133.1a| 149.3a| 145.4a| 155.8a | 137.8a | 146.4a|
| Root biomass/plant (g)              | 125.1a  | 190.7a| 151.6a| 148.3a| 152.6a | 154.1a | 138.3a|
| Root length (cm)                    | 23.4b   | 26.0ab| 28.0a | 26.8a | 23.5b  | 27.5a  | 27.5a |
| Ear length (cm)                     | 16.4a   | 17.4a| 17.1a | 17.8a | 17.6a  | 16.6a  | 17.3a |
| Ear circumference (cm)              | 14.1a   | 14.4a| 14.9a | 14.4a | 14.8a  | 14.7a  | 14.4a |
| Number of rows of seeds per ear     | 12.7a   | 13.2a| 13.0a | 12.5a | 13.3a  | 12.8a  | 12.8a |
| Number of grains of corn per ear     | 30.1a   | 30.4a| 31.5a | 30.8a | 32.1a  | 30.2a  | 32.5a |
| Weight of 1,000 seeds (g)           | 280.7a  | 290.3a| 320.0a| 320.0a| 310.4a | 290.2a | 290.8a|
| Weight of seeds per ear (g)         | 114.5a  | 125.2a| 126.0a| 123.0a| 133.7a | 117.8a | 123.9a|
| Yield (t ha⁻¹)                      | 7.2b    | 9.1a | 8.5a | 8.3a | 8.8a   | 8.6a   | 8.2a  |

Note: The numbers followed by the same letter on the same line do not differ at the 5% DMRT level.
The results of statistical analysis show that the application of ameliorant had a significant effect on increasing root length and yield, and had a very significant effect on increasing plant biomass. The highest root length was obtained in the PK treatment and was not significantly different from the treatment of Bio, KM, Bio+KM and PK+KM. The Bio treatment had the highest effect on increasing plant biomass compared to other treatments but it was not significantly different from Bio+PK treatment. The Bio treatment had the highest yield compared to control, but it was not significantly different from the treatment of other ameliorant substances. This is in line with the data of soil nutrient content and plant biomass.

This research shows that the application of ameliorants has a significant effect on increasing corn’s growth and yield. It is strongly attributed to the function of the ameliorants that occurs at least through 3 mechanisms, namely: 1) direct nutrient supply [33-34], 2) nutrient retention capabilities [31-32], and 3) maintaining soil moisture [35].

4. Conclusions
Application of ameliorants in the form of biochar, cattle manure, and mucuna compost at a rate of as much as 20 t ha\(^{-1}\) applied with a thorough mixture with the soil of ex-tin mining land has significantly improved the soil chemical properties. The improved soil chemical properties due to the addition of the ameliorant materials include soil reaction (pH), the soil nutrient status (P, K, Ca, Mg and Na) and the soil base saturation with the highest effects was on pH, P, K and base saturation.

The application of ameliorant significantly increased plant height, leaf number, plant biomass, root length and crop yield. Application of biochar or biochar in combination with cattle manure and mucuna compost as much as 20 t ha\(^{-1}\), gave the best effects in improving soil chemical properties and crop yields.

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