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Growth Performance of Sweet Corn (Zea Mays) On The Mineral Soil Amended With Sago Waste Biochar

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ABSTRACT

Sago waste is a viable and utilisable resource for conversion into value-added products. Sago fronds and bark have great potential for use as biochar feedstocks due to their availability and high starchy-lignocellulosic compounds content. However, few studies have been conducted regarding sago waste conversion into biochar. Hence, this study evaluates the viability of converting sago waste into biochar and as a soil amendment for mineral soil planted with sweet corn (Zea mays) plants. The study was located at the Farm Unit, UiTM Samarahan, Sarawak. Five treatment combinations of sago bark (SB) biochar and sago frond (SF) biochar were used in a randomised complete block design (RCBD) with eighty plants per treatment. The procedure was replicated three times. Parameters were measured at harvest 85 days after treatment (DAT), including total dry biomass, cob weight, cob number and cob grade. All the recorded data were statistically analysed by the analysis of variance (ANOVA) using SAS 9.4 (2013). Different treatments showed significant effects for all the parameters studied. The highest values for total dry biomass and cob yield were obtained using SB biochar 100%. The results of this study reveal the potential of SB biochar as an alternative soil amendment to increase sweetcorn biomass and yield.

***Keywords**: biochar, sago bark; sago frond; soil amendment*

INTRODUCTION

In Malaysia, more than 90.0% of all sago-planting areas are in the state of Sarawak, one of the world's largest sago exporters. It exports around 25,000-40,000 tons of sago products annually to Peninsular Malaysia, Japan, Taiwan and Singapore [1-2]. For decades, Sarawak has been the main exporter of sago starch in Malaysia. Sago palms (Metroxylon sagu Rottb.) are commonly found in Sarawak, comprising an estimated area of 54,087 ha and largely found in Mukah division, which has an area of about 46,924 ha [3]. Typically, sago palms are planted in swampy and acidic peat soil due to their ability to grow in marginal soils, including sulfidic soils.

During the processing of sago starch, one of the major by-products generated, sago trunk bark, creates a major problem within the sago industry and it also has a detrimental effect, polluting water [2]. According to Wahi [4], an estimated 15.6 tons of sago bark were produced daily. Along with rising sago starch demand, the industry is now facing waste management problems which have resulted in environmental pollution and health hazards. Currently, sago waste can be used as an absorbent, sugar source, in the production of biofuel, as nanomaterial and in ceramics [5]. However, little research has been done on the conversion of these under-utilised sago waste products and sago fronds into biochar as an alternative soil amendment.

Biochar is a light and highly porous carbonaceous material derived from the thermochemical decomposition of biomass. [6] define biochar as a carbonaceous resulting product obtained from the biomass of certain plants or animals pyrolysed at high temperatures under anoxic or hypoxic conditions. According to [6] there are numerous ways in which biochar can improve the soil quality, including optimising water-holding capacity and cation exchange capacity, acting as a source of carbon sequestration in soil, improving soil fertility through enhancing the availability of essential nutrients such as nitrogen (N), carbon (C) and phosphorus (P), as well as reducing the susceptibility of soil to erosion and bioavailability of heavy metals.

Apart from the environmental benefits, biochar significantly influences soil physico-chemical properties and fertility status [7]. Mineral soils are typically characterised by strong acidity, low clay activity and poor fertility, which are commonly due to high iron and aluminium oxide content. The potential benefits that biochar could offer are to improve soil fertility and crop yield, increase farm profitability and also assist in improving the soil physico-chemical properties. Sago waste could provide a beneficial impact on the soil and it has a commercial value when converted to biochar. Sago fronds and bark have high potential for use as biochar feedstocks due to their availability and high starchy-lignocellulosic compounds content. Hence, this study aims to evaluate the viability of converting sago waste into biochar and as a soil amendment. Bearing that in mind, this study was conducted to investigate the potential of sago waste biochar on mineral soil and to evaluate the effect of sago waste biochar on the growth performance of sweet corn as an indicator.

MATERIALS AND METHOD

Study Site and Plant Materials

The field study was conducted at the experimental Farm Unit, UiTM Sarawak Branch, Samarahan Campus, Sarawak under nursery conditions for 85 days between April and June 2019. The plant materials consisted of a pre-germinated local variety of sweet corn purchased from Agro-Popular Sdn. Bhd., Sentosa, Kuching, Sarawak.

Seedling Preparation

Pre-germinated sweet corn seeds were sown in seedling trays at the nursery plot using peat moss as a medium. Pre-sampling of the soil was performed before transplanting to analyse the soil physico-chemical properties. The field was ploughed and prepared before sweet corn seeds were sown at the site. At seven days old, the seedlings were transplanted into the various beds, according to the experimental design. Seedlings of a similar size and a uniform height were selected. Each seedling was placed in a planting hole during the transplanting process. The soil type in the plot was highly weathered, mineral soil.

Experimental Design and Treatment

The treatments were laid out in a Randomised Complete Block Design (RCBD). There were five treatments consisting of eighty plants, replicated thrice, and giving a total of 1200 experimental units. The treatments were as shown below:

Treatment 1 = Control
Treatment 2 = SB Biochar 50% + BF
Treatment 3 = SB Biochar 100% + BF
Treatment 4 = SF Biochar 100% + BF
Treatment 5 = SB Biochar 50% + SF Biochar 50% + BF
Note: BF=basal fertiliser; SB=sago bark; SF=sago frond

Biochar Feedstock and Carbonisation Preparation

The sources of biochar came from SB and SF biomass purchased from Sago Mill in Mukah, Sarawak. The raw biomass was washed and oven-dried at 150°C until it reached a constant weight, then crushed into a fine powder and ground into particles of about 2 mm in size using a heavy-duty grinder [8] The biochar carbonisation process was carried out in Block H, UiTM Sarawak Branch, Samarahan Campus, Sarawak. Biochar production was performed according to [9]. Samples were placed into ceramic crucibles with fitted lids and carbonised at 350°C for two hours in a large chamber muÆe furnace (Type 62700; Thermo Scientific Barnstead/Thermolyne, USA). They were then ground until they could pass through a 1mm sieve and kept at room temperature.

Biochar Application

Biochar was applied to sweet corn seedlings according to the treatments. It was applied twice, with 100 g per seedling at 14 days after transplanting and another application of 100 g per seedling on the 45th DAT at the field planting site. The biochar was broadcast about 5 cm from the plants' collar region and ploughed to be incorporated with the soil. Watering was carried out before biochar application to reduce soil heat and prevent biochar losses due to wind.

DATA COLLECTION ON GROWTH AND YIELD

Statistical Analysis

Data were averaged over the replications for all measuring dates and their mean averages were used to derive the relationship between biomass and yield parameters. Differences in biomass and yield between the treatments were calculated using the SAS 9.4 (2013) statistical procedure, PROC ANOVA. The Duncan's Multiple Range Test (DMRT; $p<0.05$) was used to detect significant groupings among the treatments.

Maintenance

The sweet corn plants were fertilised with a monthly application of basal fertiliser (BF), applied with sago waste biochar according to the treatments and watered daily throughout the study period.

RESULTS AND DISCUSSION

Physico-Chemical Properties of the Soil

The physico-chemical properties of the mineral soil used in this study were low in total N (0.35%), low in organic-C (7.53%), and low in exchangeable potassium (0.10 cmol+/kg). The magnesium (1.09 cmol+/kg) and calcium (0.83 cmol+/kg) were adequate for sweet corn seedlings' growth. The mean pH of 4.4 indicates strongly acidic soil and the C/N ratio of 1:22 was still tolerable for sweet corn seedlings. The soil type used was that of highly weathered mineral soil (yellow podzol clayey type). The pre-treatment soil sampling shows that the physico-chemical properties of the mineral soil indicate a lack of the organic matter and macronutrients required for plant growth.

EGects of DiGerent Sago Biochar Composition on Sweet Corn Dry Biomass and Cob Weight

Plant biomass refers to the plant's components, including the plant stems, leaves and roots. The results of the dry biomass and cob weight for each treatment are shown in Table 1. For dry biomass, treatments T2, T3, and T4 were significantly different ($p<0.05$) from T1 and T5. However, T3 gave the highest mean value (75.27 g), followed by T4 (74.73 g) and T2 (73.99 g) respectively, compared to the control, T1 (51.56 g). Sweet corn applied with 100% SB biochar obtained 45.99% and had a greater dry biomass weight compared to the control.

For cob weight, T3 was significantly different ($p<0.05$) compared to the other treatments. Treatment T3 gave the highest mean value (255.74 g), followed by T2 (218.63 g) and T4 (298.81 g). Both parameters indicated that T5 resulted in unfavourable outcomes compared to the other treatments.

Table 1: Sweet Corn Dry Biomass and Cob Weight

Treatment	Dry biomass (g)	Cob weight (g)
T1	51.56^{c}	154.36^{c}
T2	73.99^{a}	218.63^{b}
T3	75.27^{a}	255.74^{a}
T4	74.73^{a}	208.81^{b}
T5	62.16^{b}	162.52^{c}

Note: Means within a column related to particular parameters with the same superscript letter are not significantly different as a = 0.05 confidence level; values are the means of the three replications, *n* = 240

Treatment T3 gave the highest mean values for both dry biomass and cob weight. This could probably be attributed to the fact that SB biochar had substantial inherent nutrients and acted as a soil amendment to the sweet corn plants. This result is in agreement with the study conducted by [10] which indicated that the SB biochar pH mean value was 8.59 (strongly alkaline). This suggested that SB biochar had increased the soil pH, thus making the nutrients readily available for the plant's uptake. In addition, findings by [10] reported that the nutrient content in sago bark biochar accumulated and increased after the carbonisation process, as shown in Table 2.

Table 2: Elemental Compositions of Sago Bark Raw and Sago Bark Biochar

Element	Composition (%)	
	Sago bark raw Before	Sago bark biochar After
C	49.73 ± 5.31	51.36 ± 3.58
N	4.43 ± 3.65	10.65 ± 2.07
O	41.96 ± 6.19	33.24 ± 0.63
Mg	0.23 ± 0.23	0.16 ± 0.15
P	0.11 ± 0.24	0.07 ± 0.07
S	0.24 ± 0.11	0.07 ± 0.09
K	2.27 ± 1.21	4.01 ± 3.22
Ca	1.03 ± 0.23	0.44 ± 0.19

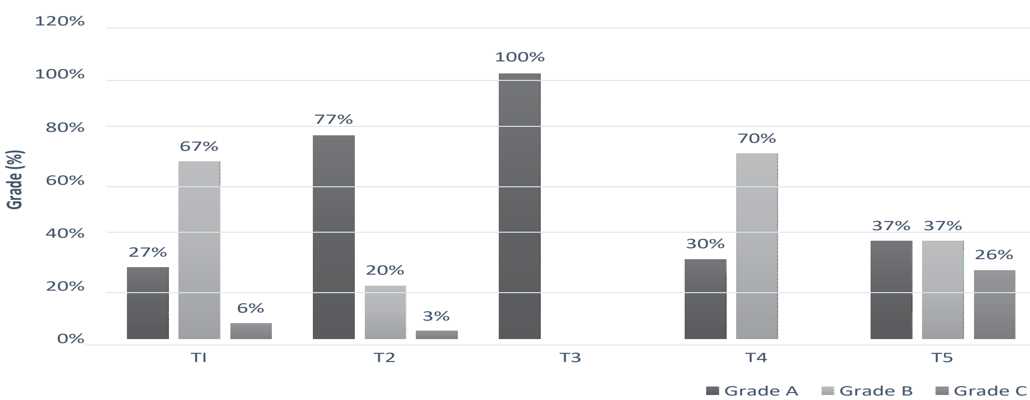
Source: [10]

Due to carbonisation, the weight loss and volatile content disappeared. In addition, biochar can be used to prevent erosion and maintain soil moisture while reducing pollution to the environment [11]. Furthermore, SB biochar is rich in minerals compared to raw sago bark.

Previous research done by [12] suggests that a combined application of inorganic fertilisers and organic amendments (e.g. crop residues and manure) are more effective than the sole application of either organic or inorganic amendments. Interestingly, although the T5 treatment had a greater mixture of amendments, the resulting dry biomass weight and cob weight were not as satisfactory. The resulting increment for dry biomass was only 20% and not significantly different ($P < 0.05$) in the mean cob weight compared to the control. The data implies that a greater number of amendments does not necessarily mean greater yield and could be a waste of resources. Additionally, biochar are fine grains of porous charcoal; in maintaining soil they have the ability to reduce the amount of CO_2 from the air [13] which is produced by slow-burning at a controlled temperature and with a reduced oxygen supply, preventing the reduction. Related to the above findings, [14] proved that the decreased rate of bulk density as a result of the addition of organic materials depends on the level of application of amendment, the types of soil, and the soil compaction. Sago waste is one type of organic material containing a high C/N ratio (50%-70%). Materials that have this high ratio have a greater influence on changing the physical properties [15] of soil organic carbon and avoiding the excessive use of fertiliser in the future [16].

Effects of Different Sago Biochar Composition on Sweet Corn Cob Weight and Cob Grade

Figure 1 shows the percentage of sweet corn cob according to the cob weight. The sweet corn cob grade was classified based on cob weight.



In term of cob grade, treatment T3 was significantly different ($p<0.05$) from the other treatments and resulted in the highest mean value for the formation of quality fruits set, with the highest-grade, grade A (240 cob; 100%), followed by T2 (184 cob; 77%), T5 (88 cob; 37%) and T4 (72 cob; 30%) respectively. On the other hand, treatment T1 (control) showed the lowest grade A (64 cob; 27%). The addition of SB biochar could be attributed to the beneficial addition of the nutrient content as well as an improvement to the soil structure. This is in agreement with findings by [17-18] on reduced nutrient leaching on the mineral soil. These findings are also supported by [19-20], who confirmed the beneficial effect of biochar amendment on soil content, with an improvement of N, P, K, Mg and grain yield. In addition, [21] confirmed that biochar improves soil pH and reduces nutrient leaching in growing media. Several studies have shown that biochar could enhance the activities of soil enzymes involved in C, N and P cycles [22].

A study by [16] found that the application of biochar from Indian Rosewood *(Dalbergia sissoo)* can enhance wheat growth which shows a better grain yield. This advantage of biochar implies that without a combination of biochar from sago waste, the sweet corn yield can be affected. As biochar is a bio-renewable source, it has given positive benefits to production systems such as improving the quality of soil organic content, water quality and crop growth and yield [23]. Moreover, a study conducted by [24] states that biochar has been recognised to improve plant growth and crop yield in soil that has a low phosphorus content. Therefore, this study implies that the addition of SB biochar and SF biochar on highly weathered mineral soil would not only further enhance their nutrient content and soil structure but would also significantly aRect the overall sweet corn biomass and yield.

CONCLUSION

Overall, there were positive correlations between the plant's dry biomass accumulation and yield that reflects the vegetative and reproductive growth of plants. The results of this study showed the addition of sago waste biochar promotes significant biomass and yield in sweet corn plants. It can be concluded that sweet corn with SB biochar (100%) resulted in the best application on mineral soil. Sago bark biochar may be better suited as an alternative organic fertiliser and it can act as a potential soil amendment for mineral soil.

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