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UNLOCKING THE POTENTIAL OF AGRICULTURE WASTE AS A SOIL AMENDMENT ON GROWTH PERFORMANCE OF SWEET CORN (*Zea Mays.*)

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Abstract:

The decline in soil fertility of agricultural land and the abundance of agricultural wastes is a major problem in the environment. To overcome these problems, agricultural wastes have the potential to serve as a beneficial product that provides sustainable agriculture. The use of agricultural wastes as soil amendments is a sustainable practice in improving soil quality and plant productivity. Therefore, this study was carried out to evaluate the potential of agricultural wastes and agriculture wastes-derived biochars as soil amendments toward sweet corn (*Zea Mays*.) growth performance. The study was conducted in the greenhouse for 75 days. A randomized complete block design with four treatments (oil palm empty fruit bunch (EFB), EFB biochar, decanter cake, corn cob and corn cob biochar) in combination with mineral soil and four replication was used during the study. Plant height, stem diameter, and number of leaves were assessed for each treatment. Results indicate that corn cob biochar significantly increased the sweet corn height and plant diameter by respectively 11.0% and 25.0% as compared to the control. An increase in the stem diameter by 10.0% due to the application of EFB was observed at 45 days compared to the other treatments. In conclusion, the agricultural waste which is corn cob biochar were observed to have the potential in enhancing the sweet corn (*Zea Mays*.) growth.

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Keywords:

Agricultural Waste, Biochar, Growth Performance, Soil Amendment, Soil Fertility

Introduction

Agriculture sector in Malaysia is one of the most important sectors that contribute towards national's incomes. The incomes are generated from oil palm, rubber and paddy industries which are the major crop that is planted in Malaysia (Fahmi et al., 2013). Through the yield production of these industries, much agricultural waste is produced. According to recent statistics, the world produces about 1 billion tons of agricultural waste yearly (Karić et al., 2022) and about 1.2 million tonnes of agricultural waste is disposed into landfills annually (Agamuthu, 2009). Agricultural waste is a waste material produced from agricultural activities such as livestock manure and plant wastes. Nowadays, there has too much demand for the production of agricultural products, and because of this situation, abundant agricultural waste had produced. These agricultural wastes can provide harmful to humans and other living things if these by-products are not managed properly. These agricultural wastes can cause pollution to the environment such as water pollution, air pollution and soil pollution. Besides, there is another option that can be approached to make these agricultural wastes will be utilized into beneficial products that will provide sustainable agriculture. This agricultural waste can be recycled because it provides valuable benefits that can be obtained which are by making animal feed, producing biofuel and fertilizer, used it as a soil amendment or soil conditioner to enhance soil fertility (Wezel et al., 2014).

Soil amendment is an addition of material in the soil which helps to improve the physical and chemical properties of soil such as increasing aggregate stability of the soil, improving the pH and nutrient content in soil and improving aeration and drainage in soil (Karami et al., 2012). According to McGeehan (2012), the use of agricultural wastes as soil amendments have received attention in recent years for agronomic application. Soil amendment can be produced from agricultural wastes such as empty fruit bunch (EFB), decanter cake (DC), corn cob and pineapple peel. The combination of agricultural waste in the soil as a soil amendment can be seen to improve soil fertility through the strengthening of the soil structure, control of the soil pH, and enhancement of nutrient availability. The application of agricultural waste in the soil can significantly affect the physical properties of the soil to improve soil fertility and enhance the soil' structural stability by increasing water-holding capacity and porosity (Eden et al., 2017).

In addition, these agricultural wastes also can be made as biochar to improve soil fertility. Biochar is potential can be used as a soil amendment for improving the agricultural soil's quality (Agegnehu et al., 2017). Biochar is the carbon-rich product produced by the pyrolysis process that involves the heating of agricultural wastes or by-products in the absence of oxygen (Zheng et al., 2010). Many studies have reported biochar improves soil fertility by increasing plant growth and crop yields after biochar application, reduces the bioaccumulation of toxic metals and mitigates climate change (Tian et al., 2012). Most of the biochar is alkaline with a pH range of 7.5 to 11. Biochar is able to increase soil pH and is suitable for neutralizing soil acidity. By increasing soil pH, there is increased nutrient availability for plants and microbes that will improve plant growth and microbial activity (Vaccari et al., 2011). Biochar in the soil

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can significantly affect the physical properties of soil by changing soil bulk density, soil texture and structure, soil aeration, and water holding capacity due to the presence of macrospores on the biochar surface (Alfadil et al., 2021). With the presence of micropores on the biochar surface, it has the potential to be a sorbent to retain the plant nutrient from fertilizer application.

Hence, this study was conducted to evaluate the potential of agricultural wastes and agriculture wastes-derived biochars as soil amendments toward sweet corn (*Zea Mays*.) growth performance.

Literature Review

Pineapple Peel

Pineapple peel is an agricultural by-product that can be used for medicinal drinks, pineapple peel paper, and animal feed as well as pineapple peel also can make as soil amendment. Pineapple peel is rich in cellulose, hemicellulose and other carbohydrates (Rani & Nand, 2004). Potassium (K) content (15.13 mg/kg) in pineapple peel is high and followed by calcium (Ca) (2.80 mg/kg), phosphorus (P) (1.21 mg/kg) and magnesium (Mg) (0.56 mg/kg). Pineapple peel can be used as organic fertilizer to enrich the nutrient content in the soil. The addition of pineapple peel in the soil as a soil amendment can help to improve water holding capacity and soil aeration due to it containing a high amount of total fiber (92.30 mg/kg) (Souza et al., 2016).

Corn Cob

Corn cobs contain an all-natural, bio-degradable, and renewable resource, corn cob is made of 47% oxygen (O) and 44% carbon (C). Corn cob can be used as a soil amendment to improve soil fertility because it has certain nutrients that are needed by plants to improve crop performance. Corn cob has 67.93% porosity (Zhang et al., 2012) and can improve soil structure due to its physical properties. The other benefits of corn cob for soil are used to cover agricultural land in order to shield the soil from rain, and wind shear that leads to soil erosion, sun radiation, moisture loss and heat flux (Mohlala et al., 2016).

Decanter Cake

Decanter cake is an oil palm waste discharge from the mill after processing. About 4% - 5% of decanter cake was contributed from total oil palm waste discharge from the mill (Dewayanto, 2010). Potassium (K) (2.39%) and nitrogen (N) (2.48%) content in the decanter cake is high and followed by, calcium (Ca) (1.02%), magnesium (Mg) (0.80%) and phosphorus (P) (0.39%) (Yahya et al., 2010). Decanter cake contains nutrient which is needed by plants to enhance their growth performance. The advantages of the decanter cake towards soil properties are it can reduce the soil pH and also has a high exchange capacity rather than the unamended soil. Previous studies have reported that the pH of the soil is reduced from 7.93 for the control soil samples to 6.64 for amended soils at 30 % decanter cake application (Embrandiri et al., 2015).

Empty Fruit Bunch (EFB)

Through the processing of oil palm in the mill, about 22.0 % of empty fruit bunch (EFB) was contributed from the total waste discharge from the palm oil mill (Yusoff, 2006). Potassium (K) (1.89%) content in the empty fruit bunch is quite high and followed by nitrogen (N) (0.87%), calcium (Ca) (0.20%), magnesium (Mg) (0.12%) and phosphorus (P) (0.05%) (Sung et al., 2010). The oil palm plantations used the empty fruit bunch (EFB) as mulching because

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the empty fruit bunch (EFB) contains nutrients that can substitute the fertilizer when the EFB was applied to the soil.

EFB Biochar

Empty fruit bunch (EFB) biochar is a charcoal that is produced from an oil palm by-product which is an empty fruit bunch through the pyrolysis process. According to Sukiran et al. (2011), chemical composition of EFB biochar is 4.02% hydrogen, 59.62% carbon, 2.31% nitrogen and 34.05% oxygen. A previous study has discovered that EFB biochar has the potential to enhance soil fertility because it has a unique ability such as it can increase soil pH and cation exchange capacity (CEC) (Shafie et al., 2012), and also can perform as carbon sequestration which helps to reduce the greenhouse gases emission produced from charcoal combustion and decrease the accumulation of toxic metals in the soil (Tian et al., 2012).

Corn Cob Biochar

Corn cob biochar is a charcoal that is produced from corn waste which is corn cob through the pyrolysis process. Based on previous studies have discovered that corn cob biochar is able to perform as carbon sequestration because the carbon content in the corn cob biochar is high. Besides, other findings also proved that the corn cob biochar contains nutrients such as potassium (K) (0.22%), phosphorus (P) (0.12%), calcium (Ca) (0.46%), magnesium (Mg) (0.42%) and sodium (Na) (1.44%) that needed by plants to encourage the growth performance (Nurhidayati & Mariati, 2014). Corn cob biochar also can increase soil pH and cation exchange capacity (CEC) value (Nurhidayati & Mariati, 2014) to ensure the soil can be used for agricultural activities.

Methodology

This study was carried out at the UiTM Kampus Jasin, Melaka for about four months of observation. This study was conducted in quantitative research which is the numerical data collected and analyzed it using statistical methods. The source of data was obtained from the parameters studied in this research.

Preparation of Soil Amendments

Pineapple peel and corn cob were collected from Taman Kekal Pengeluaran Makanan (TKPM), Kompleks Pertanian Titi Gantong, Bota, Perak. Empty fruit bunch (EFB) and decanter cake from oil palm waste were collected from Sime Darby Kempas Palm Oil Mill, Jasin, Melaka. For this study, it was divided into two categories which are non-biochar soil amendments that consist of corn cob, pineapple peel, decanter cake, and empty fruit bunch (EFB) while biochar soil amendments were consists of corn cob biochar and empty fruit bunch (EFB) biochar. For non-biochar soil amendments, the samples were oven dried for 24 hours and ground by using a mechanical grinder and for biochar soil amendments, the samples were air-dried for 24 hours and then, the air-dried samples were burned through a pyrolysis process (burning without oxygen) at temperature 300°C for 2 hours. These biochars were ground and sieved through a 2 mm sieve size.

Measurement of Soil Amendments

The pH of soil amendments was measured using a pH meter with the ratio of soil amendment to distilled water is 1:25 (v:v). The ash content of soil amendments was measured according to Standard Test Method for Chemical Analysis of Wood Charcoal (ASTM International, 2007).

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The cation exchange capacity (CEC) was determined using the leaching method (Chapman, 1965).

Determination of Soil Amendment Nutrient Content

To determine the phosphorus, potassium, magnesium, and calcium (P, K, Mg, and Ca) content in soil amendment, the dry ashing method is used (Baker et al., 1964). A 1 gram of non-biochar was weighed in a crucible and placed in the muffle furnace for 1 hour at 300°C. Then, the temperature was increased until 500°C for 5 hours until white or grayish ash was obtained in the crucible. The crucible was taken out from the muffle furnace and left cool. After that, the ash was moistened by adding a few drops of distilled water. The sample in the crucible then is poured with 2 mL of concentrated HCl before being heated on the hot plate. The sample was heated until it is dried. Next, the dried sample was added with 10 mL of 20% nitric acid and placed in the water bath for 1 hour at 100°C. The sample in the crucible was transferred to the 100 mL volumetric flask by filtering the sample through filter paper into the volumetric flask. The crucible was rinsed several times and made up the volume with distilled water. Then, the sample was transferred into the plastic vials for the phosphorus, potassium, magnesium, and calcium (P, K, Mg, and Ca) content analysis by using ICP-OES Optima 7300DV.

Experimental Design

The greenhouse study was conducted for 75 days. A 1 kilogram of topsoil was filled in the polybags which is the soil taken from Share Farm, UiTM Kampus Jasin, Melaka. These polybags were applied with different types of agricultural waste as 5 tonnes/ha of each soil amendment for treatment (Table 1). Three replications were done for each treatment and arranged in a randomized complete block design (RCBD) at Greenhouse, UiTM Kampus Jasin, Melaka. The soils were mixed with treatments were incubated for two weeks to ensure homogeneity of the mixture before starting the planting. Sweet corn plants were used as the indicator. The variety used is ‘Hibrimas’ sweet corn. The seeds of sweet corn were obtained from MARDI Serdang, Selangor. Before planting, the seeds of sweet corn were sown first to ensure the seedlings were germinated in uniform condition and then, the seedlings were transplanted into the polybags which contain soil and treatments. The sweet corn plants were watered twice a day (early morning and late evening) with water. The fertilizer used is NPK compound (15: 15: 15) was applied after 7 days of planting at rate 400 kg/hectare (Leong, 2005).

Table 1: The Types of Soil Amendments

Treatment	Types of soil amendment
T1	Soil only (without treatment)
T2	EFB
T3	Corn cob
T4	Pineapple peel
T5	Decanter cake
T6	Corn cob biochar
T7	EFB biochar
T8	Mixture of EFB biochar and decanter cake

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Growth Performance of Sweet Corn

Sweet corn growth performance was measured after harvest. The parameter includes the plant height, number of leaves, and stem diameter from each plant. Plant height was measured using measuring tape from the bottom of the plant to the tip of the tallest leaf in the plant (Mensah & Frimpong, 2018). The number of leaves was counted manually and the stem diameter of sweet corn plants was measured using a vernier caliper.

Statistical Analysis

The collected data were statistically analyzed using SPSS Version 26. The differences in mean values were evaluated by One-way analysis of variance (ANOVA) followed by the Tukey test. Differences at the probability level, $P < 0.05$ were considered significant. The correlation among data was calculated using Pearson's correlation to measure the degree of relationship between parameters. All diagrams were drawn using Microsoft Excel 365.

Findings

The results of this study were obtained from two parts which are the evaluation of agricultural wastes as a potential soil amendment and the greenhouse study. Figure 1 illustrates the flowchart of this research's process.

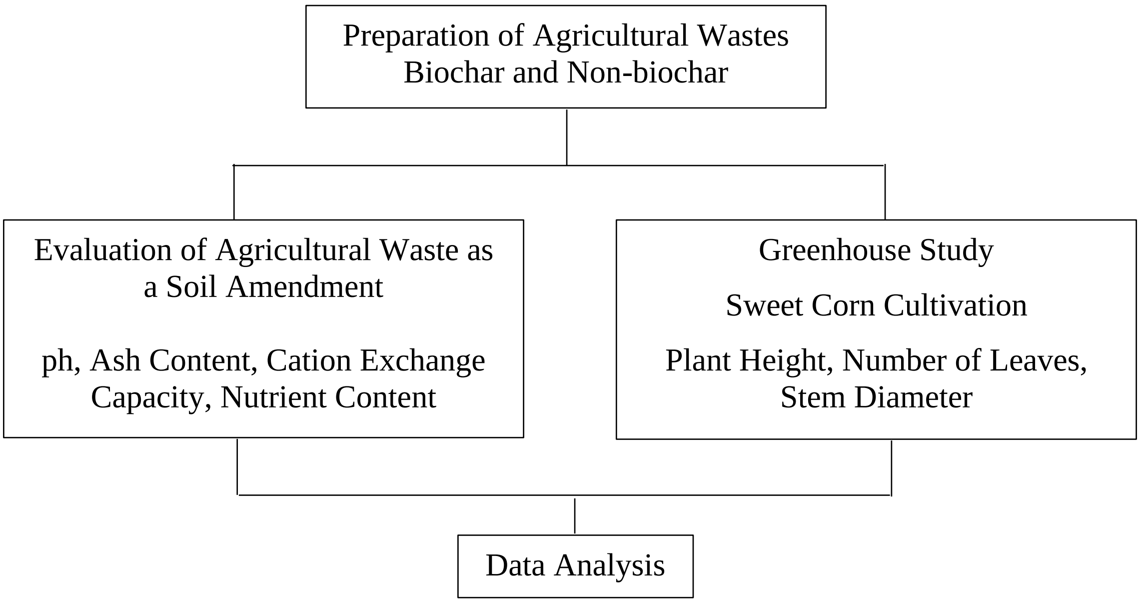

Figure 1: The Flowchart of This Research's Process

Properties of Soil Amendments

Based on the result in Table 2, there were two categories of soil amendments which are non-biochar amendments and biochar amendments. For non-biochar soil amendments pH value for EFB (6.78), corn cob (5.22), pineapple peel (4.33) and decanter cake at (4.46). For the biochar soil amendments, it was produced from the pyrolysis process which is the pH for corn cob biochar (7.8), EFB biochar (9.48) and the mixture of EFB biochar with the decanter cake (6.94). Data analysis revealed that the EFB biochar was significantly higher than the other soil amendments. The result also showed that the biochar soil amendments contain a high pH value

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compared to non-biochar soil amendments. The pH value of the biochar soil amendment is from 6.5 to 10. The nature of the biochar from the pyrolysis process is usually alkaline that pH is more than 7.00 (Mukherjee & Lal, 2014).

The ash content of soil amendments was measured and expressed in percentage (%). Based on Table 2, the highest ash content was obtained in the mixture of decanter cake and EFB biochar (15.27%) whilst the lowest ash content was recorded in the corn cob (2.06%). The increase in ash content from biochar produced at 300–500°C is the result of a progressive concentration of minerals and destructive volatilization of lignocellulosic matters as temperature increases (Cao & Harris, 2010; Tsai et al., 2012). The cation exchange capacity (CEC) analysis was conducted for 3 soil amendments which are decanter cake, corn cob biochar, and the EFB biochar. The result shows that there was a significant difference between soil amendments which is decanter cake (19.17 cmol/kg), corn cob biochar and EFB biochar is 14.24 cmol/kg and 14.40 cmol/kg respectively. This could be due to the high negative charge potential of surface functional groups in decanter cake compared to corn cob biochar and EFB biochar. Besides, corn cob biochar and EFB biochar has low CEC value compared to decanter cake might be due to the high temperature applied during biochar production which caused the loss of acidic surface functional groups (Gaskin et al., 2008).

Table 2: Properties of Soil Amendments

Soil amendment	Parameter		
	pH (H_2O)	**Ash content (%)**	**CEC (cmol/kg)**
EFB	6.78 ± 0.05^{c}	3.46 ± 0.37^{bc}	-
Corn cob	5.22 ± 0.01^{d}	2.06 ± 0.04^{c}	-
Pineapple peel	4.33 ± 0.01^{e}	4.00 ± 0.35^{bc}	-
Decanter cake	4.46 ± 0.01^{e}	14.68 ± 0.46^{a}	19.17 ± 0.05^{a}
Corn cob biochar	7.80 ± 0.02^{b}	4.74 ± 0.33^{b}	14.24 ± 0.01^{b}
EFB biochar	9.49 ± 0.02^{a}	14.97 ± 0.93^{a}	14.40 ± 0.02^{c}
Decanter cake + EFB biochar	6.94 ± 0.10^{c}	15.27 ± 0.61^{a}	-

Mean ± standard error. Mean values followed by the same letter within a column were not significantly different ($p \geq 0.05$). EFB = Empty fruit bunch, CEC = Cation exchange capacity

Nutrient Content of Soil Amendment

Essential elements used by plants in relatively large amounts for plant growth are called macronutrients which are nitrogen (N), phosphorous (P), and potassium (K). calcium (Ca), magnesium (Mg), and sulfur (S). All six nutrients are important constituents in soil that promote plant growth. By adding soil amendment, it will improve nutrient content to enhance soil fertility. Data on the nutrient content of soil amendment are presented in Table 3. Data analysis revealed that the soil amendment which highly contains nutrients than the other soil amendment is EFB biochar. The EFB biochar was significantly higher in potassium (K) (8.93%), magnesium (Mg) (6.07%), and calcium (Ca) (1.69%) respectively. In contrast, the corn cob was significantly lower compared to other soil amendments. Besides, the phosphorus content is highly significant in corn cob biochar with 2.06% higher than the other soil amendment phosphorus content.

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Table 3: Nutrient Content of Soil Amendments

Soil amendment	Nutrient content			
	Total phosphorus (%)	**Total potassium (%)**	**Total magnesium (%)**	**Total calcium (%)**
EFB	0.08 ± 0.01^{b}	1.49 ± 0.16^{bc}	0.09 ± 0.01^{c}	0.17 ± 0.02^{bc}
Corn cob	0.34 ± 0.04^{b}	1.00 ± 0.10^{c}	0.10 ± 0.01^{c}	0.05 ± 0.01^{c}
Pineapple peel	0.18 ± 0.03^{b}	1.91 ± 0.20^{bc}	0.95 ± 0.01^{c}	0.34 ± 0.04^{bc}
Decanter cake	0.19 ± 0.01^{b}	1.06 ± 0.11^{c}	1.96 ± 0.01^{bc}	0.87 ± 0.06^{abc}
Corn cob biochar	2.06 ± 0.21^{a}	5.75 ± 0.60^{ab}	5.32 ± 0.01^{ab}	0.53 ± 0.03^{bc}
EFB biochar	0.50 ± 0.15^{b}	8.93 ± 2.16^{a}	6.07 ± 0.18^{a}	1.69 ± 0.43^{a}
Decanter cake + EFB biochar	0.24 ± 0.03^{b}	1.60 ± 0.27^{bc}	2.63 ± 0.03^{abc}	0.90 ± 0.10^{ab}

Mean ± standard error. Mean values followed by the same letter within a column were not significantly different ($p \geq 0.05$).

Effect of Soil Amendment on Sweet Corn Growth Performance

In general, the plant height of the sweet corn was affected by the different soil amendments after harvest on Day 45. An increasing trend was observed though there were no significant differences in the plant height in all treatments. The plant height of sweet corn with corn cob biochar (T6) as soil amendment achieved the highest increment with a value of 31.48 cm, whilst the sweet corn planted with decanter cake (T5) exhibited the lowest increment at 26.35 cm throughout the planting period. Compared with the control (T1), the plant height of sweet corn significantly increased by 11.0% when applying the corn cob biochar (T6) as a soil amendment. Based on the previous analysis, corn cob biochar contains a high macronutrient content compared to other soil amendments and the sweet corn plants might receive more nutrient availability through this soil amendment. Biochar also can contribute in improving the nutrient retention capacity of soil due to its large surface area, porosity, and presence of both nonpolar and polar surface sites (Ahmad et al., 2014; Hussain et al., 2017; Mukherjee et al., 2011; Yu et al., 2018).

The application of different types of soil amendment had positively affected the number of leaves for sweet corn plants. The highest number of leaves was found in the sweet corn planted with corn cob biochar (T6) and without treatment (T1) whilst the lowest number of leaves was found in the sweet corn planted with the application of decanter cake as a soil amendment. Besides, the sweet corn leaves number showed no significant difference between each soil amendment. From the observation, some treatments are slow in development, and some are speedy in growth, so the formation of leaves are depending on the sweet corn development stage. Another factor that affects the number of leaves may because of the pest attack. There should be no pests during the planting because it was planted in the greenhouse as we already know that there cannot be any pests because the conditions are under control. This factor must be taken care of for further study to prevent it from happening again.

The bar chart below also showed the stem diameter of the plants for each treatment, ranging from 0.7 mm to 1.0 mm. The highest stem diameter measured is the corn cob biochar (T6) and was followed by the pineapple peel (T4). Other than that, the result also shows that there are no significant differences between those treatments applied. The stem diameter of all the treatments shows that they are in the closed range. Compared with the control (T1), the stem

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diameter of sweet corn significantly increased by 25.0% when applying the corn cob biochar (T6) as a soil amendment. The difference between the stem diameter measures may be because of the plant spacing distance, which is the higher the plant density or spacing, it will become a limiting factor towards the stem growth (Mahemoud & Solieman, 2007). There were reflections towards this experiment which is it has planted in a polybag. The soil-applied is not sufficient that causing limitations to the stem diameter development.

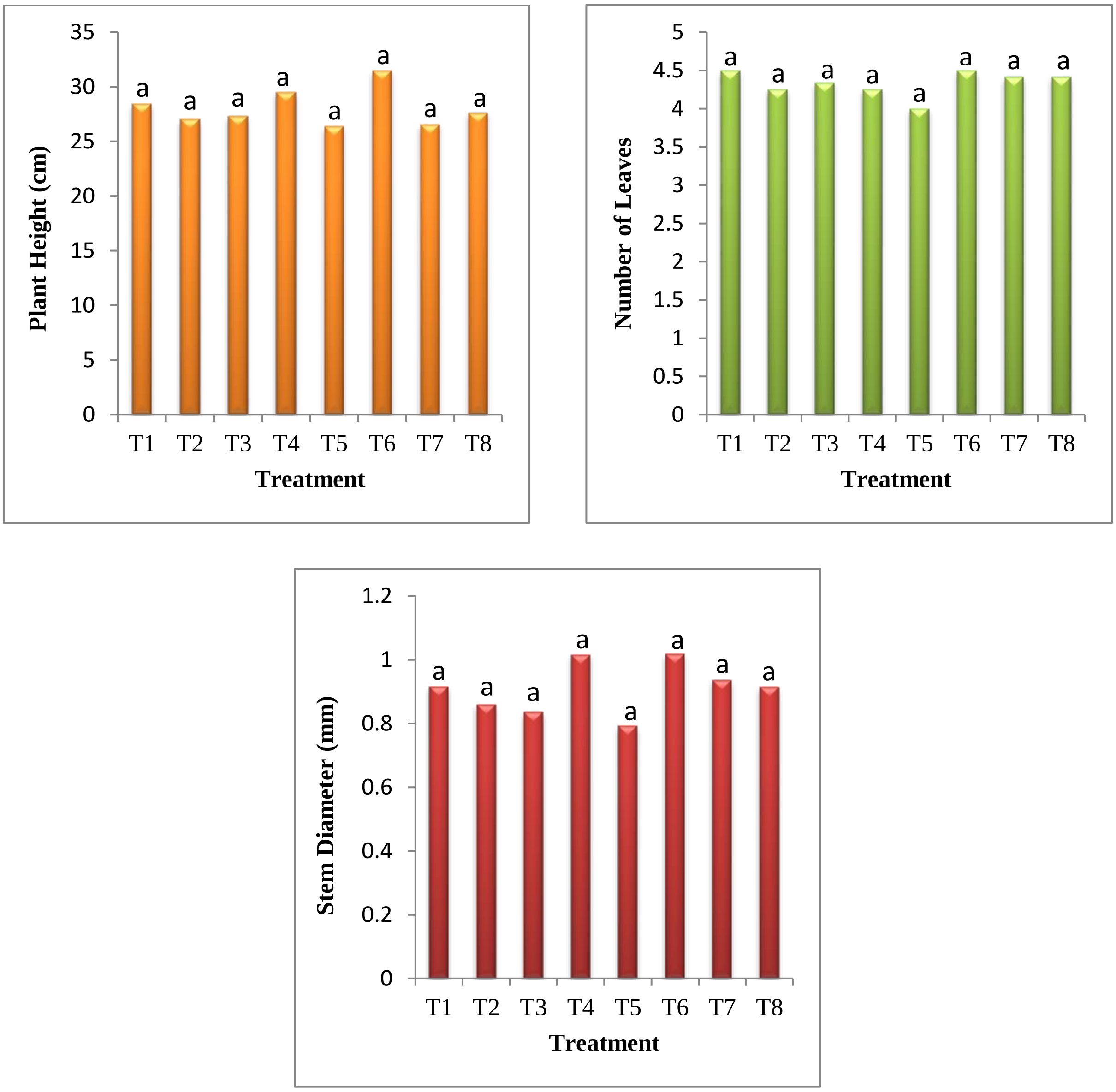

Figure 2: Effect of different soil amendments on sweet corn (*Zea mays.*) growth performance after harvest. Each data item represents the mean of replicates. Mean values followed by the same letter were not significantly different ($p \geq 0.05$). T1 = Without treatment, T2 = Empty fruit bunch (EFB), T3 = Corn Cob, T4 = Pineapple peel, T5 = Decanter cake, T6 = Corn cob biochar, T7 = EFB biochar, T8 = Mixture of decanter cake and EFB biochar.

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Figure 3: The sweet corn was planted in the polybags at the Greenhouse, UiTM Kampus Jasin, Melaka for 30 days after transplanting with different types of treatments.

Correlation between Properties of Soil Amendment and Sweet Corn Growth Performance

The correlations between the properties of soil amendments and the growth performance of sweet corn were analyzed. Based on Table 4, the pH showed a significant positive correlation with the number of leaves with r value is 0.639. The CEC also demonstrated a strong negative correlation with the number of leaves (-0.993) and stem diameter (-0.949) of sweet corn significant at the 0.05 level. The phosphorus content showed a positive correlation with plant height, number of leaves and stem diameter. Moreover, data analysis also revealed a strong positive correlation between potassium and magnesium with the number of leaves, with r values of 0.500 and 0.449. These indicate that the increase in plant macronutrients significantly contributed to the increase in plant growth parameters. These nutrients are important to support the plant's growth and development (White & Brown, 2010).

Table 4: Correlation between Properties of Soil Amendment and Growth Performance of Sweet Corn (*Zea mays.)*

	pH	Ash content	CEC	P	K	Mg	Ca	Plant height	Number of leaves	Stem diameter
pH	1									
Ash Content	0.305	1								
CEC	-0.934**	0.496	1							
P	0.414	-0.177	-0.626	1						
K	0.807**	0.367	-0.780*	0.519*	1					
Mg	0.746**	0.425	-0.736*	0.650**	0.956**	1				
Ca	0.560**	0.812**	-0.156	0.077	0.795**	0.783**	1			
Plant height	0.016	-0.509*	-0.552	0.763**	0.132	0.193	-0.320	1		
Number of leaves	0.639**	-0.206	-0.993**	0.534*	0.500*	0.449*	0.049	0.469*	1	
Stem diameter	0.245	-0.388	-0.949**	0.549**	0.400	0.313	-0.060	0.812**	0.621**	1

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*Correlation is significant at 0.01 level (2-tailed) **Correlation is significant at 0.05 level(2-tailed). CEC = Cation exchange capacity, P = Phosphorus, K = Potassium, Mg = Magnesium, Ca = Calcium

Conclusion

This study has achieved its objectives by indicating that agricultural waste can be a potential soil amendment, particularly in the biochar state, due to its physicochemical characteristics which are good for plant growth. The different types of soil amendment used in planting sweet corn had positively affected its growth performance. The present study showed that the corn cob biochar increased the growth performance of sweet corn such as plant height, number of leaves, and stem diameter. Therefore, the agricultural waste which is corn cob biochar was observed to have the potential in enhancing sweet corn growth.

Besides, this study provides several important contributions, especially to the farmers which can help in reducing the demand for commercial fertilizer usage and offers additional nutrients for crop development. In addition, further study on the effect of agricultural waste as a potential soil amendment on the nutritional content of sweet corn is suggested for the high production and quality of sweet corn.

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