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THE RESPONSES OF LOWLAND CHERRY TOMATO (*SOLANUM LYCOPERSICUM* VAR. CERASIFORM) PLANTED UNDER SOILLESS CULTURE SYSTEM TO DIFFERENT BIOCHAR SUBSTRATES AND SEAWEED EXTRACT

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Abstract: A field experiment has been conducted to evaluate the effect of different biochar substrates in combination with and without seaweed extract on the growth of lowland cherry tomato and its fruit quality attributes. The experiment was arranged according to the randomized complete block design with two factors viz. (i) Different biochar substrates (Palm Kernel Shell, PKS; Sugarcane Bagasse, SB; Coconut Shell, CS; and Walit Bird Waste; WW), and (ii) With (W) and without seaweed (WO) extract. The experimental treatments were (i) Cocopeat with seaweed; (ii) Cocopeat (C) alone (serve as control); (iii) C and PKS with seaweed; (iv) C and PKS without seaweed; (v) C and SB with seaweed; (vi) C and SB without seaweed; (vii) C and WW with seaweed; (viii) C and WW without seaweed; (ix) C and CS with seaweed; and (x) C and CS without seaweed with four replications. The parameters evaluated were pre- (stem diameter) and postharvest parameters (number of fruits, fresh weight, fruit colour, fruit diameter, soluble solids concentration, titratable acidity, and fruit firmness). For the results, both factors were not significantly interacted in all parameters assessed as well as its single factor. However, in general, some of the parameters with biochar and seaweed showed a tendency to improve stem diameter and fruit quality. In conclusion, regardless of seaweed extract, all substrates can be developed into commercial growth media exclusively for cherry tomatoes as they had comparable growth in term of stem diameter and postharvest quality without causing adverse effects. The best biochar substrate could not be revealed as all the substrates had a similar effect with the control. Meanwhile, seaweed extract had the potential to be commercialized as a foliar biofertilizer, however, the pure solution should be more concentrated.

Keywords: Biochar, foliar fertilizers, growth, fruit quality.

Introduction

Cherry tomatoes have become popular fruit vegetables among the world's communities not only because of their large consumption but also high in nutritional value for health. It is also known as one of the most important vegetables in the world due to its increasing commercial and dietary value, widespread production as well as model for research (Kimura & Sinha, 2008). Ingestion of tomatoes is highly associated with disease risk reduction due to their lycopene content (Collins *et al*., 2022). According to Canene-Adams *et al*. (2005), the risk of inflammatory processes, cancer, and chronic non-communicable disease (CNCD) including cardiovascular diseases (CVD) such as coronary heart disease, hypertension, diabetes, and obesity can be reduced with tomato intake. Thus, improving its agronomic aspect which includes growth medium, and fertilizers are crucial.

In Malaysia, tomato production is concentrated in highland areas such as Cameron Highland and Kundasang. Overall, Kelantan (368 hectares), Cameron Highlands, Pahang (627 hectares), and Sabah (85 hectares) are the main tomato production areas seeing that these locations provide environments and temperatures that are salutary for tomatoes cultivation (Rahim *et al*., 2017). There are several ways in planting tomatoes such as conventional (open system), hydroponics (closed system), and fertigation (drip system using a closed stream aggregate) (Rahim *et al*., 2017). Adding to crop cultivation techniques, a soilless culture system has been used as a tool to save water and fertilizer compared to soil (Fussy & Papenbrock, 2022). Soilless culture is the cultivation of plants in a system without soil in situ (Gruda *et al*., 2016). Soilless cultivation provides an advantage to the grower because water and nutrient supply could be given according to the plants' requirements at the growth stage. Substrates with good performance under local conditions of water quality, low cost, and without pollution effects are recommended to be used as the planting media (Al-Ajmi *et al*., 2009). One of the important factors for plant growth is adequate substrate aeration and managing the microflora in the rhizosphere as well as optimal water and nutrient and holding capacity, exchange of oxygen, carbon dioxide, and ethylene. Soilless cultivation, therefore, aids in sustainable vegetable production along with reduction of soil-related issues (Hussain *et al*., 2014) such as soilborne disease.

Cocopeat is widely used in soilless culture systems to avoid soilborne disease, leaching of mineral nutrients, and reduce pesticide and herbicide. However, cocopeat contains less nutrients and is quite expensive. Thus, combining cocopeat and biochar could be the alternative approaches to reduce cost. Many studies reported that cocopeat combined with other organic matter such as biochar improves the growth of various crops under a soilless culture system. Biochar, the solid product of pyrolysis has been discussed enormously in much research (Gurwick *et al*., 2013). It contains lots of condensed aromatic structures that are decomposition resistant in soil and effectively isolate a portion of the applied carbon for years (Biederman & Harpole, 2012). Biochar can be a good soil condition as it will help to provide carbon sources to the plant without risking the soil's properties. Not only biochar is beneficial, it also can be easily collected as they are initially referred to as 'waste' before being processed and called biochar. Adding to that, biofertilizers such as extract of seaweed also can be a good replacement for chemical fertilizers. Seaweed can be easily obtained and purchased in Terengganu due to its topography near the sea. Seaweed has an abundance of microelements and plant growth regulators such as cytokinin (Benítez García, 2020). Therefore, this study aims at evaluating the impact of different biochar substrates in combination with and without seaweed extract on the growth and quality of cherry tomatoes.

Materials and Methods

Planting Material and Experimental Location

The experiment was conducted under the shade house at the Fertigasi Mega, Kampung Pela, Ajil. The cherry tomato seeds and cocopeat (CP) were purchased from Green World Genetics Sdn. Bhd. and Pertubuhan Peladang Bukit Bayas, Kuala Terengganu, respectively. Meanwhile, the agricultural wastes such as palm kernel shell, walit bird waste, sugarcane bagasse, and coconut shell were obtained from Malaysian Palm Oil Board (MPOB) and local supplier from Kuala Terengganu, respectively. All these agricultural wastes were converted into biochar through pyrolysis techniques. Seaweed was purchased from Pasar Besar Kedai Payang, Kuala Terengganu.

Preparation of Biochar Substrate

Agricultural wastes as above mentioned were sieved and burned through a conventional pyrolysis technique in a modified drum for 24 to 48 hours with estimated temperature, 550°C. Once the agricultural wastes have been completely burned into charcoal, they were placed into polybag based on the assigned treatment.

Preparation of Seaweed Extract

A total of 1 kg of seaweed was cleaned three times thoroughly using tap water to remove all the debris, snail and sand that attached to the seaweed. Once cleaned, seaweed is then air-dried for four to five hours. After that, dried seaweed was cut manually using a knife or scissors into smaller pieces and soaked with distilled water. After soaking, seaweed was blended with its extracted solution using a blender. Then, they were filtered using a filter to separate any solid within the solution. Only seaweed extract was used as a seaweed foliar fertilizer in this research (Pise & Sabale, 2010).

Preparation of Plant Material

Eighty cherry tomato seeds were sown in a seedlings tray containing peat moss as the growth medium. To speed germination, a tray containing seeds was then covered with plastic wrap for two days. As soon as the seedlings break the surface, move them to bright light and water twice a day. After 25 days, the mature seedlings were transferred into polybags (18 cm x 15 cm) containing different growth media. Fertilizers used in this study were type A (ammonia nitrate, potassium sulfate, phosphoric acid, nitric acid, and magnesium nitrate) and type B (calcium nitrate, ammonium nitrate, magnesium nitrate, urea, and potassium nitrate). Irrigation was equipped with a droplet system and scheduled for 5 min per day (1000 mL). Irrigation water filled with fertilizers was applied at every 0800 h and 1700 h per day. The experiment was arranged in the randomized complete block design (RCBD), comprising different combinations of soilless growing media. The experiment was laid out according to the RCBD with two factors viz. (i) different biochar substrates (Palm Kernel Shell, PKS; Sugarcane Bagasse, SB; Coconut Shell, CS; and Walit Bird Waste; WW) and (ii) with (W) and without seaweed (WO) extract. The experimental treatments were (i) cocopeat with seaweed; (ii) cocopeat (C) alone (serve as control); (iii) C and PKS with seaweed; (iv) C and PKS without seaweed; (v) C and SB with seaweed; (vi) C and SB without seaweed; (vii) C and WW with seaweed; (viii) C and WW without seaweed; (ix) C and CS with seaweed; and (x) C and CS without seaweed with four replications. A 200g of biochar substrates were added to the above-assigned treatments. All treatments received similar agricultural practices such as watering, trellising, pruning, and pesticide sprays.

Parameter Evaluations

Preharvest and postharvest parameters were evaluated which includes stem diameter, soluble solids concentration (SSC), titratable acidity (TA), firmness, fruit color, fruit fresh weight, number of fruits, fruit length, and fruit width. Stem diameter was measured once every seven days interval i.e., 0, 7, 14, 21, 28, 35, 42, 49, 56, 63 days after transplanting. The measurement was recorded using digital vernier caliper and set to millimeter (mm) unit. Data taken was set at 5 cm from the ground. Meanwhile, the fruit colour was measured using Konica Minolta CR-400 reflectance colorimeter (Minolta camera Co. Ltd., Japan) according to CIELAB colour parameters: L*, chromaticity a* and chromaticity b* (McGuire, 1992). L* represents the lightness coefficient which ranges from 0 (black) to 100 (white). a* ranges from -60 to +60, in which +60 indicates red colour and -60 indicates green colour. b* also ranges from -60 to +60, but +60 represents yellow colour while -60 represents blue colour. a* and b* were further used to calculate chroma [C* = (a*2+b*2) 1/2] and hue angle (h° = tan-1 b*/a*). Chroma (C*) refers to colour intensity while hue angle represents red-purple (0°), yellow (90°), bluish-green (180°) and blue (270°). Flesh firmness was measured using TA.XT plus texture analyzer (Stable Micro Systems, United Kingdom) and expressed in newton (N). A P/2 probe with 2 mm distance and 0.05 mm sec^{1} test speed were set for firmness determination (Lana *et al*., 2007; Teka, 2013). Soluble solids concentration was determined using a handheld refractometer while titratable acidity was measured using the titration method, expressed as % of malic acid (AOAC, 1994). The number of fruits were recorded by the number of healthy ripe cherry tomato that were freshly harvested from the farm based on their treatments. Fresh weight of harvested cherry tomato was recorded according to its treatment once the fruit was fully ripe. Measurement was taken in grams (g) using electronic balance. Fruit diameter was recorded by measuring the horizontal and longitudinal diameter of the fruit using external caliper which was expressed in mm units. A total of five fruits per treatment were measured to obtain precise data.

Statistical Analysis

The experimental data collected were subjected to the analysis of two-way ANOVA using GLM (General Linear Model) procedures with SAS 9.1 software package, SAS Institute Inc. Cary, NC, USA. Treatment means were further separated by Tukey for at least significance at $p \leq 0.05$ (SAS Institute Inc., 1990).

Results and Discussions

Biochar is a solid organic and stable form of carbon produced via the pyrolysis of biomass. Awad *et al*. (2018) claimed that biochar, being used as soil amendment have a significant effect on soil fertility by altering the chemical, biological and physical characteristics of the soil. On the other hand, seaweed extract was reported to possess plant growth promoting activity and have universal and continuing relevancies in agriculture and horticulture as organic manures and fertilizers. Even at low concentrations, seaweed extract is capable in reducing physiological and plant responses, such as promotion of plant growth, improvement of flowering and yield as well as enhancing the quality of products, improved nutritional content, and shelf life (Battacharyya *et al*., 2015). In the present study, there was no interaction between the two factors for the stem diameter, fresh weight and fruit number, fruit length and width, and the postharvest parameters such as fruit color, soluble solid concentration (SSC), and titratable acidity (TA).

As shown in Figure 1(A), even though no the apparent effect was observed between the two factors, plants treated with PKS tend to show bigger stem diameter on day 70 compared to the control. Similarly, Graber *et al.* (2010) claimed that combination of biochar with coconut fiber and tuff may increase the plant height and leaf size in tomatoes. Additionally, Ain Najwa *et al*. (2014) stated that combinations of cocopeat with biochar substrates increased the stem diameter, fruit number, and fresh weight of cherry tomatoes. Interestingly, seaweed application as foliar fertilizer had the potential in improving plant stem diameter as exhibited at day 70 (Figure 1B). According to Mattner *et al*. (2013), seaweed extract can positively affect stem diameter, leaf area, and biomass and enhance the early growth of broccoli. Adding to that, Osman and Abd El-Gawad (2014) also obtained an increment in stem diameter and yield when seaweed extract was used as the treatment for eggplant. Seaweed extract contains components that will affect plants' metabolism towards crop yield and growth enhancement like macro- and microelement nutrients, amino acids, vitamins, complex polysaccharides, cytokinins, auxins, and auxin-like compounds, and abscisic acid (ABA)-like growth substances (Mohamad *et al*., 2021). Plant growth regulators (PGRs) coordinate cell division and differentiation in plant cells although the exact mechanism between chemical components of seaweed extract is not well-known.

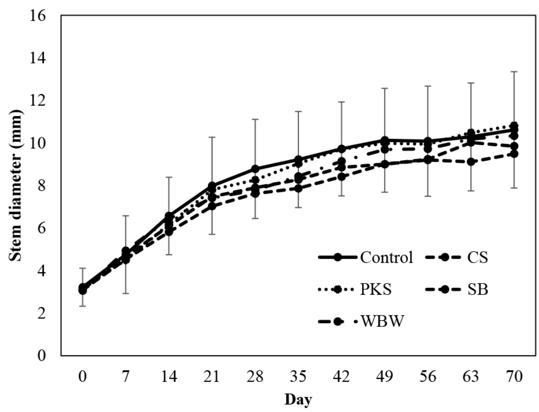

Figure 1(A): Effect of different biochar substrates on stem diameter of cherry tomato plant. Vertical bars represent HSD at 5% level. (CS: Coconut shell, PKS: Palm kernel shell, SB: Sugarcane bagasse, WBW: Walit bird waste)

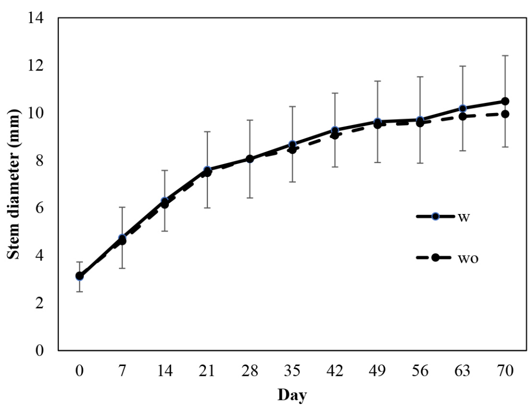

Figure 1(B): Effect of seaweed foliar fertilizer on stem diameter of cherry tomato plant. Vertical bars represent HSD at 5% level. (w: with seaweed application, wo: without seaweed application)

As depicted in Table 1, control plants had better results in the number of fruits, fresh weight as well as fruit length and width. Like Wan Zaliha and Anwaruddin (2017) and Ain Najwa *et al*. (2014), the results of this study showed that different types of biochar did not affect the yield and weight of cherry tomatoes. Biochar can improve soil fertility, but an extreme repercussion of fruit yield reduction might happen under very abundance of fertilization as the soil fertility can affect the balance between vegetative and reproductive growth of tomatoes (Guo *et al*., 2021). However, CS treated plant has almost similar reading for fruit number as observed in the control. According to Mohammad Hariz *et al*. (2015), CS possesses smaller pores on its surface, providing a higher surface area. This characteristic, perhaps, contributed to the difference in nutrient and water holding capacity of the compound. The presence of small pores on the surface of coconut shell biochar may act as the nitrogen (N) binding site, consequently, enhancing its capacity to retain N. Nitrogen has a notable involvement in creating energy for plant growth and fruit production through photosynthesis.

In addition, biochar had been reported to enhance the yield of rice by 146% in the presence of NPK (Zhang *et al*., 2010) and double the yield of maize (Kimetu *et al*., 2008). Seaweed applications affected the fruit number, fresh weight, and fruit diameter where they tend to show higher values than without seaweed. Yao *et al*. (2020) claimed that a maximum of 4.7% significant increase in tomato yield using seaweed extract and an improved yield and concentration of calcium (Ca), potassium (K), and magnesium (Mg) in the leaf of lettuce, respectively. The increase in yield may be related to PGRs in seaweed extract, mainly cytokinin (Khan *et al*., 2009) which play a vital role in promoting nutrient mobilization and triggering fruit set. Adding to that, seaweed extract has been published to increase root length of tomato, improve nutrients uptake, and boost the yield.

Table 1: The effects of different biochar substrates in combination with and without seaweed-based foliar fertilizer on fresh weight, number of fruits, fruit length, and fruit width

Treatments	**Number of Fruits**	**Fresh Weight (g)**	**Fruit Length (mm)**	**Fruit Width (mm)**
<u>Biochar (B)</u>				
Control	96.13[a]	333[a]	34.20[a]	23.96[a]
PKS	69.37[a]	256[a]	33.35[a]	23.21[a]
SB	54.50[a]	179[a]	32.69[a]	22.78[a]
WW	68.33[a]	226[a]	33.15[a]	22.62[a]
CS	93.50[a]	273[a]	33.79[a]	22.43[a]
HSD B ≤0.05	1.39[ns]	1.75[ns]	1.29[ns]	0.97[ns]
<u>Seaweed (S)</u>				
w	81[a]	259[a]	33.58[a]	23.37[a]
wo	71[a]	250[a]	33.34[a]	22.63[a]
HSD S ≤0.05	0.50[ns]	0.09[ns]	0.16[ns]	1.22[ns]
HSD≤0.05 B*S	0.49[ns]	0.51[ns]	1.40[ns]	0.65[ns]
Replicate	5.11***	4.68***	4.72**	1.66[ns]

[ns] means not significant at HSD $p \geq 0.05$. ** means very significant ($p \leq 0.05$) and *** means highly significant ($p \leq 0.01$).

Color plays a crucial part in the total appearance of fruit and its acceptance in the market. Ain Najwa *et al*. (2014) claimed that a reduction in h°, L*, b* and high a* indicated more saturated red on the fruit skin. As shown in Table 2, PKS seemed to achieve a better result for L* and h° followed by WW for a*, b* and C*. In contrast, CS displayed lower values of L*, a*, b* and C*. Ain Najwa *et al*. (2014) reported that the development of cherry tomato fruit color was enhanced with the application of cocopeat and biochar. Christou *et al*. (2022) also reported that biochar can highly influence and increase all photosynthetic (chlorophyll a, chlorophyll b and total chlorophyll) and accessory pigments (anthocyanin, carotenoids, and lycopene) of tomato. It is possible that an increase in tomato lycopene content results in redder fruit colour. Seaweed has been reported to increase the chlorophyll content due to the biogenesis of chloroplast, chlorophyll degradation, and senescence delay (Espinosa-Antón *et al*., 2023).

Table 2: The effects of different biochar substrates in combination with and without seaweed-based foliar fertilizer on lightness (L*), chromacity value a*, b*, C*, and hue angle (h°)

Treatments	Lightness (L*)	Chromacity Value a*	Chromacity Value b*	Chroma (C*)	Hue Angle (h°)
Biochar (B)					
Control	42.50[a]	28.70[a]	28.99[a]	40.80[a]	45.30[a]
PKS	43.23[a]	26.77[a]	28.98[a]	39.50[a]	47.16[a]
SB	43.16[a]	26.33[a]	27.61[a]	38.17[a]	46.33[a]
WW	42.73[a]	29.51[a]	30.38[a]	42.39[a]	45.87[a]
CS	42.23[a]	25.75[a]	27.09[a]	37.47[a]	46.55[a]
HSD B ≤0.05	3.64**	1.16[ns]	0.50[ns]	0.82[ns]	0.51[ns]
Seaweed (S)					
w	42.65[a]	26.63[a]	26.97[a]	37.94[a]	45.35[a]
wo	42.83[a]	27.93[a]	29.97[a]	41.02[a]	47.12[a]
HSD S ≤0.05	0.60[ns]	1.64[ns]	4.79**	3.39[ns]	2.91[ns]
HSD≤0.05 B*S	0.96[ns]	2.26[ns]	0.23[ns]	0.96[ns]	3.06**
Replicate	2.18[ns]	0.37[ns]	0.55[ns]	0.40[ns]	0.79[ns]

[ns] means not significant ($p \geq 0.05$). ** means very significant ($p \leq 0.05$) and *** means highly significant ($p \leq 0.01$).

From Table 3, Although, no apparent effect was observed in all SSC, TA, and fruit firmness, cherry tomatoes fruit treated with CS and WW tend to show high value as compared to other types of biochar. Akhtar *et al*. (2014) noted that biochar significantly increased TA in tomatoes under reduced irrigation. Meanwhile, Yao *et al*. (2020) reported a significant increase in SSC in tomatoes when treated with seaweed extract. Hence, a better flavor and taste can be achieved as the sugar/acid ratio increases.

Table 3: The effects of different biochar substrates in combination with and without seaweed-based foliar fertilizer on soluble solid concentration, titratable acidity, and fruit firmness

Treatments	Soluble Solid Concentration (% brix)	Titratable Acidity (% malic acid)	Fruit Firmness (N)
Biochar (B)			
Control	6.14[a]	0.62[a]	4.25[a]
PKS	6.15[a]	0.58[a]	4.34[a]
SB	6.17[a]	0.56[a]	4.08[a]
WW	6.60[a]	0.65[a]	3.98[a]
CS	6.61[a]	0.68[a]	4.24[a]
HSD B ≤0.05	1.19[ns]	0.90[ns]	0.60[ns]
Seaweed (S)			
w	6.37[a]	0.58[a]	4.08[a]
wo	6.28[a]	0.65[a]	4.32[a]

HSD S ≤ 0.05	0.08[ns]	2.26[ns]	3.52[ns]
HSD ≤ 0.05 B*S	0.15[ns]	0.74[ns]	1.19[ns]
Replicate	1.76[ns]	0.35[ns]	1.40[ns]

[ns] means not significant ($p \geq 0.05$). ** means very significant ($p \leq 0.05$) and *** means highly significant ($p \leq 0.01$).

Conclusion

Different biochar substrates such as palm kernel shell, sugarcane bagasse, walit bird waste, and coconut shell have been used widely in agricultural research and industries. The use of these substrates in combination with seaweed extract had the ability to show a promising effect on the growth performances and quality of lowland cherry tomatoes. Additionally, biochar and seaweed tend to show positive performances for both plants and their fruit. Biochar can be used as a newly developed media as the use of cocopeat with various biochar, substrates can replace the use of cocopeat alone. On the other hand, seaweed extract may favor the growth of the plant stem diameter as well as fruit yield. However, this experiment still requires further research on the application of higher concentrations of seaweed extract as foliar fertilizer and its effect on plant growth and postharvest qualities. In addition, the utilization of biochar and seaweed extract as postharvest treatments for fruits might add a significant discovery in the future.

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