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EFFECT OF SAGO BARK BIOCHAR APPLICATION ON *Capsicum annuum* L. var. *Kulai* GROWTH AND FRUIT YIELD

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ABSTRACT

Applying biochar in crop farming or agriculture activity generally increases productivity through improved soil fertility and water holding capacity. However, there is a lack of empirical data on the effects of sago bark waste-derived biochar on the growth media of *Capsicum annuum* L. This work, reported the effect of sago bark biochar and acid-base treated sago bark biochar on *Capsicum annuum* L. var. *Kulai* growth media fertility. The plant growth study was carried out using completely random design experimental layouts with five replicates and 8 treatments at various biochar application rates (0.5,1.5, & 3.0%, w/w). Results showed that plant grown with 1.5% sago bark biochar has the highest number of the leaf (122.90). Plant with 1.5% acid-base treated sago bark biochar showed a significantly (p<0.05) higher number of flower buds (1.90) and stem height (69.00 cm) during 4 months of the vegetative period. Meanwhile, plants with 3% acid-base treated sago bark biochar obtained the highest yield of fruit fresh weight (67.64 g). In general, acid-base treated sago bark biochar application increase the yield of *Capsicum annuum* L. var. *Kulai*.

Key words: Chili, completely randomized design, crop yield, Kulai, sago bark, soil fertility

INTRODUCTION

Chili is among the most popular vegetables in Asia including Malaysia. This vibrant red color vegetable has its level of heat and is usually used in various cuisines, in dried and powdered forms, or even in flakes. *Capsicum annuum* L. var. *Kulai* originated in South America but is favored in Asia (Khandaker *et al*., 2017). According to the Food and Agriculture Organization of the United Nations [FAO] (2019), the total harvested area of chili in the world was 1,990,926 hectares, with Malaysia roughly covering only 0.14% (2,843 hectares) of the worldwide area. Total chili production in Malaysia has been decreasing over time, with 27,555 tonnes produced in 2019 compared with 59,775 tonnes in 2013 (FAO, 2019). Agriculture and Agro-based industry stated that approximately 300,000 tonnes of chili per year had been consumed by Malaysians between January and July 2018 (Daros, 2019). The average chili production in Malaysia is still very low, and it is necessary to increase crop productivity to meet the current demand for chili.

According to the Department of Statistics Malaysia, chili production had the greatest Import Dependency Ratio (IDR) and Self Sufficiency Ratio with an estimation of 73.6 and 30.8% respectively. In 2019, 2,370 tonnes were produced, and high demand has prompted more farmers to plant chili (Mahidin, 2019). Excessive use of inorganic fertilizers which are mostly made from synthetic materials, provides rapid nourishment for plant development but increases farming costs and results in soil degradation (Khandaker *et al*., 2017).

Therefore, biochar is used as a soil amendment to enhance soil fertility and it improves growth media by increasing soil pH, enhancing soil aeration, and changing the soil structure due to changes in physicochemical properties (Ajema, 2018). Chemical activation treatments for biochar have offered greater improvement in surface area and porosity development, and have further increased the sorption capacity of biochar (Sahin *et al*., 2017; Tan *et al*., 2017; Zhao *et al*., 2017). Biochar could be a promising material for boosting acid soil productivity due to its liming effect, water and nutrient retention capability, and carbon sequestration capacity (Berek, 2019). The modification process of biochar is important to study the enhancement of physical and chemical properties

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and their effects on plant growth media. Recently, a modification of pristine biochar has attracted interest as a potential plant growth media (Sukartono *et al*., 2011; Carter *et al*., 2013; Wisnubroto *et al*., 2017). However, less attention has been paid to the effect of chemical properties of biochar which subsequently affects crop production.

In this study, sago palm-derived (*Metroxlon sago* Rottb.) is indigenous to the Southeast Asia region and it is grown well in moist environments such as low-land freshwater swamps and tropical rain forests (Amin *et al*., 2019; Whye *et al*., 2019). There are three major by-products produced during the processing of sago starch which are sago bark, fibrous pith residue, and sago wastewater (Mahdian *et al*., 2021). In estimation, 600 logs of sago palm would produce 15.6 tons of woody bark, 238 tons of wastewater, and 7.10 tons of fibrous pith daily, which would negatively affect the environment (Amin *et al*., 2019). More than 20,000 tons of SB are discarded from Malaysia's sago industry every year and destroyed through open or controlled burning and into rivers, which can cause a hazard to the environment (Wahi *et al*., 2016; Amin *et al*., 2019). A few initiatives have been made to overcome this irritating issue due to the high amount of residual waste produced annually by evolving the wastes into value-added materials. Therefore, this work aimed to determine the effect of sago bark biochar (SBB) and treated sago biochar (TSB) as soil amendments on *Capsicum annuum* L. var. *Kulai* plant growth quality.

MATERIALS AND METHODS

Preparation of acid-base treated sago biochar

The SBB samples were collected from a sago bark burning chamber at a sago flour processing mill. Then, the samples were washed, oven-dried (60 °C), ground, and sieved into particles size ranging from < 2.00 mm. An SBB sample (5 g) was soaked in NaOH solution (2 M, 25 mL) at 60 °C for 2 h before oven-drying (105 °C, 24 h). Later, it was heated under reflux with HCl (5 M, 25 mL) at 95 °C for 2 h, washed with hot distilled water to obtain a TSB of pH 7, and then, oven-dried (105 °C, 24 h). The SBB was first treated using 20% NaOH which was used to adsorb a greater number of negatively charged species as the alkaline-treated activated carbon generates positive charges on its surface (Tan *et al*., 2017). Acid modification of biochar has significantly reduced the pH, which is suitable for alkaline soil and also could enhance the overall water-soluble nutrient content of biochar (Sahin *et al*., 2017).

Experimental design and treatment preparation

The plant growth experiment was conducted using chili plants (*Capsicum annuum* L. var. *Kulai*) as the test crop in the growth house. The seeds were purchased from the Malaysian Agricultural Research and Development Institute, Selangor. Initially, the seeds were placed between two damp paper towels with distilled water for five days until the seeds sprouted. The pre-germinating seeds were sown on a peat moss seedling tray under a shed for four weeks before being transferred into polybags (16 inch × 16 inch, HDPE) in the growth house. The mean relative humidity and temperature readings of the study site were taken daily.

Previously, the soil texture was determined by the hydrometric method (Gangwar & Baskar, 2019). The proposed modification of growth media for better nutrient retention, water storage, and drainage for potential study application was done using biochar and was based on the finding of the soil texture analysis. Soil pH and electrical conductivity were determined by using a CyberScan pH/Conductivity/TDS meter; (Eutech Instrument™). The total organic carbon of soil was determined by using 1 g of air-dried soil and weighed into a 500 mL conical Erlenmeyer flask. A 10 mL potassium dichromate solution was added and followed by 20 mL of concentrated sulphuric acid (H_2SO_4 ≥97%) (Merck, Germany). The contents were shaken gently for one min and the reaction was allowed to take place for 30 min. Next, 200 mL of distilled water and 5 mL of phosphoric acid were added and the mixture was allowed to cool. Ten to 15 drops of diphenylamine indicator were then added, and the mixture was titrated with a 0.5 M solution of ferrous ammonium sulfate until the color changed from purple to green. The total amount of nitrogen samples was determined by using 1 g of ground soil, and they were weighed into a digester tube. A 12 mL sample of concentrated sulphuric acid (H_2SO_4 ≥97%) (Merck, Germany) was added and the tube was left still with 30 min of frequent shaking. Two tablets of catalyst ST (CT0006609: Velp Scientifica™) were added to the mixture. The mixture was then heated on a digestion rack (Heating Digester, Model: Velp Scientifica™, DKL) for about one hr at 420 °C. Next, the mixture was cooled down until it achieved a temperature ranging from 50 °C to 60 °C. Later on, the mixture went through a distillation process using a distillation unit (Semi-Automatic Distillation Unit, Model: Velp Scientifica™, UDK 139) with 10 mL of 30% sodium hydroxide and 50 mL of distilled water added into the mixture. The distillate solution was collected with 5 mL of 4% boric acid in a conical flask. It was later titrated against 0.02 M HCl using a methyl red indicator from yellowish to pink in color. A UV-Vis spectrophotometer (AgilentTM Cary 60-UV Vis) at 660 nm was used to determine the availability of phosphorus samples. Exchangeable Na, K, Mg, and Ca samples were determined using AAS instruments (Analytik Jena, Model: Cary 500, ThermoScientific™). Next, the growth media was prepared using topsoil mixed with SBB and TSB at

Table 1. Treatment rates.

Treatment No.	Description	Biochar rates (g/kg)
T1	0.5% SBB + NPK	Fertilized soil with 35 g of SBB
T2	1.5% SBB + NPK	Fertilized soil with 105 g of SBB
T3	3.0% SBB + NPK	Fertilized soil with 210 g of SBB
T4	0.5% TSB + NPK	Fertilized soil with 35 g of TSB
T5	1.5% TSB + NPK	Fertilized soil with 105 g of TSB
T6	3.0% TSB + NPK	Fertilized soil with 210 g of TSB
T7	Control	Non-fertilized soil without biochar
T8	NPK	Fertilized soil without biochar

Note: SBB= Sago bark biochar; TSB= Treated Sago bark biochar; NPK = commercial fertiliser.

rates, of 0.5, 1.5, and 3% (by weight) (Table 1). Each filled polybag was weighed at 7 kg.

The germinating seeds were transplanted into eight different treatments, which comprised different application rates of SBB and TSB (Table 1). The plants were arranged in completely random design (CRD) experimental layouts with five replicates. The inorganic fertilizers, NPK were applied at the rate of 0.36 g to the respective treatment every 30, 60, and 90 days after transplant (Syuhada *et al*., 2016) (Table 1). The plants were watered two times per day, meanwhile, weeding and other management practices were undertaken if necessary.

Plant growth analysis

The stem height (SH) (cm) and the number of leaves (NoL) were recorded monthly. Stem height was measured from the base of the stem to the tip of the highest leaf using a measuring tape. Meanwhile, the number of flower buds (NoB) was recorded weekly, after the buds emerged. The number of fruits (NoF) and fresh weight (g) were recorded at 120 days of growth. Before weighing the leaves, stems, roots, and fruits, the plants were harvested at 120 days of growth. The soil adhered to the roots was washed off and then the samples were weighed (g) using an analytical balance with two decimals (Shimadzu). Next, the samples were oven-dried using a convection oven (Spectrum Chemical) (60 °C for 48 h) until they were at a constant weight to record the dry weights (Khandaker *et al*., 2017).

Statistical analysis

Data for each month were averaged across five replications, and the mean averages were used to determine the relationship between biochar and plant growth studies. Using SPSS version 16.0 (IBM), the data were subjected to analysis of variance (ANOVA). Significant differences between treatments were further analyzed by the Tukey pair-wise comparison test at a 5% significance level.

RESULTS AND DISCUSSION

Physico-chemical properties of the soil, sago bark biochar, and acid-base treated sago bark biochar

The soil texture analysis indicated that the topsoil used in this study was a loam soil type that consists of 30% sand, 45% silt, and 25% clay. Before the experimental setup, the physico-chemical properties were analyzed following plant analysis handbook (2021) methods and the results are summarised in Table 2. The soil pH of 5.37 indicated a slightly acidic soil, and the recommended pH 6.5 and 7 are considered optimum for chilies production (Bush *et al*., 2016). Further analysis showed that all samples (soil, SBB, & TSB) were deficient in nitrogen (N) content when the critical level is at least 3%. Therefore, the N level could be maintained within prescribed limits by the usage of N fertilizer. The soil was moderately supplied with K content as the critical values ranged from 0.75 to 1.25%. The results also showed that the soil has an insufficient amount of available P (3.69%), exchangeable Na (0.07 me/100 g), exchangeable K (0.21 me/100 g), exchangeable Ca (2.72 me/100 g), and is deficient in TOC (0.28%) as compared to a previous study by Ahmad *et al*. (2018). These results indicated that the soil alone has low fertility status since it is deficient in a considerable amount of nutrients and requires either an external source such as biochar or fertilizer to improve the yield of plant growth.

Meanwhile, the SBB and TSB were slightly alkaline in pH, 10.41 and 8.98, respectively. The results implied that both biochar samples can be used to fix the soil acidity problems as they have a good natural lime function. According to Berek (2019), the presence of carbonates and oxides (basic cations) in biochar will neutralize the excess H^+ ions from the acidic soil causing an increase in soil pH. In addition, SBB recorded higher electrical conductivity (EC) (18.18 mS) compared to TSB which implies more ionic concentration in the SBB.

In a previous study, the surface area of TSB was 59.61% which is higher than SBB due to pore enlargement and surface destruction during acid-base modification (Mohamad Fathi *et al*., 2021). Meanwhile, in previous work by Riaz *et al*. (2018), the results of high porosity and greater pore volume were attributed to decreasing soil bulk density and better soil aeration. Results indicated that TSB could offer a greater adsorption capacity compared to SBB likely attributable to the presence of functional groups (acid treatment: carboxyl group; alkaline treatment:

hydroxyl group) on the biochar surface (Huang *et al*., 2021).

The water holding capacity (WHC) of soil (53.91%) was high when the critical value ranges from 35 to 45%. The WHC of TSB (97.63%) was significantly (p<0.05) higher than SBB (86.34%). High WHC could improve soil water content, decrease the mobility of water in the soil, and reduce water stress in plants (Batista *et al*., 2018). Therefore, the fine-textured material of TSB results in rapid water drainage due to its large pore size and potentially enhances the fertility of the rapid water drainage.

The available phosphorus (P) for both SBB and TSB samples is not significantly different (1.40% & 1.57%, respectively). This indicates that P availability in both samples would modify the increase of soil pH and improve the retention of exchangeable anions (Ndor *et al*., 2016). K (6.47%) was found to be the highest in SBB, while Ca (6.67%) and Mg (4.37%) were found to be the highest in TSB.

Number of leaves

Table 3 shows the number of leaves (NoL) for different application rates of SBB and TSB. The NoL was not significantly (p>0.05) affected on day 30. However, there was a significant (p<0.05) increase on days 60, 90, and 120 when the application of biochar and inorganic fertilizer was conducted. The lowest NoL was recorded in T7 with an average of 10.40 on day 120. At the end of the experiment (120 days of treatment), plants in T2 showed a significantly (p<0.05) higher NoL, which was 122.90. The result was supported by Upadhyay and Neupane (2020), who found a significant effect of rice-husk biochar on an increased final number of leaves compared to the ones without biochar application.

The results indicated that the relationship between biochar type and application rate was significantly (p<0.05) correlated for NoL in the first, second, and third months after planting. However, the effect was more prominent in the fourth month. The increased NoL per plant was due to a sufficient amount of mineral nutrients from biochar and fertilizer, especially N as this element is very essential in protein synthesis (Khandaker *et al*., 2017).

Stem height

Table 4 shows the effect of different application rates of SBB and TSB on stem height (SH). There was a significant difference (p<0.05) between the treatments after 30 days of treatment. Different rates of biochar treatment had shown a different potential to increase plant height by improving the physicochemical stress scarcity of nutrients (Hafeez *et al*., 2017). Stem height had significantly (p<0.05) increased on the 120th day of treatment for all treatments except for the control treatment. The plant in T5 recorded the highest stem height (69.00 cm) on day 120 of treatment compared to T7 (14.80 cm).

The increased plant growth in soil treated with biochar compared to soil without biochar can be associated with biochar porosity, which has a higher ability to retain water in soil (Upadhyay & Neupane, 2020). The result was supported by Yilangai *et al*. (2014), who reported that the stem growth of tomatoes increased by 35% with increasing fruit yield, on beds covered with charcoal and it was attributed to the good photorespiration undergone by the plant. The amount of biochar applied to soil showed no linear response as T5 had the highest average values (69) compared to T3 and T6 (66.50 & 64, respectively) during plant development at the end of the vegetative period (120 days of treatment). A similar trend was reported by Pokovai *et al*., (2020) as 2.5% of biochar (wood chips, fiber sludge, and grain husks) amendment applied into soil had the highest average values of pepper plant height (304.13 mm) compared to 5% of biochar treatment. According to Riaz *et al*.

Table 2. Chemical and physical characteristics of the topsoil, SBB, and TSB

Parameters	Topsoil	SBB	TSB
Sand (%)	30	-	-
Silt (%)	45	-	-
Clay (%)	25	-	-
pH (1:2.5 water)	5.37	10.41	8.98
Electrical conductivity (mS)	14.55	18.78	5.17
BET Surface area (m^2/g)	-	64.140	158.817
Water holding capacity (%)	53.91 ± 0.95	86.34± 0.38	97.63±0.14
Available Phosphorus (%)	3.69 ± 0.08	1.41±0.05	1.57±0.07
Exchangeable Na (me/100g)	0.07 ± 0.02	nc	nc
Exchangeable K (me/100g)	0.21± 0.02	6.47±0.43	1.27±0.01
Exchangeable Mg (me/100g)	2.02 ± 0.06	0.66±0.03	4.37±0.15
Exchangeable Ca (me/100g)	2.72 ± 0.03	5.44±0.39	6.67±0.58
Total organic carbon (%)	0.28 ± 0.05	nc	nc
Soil organic matter (%)	0.48 ± 0.08	nc	nc
Total Nitrogen (%)	0.03 ± 0.00	0.58 ± 0.66	0.18 ± 0.01

Note: SBB=Sago bark biochar; TSB=Treated sago bark biochar; nc=not conducted

(2018), the high amount of organic matter and less N leaching in the biochar-soil treatment were attributed to an improvement in plant height.

Number of flower bud

Results showed that biochar treatments significantly ($p<0.05$) affect the number of flower buds (NoB) (Table 5). The NoB during vegetative growth for both SBB and TSB applications was high, except for the control treatment. The flowers started to bloom during 90 days of treatment and the plants in T3 recorded the highest NoB (5.20) on the 111th day of treatment. The result indicated that the yield was 88.46% higher compared to plants without biochar application. In this study, all biochar treatments showed no significant difference ($p>0.05$) to NoB, except for control and NPK applications. Treatment with T6 has the highest TN content (0.06±0.00%). According to Moneruzzaman *et al*. (2017), the high number of flowers and fruits is caused by the increase in nitrogen content in the treatment of 180 kg ha^{-1} N levels. In addition, another study reported that the high number of leaves would produce abundant flower buds, which is due to plant vitality (Khandaker *et al*., 2017). Jenberu (2017) stated that the application of both biochar and N fertilizer, which contains a moderate level of N (23-69 kg/ha) has an essentially positive effect on increased yield. On day 132 of treatment, most of the flower petals fell off as the buds started to push from the calyx, providing nutrients for fruit formation. This, however, did not happen in the NPK treatment as the flowers started to bloom at this phase.

Number of fruits

The results showed that all treatments had a significant difference ($p<0.01$) in the number of fruits (NoF) throughout the study period, except on days 97 and 104 of treatment (Table 6). The plants in T5 gave the highest NoF (9.00) on day 132 of treatment, which was significantly different ($p<0.05$) from the control treatment. The plants in T3 and T6 showed no significant difference ($p>0.05$), where both treatments showed 7.60 and 7.70 NoF, respectively. Therefore, biochar treatment encouraged plant growth and fruit growth better than plants without biochar treatments. In another work, tomato yield increased by 76% on a plot with charcoal as a soil amender compared to plants without charcoal due to the effectiveness of biochar in retaining and preventing the leaching of nitrogen beyond the reach of plants. It can be concluded that plant yield might be increased when biochar is applied to the soil and fertilizer.

Table 3. Comparison of numbers of leaves (NoL) in different treatments

Treatment	Days of treatment				
	0	30	60	90	120
T1	3.90±0.74^{a}	8.40±1.26^{a}	23.80±8.39^{abc}	91.50±18.69^{a}	97.90±15.07^{abc}
T2	3.80±0.79^{a}	8.40±2.22^{a}	31.70±11.50^{a}	90.00±22.98^{a}	122.90±31.02^{a}
T3	4.10±0.82^{a}	8.90±0.88^{a}	34.90±14.38^{a}	92.30±32.37^{a}	118.00±31.51^{ab}
T4	4.00±0.82^{a}	8.50±1.27^{a}	25.60±13.01^{ab}	77.70±17.86^{a}	89.80±20.27^{bc}
T5	4.00±0.67^{a}	8.20±2.20^{a}	26.30±16.05^{ab}	86.30±16.71^{a}	111.40±19.02^{ab}
T6	4.00±0.47^{a}	9.50±2.64^{a}	35.40±15.31^{a}	92.80±25.86^{a}	111.30±28.67^{ab}
T7	4.20±0.63^{a}	7.40±1.26^{a}	7.70±2.71^{c}	13.00±7.92^{b}	10.40±2.22^{d}
T8	4.10±0.32^{a}	8.10±1.73^{a}	12.90±4.72^{bc}	38.10±19.00^{b}	69.40±21.18^{c}
F value	0.401	1.173	7.271	20.265	25.895
LSD *p<0.05*	0.899	0.329	0.0001	0.0001	0.0001

The numbers to the right of each value represent the standard deviation of the mean. Significant differences between treatments are indicated by different letters^{abc} in superscripts to the right of each value in each column.

Table 4. Comparison of stem height (cm) in different treatments

Treatment	Days of treatment				
	0	30	60	90	120
T1	5.07±0.72^{a}	10.53±1.21^{ab}	30.35±5.57^{a}	57.60±9.56^{a}	63.80±10.80^{a}
T2	5.10±1.10^{a}	10.79±1.93^{a}	34.10±6.10^{a}	56.40±8.09^{a}	62.90±8.33^{a}
T3	5.25±1.02^{a}	10.88±2.25^{a}	31.80±9.45^{a}	56.30±14.59^{a}	66.50±12.67^{a}
T4	5.42±1.09^{a}	9.79±1.70^{ab}	30.30±7.60^{a}	58.30±11.11^{a}	59.90±12.51^{a}
T5	5.83±1.33^{a}	10.76±2.01^{a}	33.10±11.38^{a}	58.50±9.19^{a}	69.00±14.42^{a}
T6	4.83±0.80^{a}	8.20±1.72^{ab}	31.70±8.21^{a}	54.00±7.13^{a}	64.00±10.47^{a}
T7	5.10±0.44^{a}	8.17±1.54^{b}	12.60±2.59^{b}	13.20±3.77^{c}	14.80±5.03^{b}
T8	5.75±0.89^{a}	9.75±1.36^{ab}	17.10±6.69^{b}	37.50±11.71^{b}	54.10±9.64^{a}
F value	1.321	2.658	11.270	26.348	26.314
LSD *p<0.05*	0.253	0.017	0.0001	0.0001	0.0001

The numbers to the right of each value represent the standard deviation of the mean. Significant differences between treatments are indicated by different letters^{abc} in superscripts to the right of each value in each column.

Table 5. Comparison of the number of flower buds in different treatments

Treatment	Days of treatment					
	90	97	104	111	118	132
T1	0.00±0.00^{a}	0.00±0.00^{a}	2.00±1.33^{a}	3.50±3.47^{a}	2.30±1.64^{a}	1.30±1.64^{ab}
T2	0.00±0.00^{a}	0.50±0.85^{a}	1.50±1.35^{ab}	4.60±2.07^{a}	3.10±1.85^{a}	1.70±0.82^{ab}
T3	0.10±0.32^{a}	0.70±1.06^{a}	1.40±1.51^{ab}	5.20±2.20^{a}	3.20±1.62^{a}	1.30±1.64^{ab}
T4	0.50±0.97^{a}	0.30±0.68^{a}	1.40±1.65^{ab}	3.30±1.64^{ab}	2.50±1.72^{a}	1.80±1.62^{a}
T5	0.10±0.32^{a}	0.20±0.63^{a}	1.40±1.71^{ab}	3.50±2.59^{a}	2.70±1.42^{a}	1.90±1.52^{a}
T6	0.00±0.00^{a}	0.90±1.10^{a}	1.80±1.55^{ab}	4.40±0.97^{a}	2.00±1.25^{ab}	0.60±1.08^{ab}
T7	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{b}
T8	0.00±0.00^{a}	0.00±0.00^{a}	0.10±0.32^{b}	0.60±0.84^{bc}	1.70±1.25^{ab}	3.90±0.99^{c}
F value	2.085	2.440	3.146	8.713	4.955	7.977
LSD *p<0.05*	0.056	0.027	0.006	0.0001	0.0001	0.0001

The numbers to the right of each value represent the standard deviation of the mean. Significant differences between treatments are indicated by different letters[abc] in superscripts to the right of each value in each column.

Table 6. Comparison of numbers of fruits in different treatments

Treatment	Days of treatment				
	97	104	111	118	132
T1	0.00±0.00^{a}	0.40±1.27^{a}	0.80±2.20^{ab}	5.70±2.79^{a}	8.30±3.00^{a}
T2	0.00±0.00^{a}	0.50±0.85^{a}	2.30±2.41^{ab}	4.70±2.41^{a}	6.90±2.42^{a}
T3	0.48±0.15^{a}	0.90±1.60^{a}	2.80±2.00^{a}	5.30±1.83^{a}	7.60±3.41^{a}
T4	0.32±0.10^{a}	0.30±0.95^{a}	1.10±2.51^{ab}	5.90±3.04^{a}	7.90±3.87^{a}
T5	0.32±0.10^{a}	0.30±0.48^{a}	2.10±2.51^{ab}	5.90±1.91^{a}	9.00±2.54^{a}
T6	0.00±0.00^{a}	0.20±0.42^{a}	1.10±1.29^{ab}	4.10±2.13^{a}	7.70±3.16^{a}
T7	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
T8	0.00±0.00^{a}	0.00±0.00^{a}	0.10±0.32^{b}	0.30±0.95^{b}	6.70±2.83^{a}
F value	2.077	1.101	2.897	13.620	9.721
LSD *p<0.05*	0.057	0.372	0.010	0.0001	0.0001

The numbers to the right of each value represent the standard deviation of the mean. Significant differences between treatments are indicated by different letters[abc] in superscripts to the right of each value in each column.

Fresh and dried weight of stems, roots, leaves, and fruits

The fresh and dry weights of stems, roots, leaves, and fruits were recorded and presented in Figure 1. Statistical analysis showed that different treatments had a significant difference ($p<0.001$) in the fresh and dried weights of all samples. However, all biochar treatments showed no significant difference ($p>0.05$) in fresh weight of fruits and stems, except in control and NPK treatments. There was a significant difference ($p<0.05$) between the weight of fresh leaves and roots.

The weight of fresh stems (Figure 1a) and roots (Figure 1b) were significantly ($p<0.05$) higher in T2 (28.76±5.22 g & 18.00±4.11 g, respectively). The results showed that T2 had an increase of 98% for fresh stem weight compared to the control treatment. However, the highest yield of the weight of fresh fruit was recorded in T5 and T6 (63.97±18.69 g and 67.64±17.50 g, respectively) (Figure 1d).

Meanwhile, all biochar treatments showed no significant difference ($p>0.05$) in dried weight in all samples, except in the control treatment. Plants in T2 showed the highest weight of dried stems (Figure 1a). Meanwhile, plants in T4 showed the highest weight of dried leaves (12.52±3.08 g) (Figure 1c). The highest weights of dried roots (Figure 1b) and fruits (Figure 1d) were recorded in 1.5% of the TSB treatment (10.83±7.30 g & 4.10±3.62 g, respectively). In addition, the control treatment showed the lowest weight of dried stems, roots, and leaves samples (0.24±0.13 g, 0.43±0.8 g, & 0.30±0.22 g, respectively).

The weight for the fresh and dried parts of the plant was the lowest in the control treatment due to a lack of nutrient supplies (Hashmi *et al*., 2019). The biochar has several properties that can improve the physical and chemical properties of the soil (growth media), including improving the structure of soils from being too dense, increasing porosity so that drainage is improved, and enhancing soil binding capacity to nutrients (Amaral *et al*., 2019). A study by Wisnubroto *et al*. (2017), reported that red chili planted in a plot with biochar resulted in a better soil fertility status compared to non-biochar treated soil. The current results were also supported by Gonzaga *et al*. (2018), which showed that biochar treatment gives positive results on maize plant biomass by about 90% as compared to without biochar.

In most of the growth parameters, the effects of T5 and T6 were similar in the weight of fresh leaves and fruit. According to Situmeang and Suarta (2016), incorporation of biochar into the soil will encourage improved physical properties of the soil and plant growth due to the high porosity of biochar which could increase the population of microbial activity in the soil. In a study conducted by Mohamad Fathi *et al.* (2021), the water holding capacity of TSB (97.63%) was reported to be higher compared to SBB (86.34%) which demonstrates that the fine-textured material of TSB causes speedy water drainage due to its large pore size. According to Upadhyay *et al*. (2020), the biochar application had a significantly more beneficial effect than the control treatment. The best performance of the chili yield component was obtained by a combination of nitrogen fertilizer, farmyard manure, and a biochar-treated plot, demonstrating that even after four years, biochar still had a positive effect on crop production (Wisnubroto *et al*., 2017).

The crop yield gives a positive effect on the treatment together with fertilizers due to organic treatments creating a more porous and friable soil, which results in enhanced root growth and development (Jenberu 2017; Upadhyay *et al*., 2020) The study by Shi *et al*. (2020) demonstrated that treatment of soil with biochar urea showed an increase in weight of fresh shoot (13.8%) and roots (25.1%) compared to the control treatment. Hence, the role of biochar in improving root development and increasing resistance to environmental stress conditions such as salinity and drought has been recognized (Shi *et al*., 2020; Zainul *et al*., 2020).

CONCLUSION

The study showed the incorporation of T5 has promoted a significant increase in the number of fruits, stem height, and flower buds during the four months of the vegetative period in *Capsicum annuum*

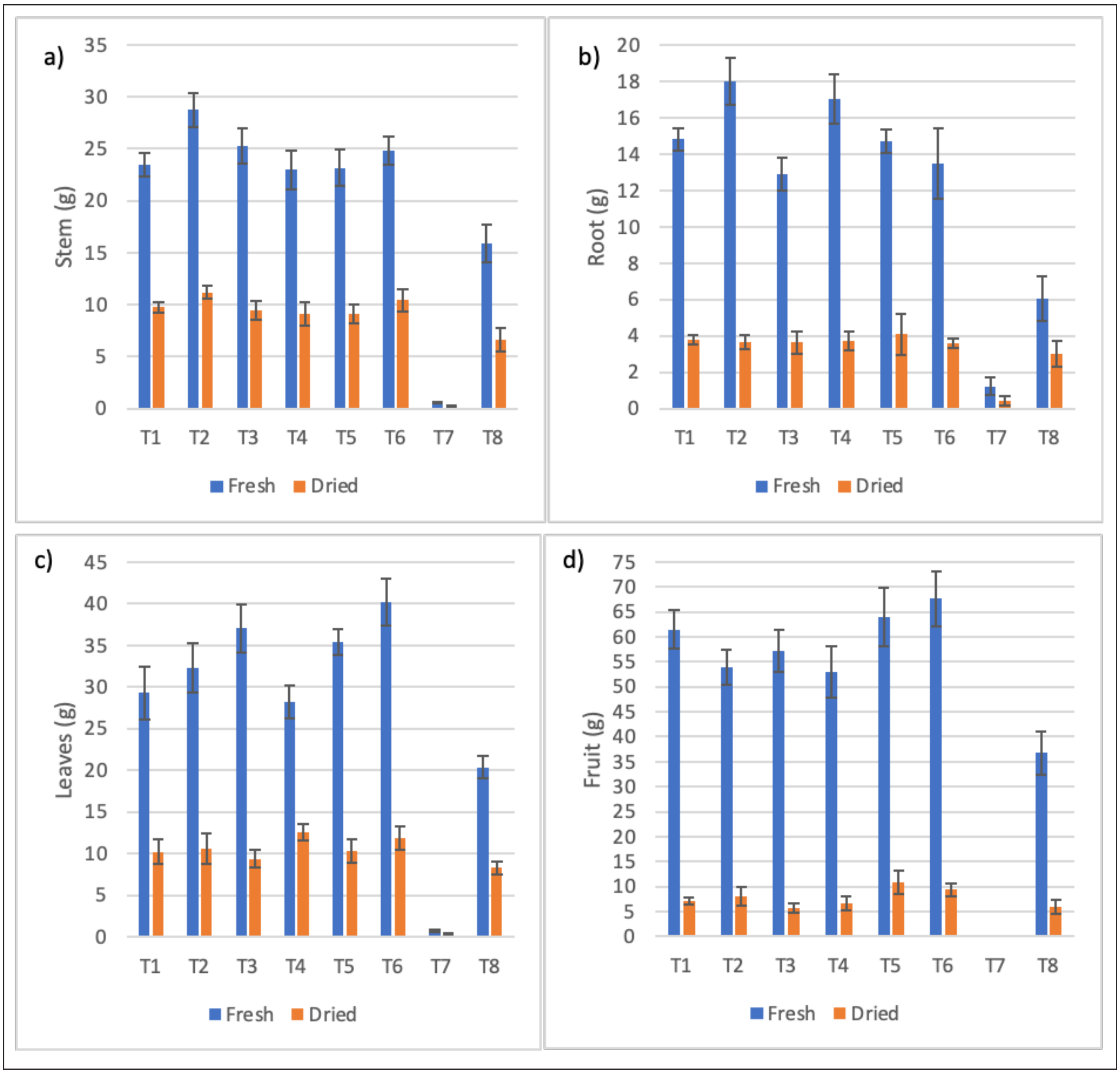

Fig. 1. Weight of fresh and dried a) fruit, b) leaves, c) stems, and d) roots of different rates of treatment. The error bars represent the standard deviation of the mean (n=10) and bars with different letters[abc] indicate statistically significant ($p<0.001$) differences.

L. var. Kulai. This includes the highest yield of weight for fresh fruits in T5 (63.97 g) and T6 (67.64 g). The highest weight of dried fruits (10.83 g) and roots (4.10 g) were recorded in the T5 treatment. Meanwhile, plants in T7 showed the lowest weight of dried stems (0.24 g), roots (0.43 g), and leaves (0.30 g). Therefore, biochar should be applied along with organic or inorganic fertilizer to mitigate the effects during plant growth to improve crop productivity. Soil amender is also a useful alternative strategy and is cost-effective in farming, which reduces the cost and usage of commercial fertilizer. For further recommendation, more studies on the effects of biochar mixture and other organic amendments such as compost for plant growth should be carried out, to reduce the usage of inorganic fertilizer.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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