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Effect of Co-application of Different Biochars and Inorganic Fertilizers on the Growth and Yield of Okra (*Abelmoschus esculentus* L.) in sandy soil

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Abstract: To manage necessary amount of food for the growing world population, it is very important to maintain fertility of usual arable land as well as to bring problem soils including sandy soil under coverage of regular crop cultivation. In this context, biochar is a very promising option as soil conditioner and therefore, a plant growth trial in pot was operated at the net house of the Department of Agroforestry and Environmental Science, Sylhet Agricultural University, Sylhet to evaluate the influence of tea waste and sugarcane bagasse biochar on the morphology, yield and yield contributing traits of okra (*Abelmoschus esculentus*) in sandy soil. The experimental set-up was arranged following randomized complete block design with three replications under eight treatments. The treatments were: T_0 (CK, Control, no amendment), T_1 (CF, Chemical fertilizers), T_2 (2.5 % TWB (tea waste biochar) + CF), T_3 (5% TWB + CF), T_4 (10% TWB + CF), T_5 (2.5% SBB (sugarcane Bagasse biochar) + CF), T_6 (5% SBB + CF); and T_7 (10% SBB + CF). The results revealed that the different morphological characteristics like plant height (PH), number of leaf plant^{-1} (NLP), leaf length (LL), plant fresh weight (PFW), and stem diameter (SD) showed no significant difference among the treatments. The highest PH (107.33 cm) and RL (70.67 cm) were found in T_0 (CK) whereas the maximum LL (27.33 cm), SD (16.83 mm), and fresh root weight (FRW) (19.67g) were noted in T_3. The maximum number of leaves plant^{-1} (NLP) (20) and PFW (110.67 g) of okra were observed in T_2 and T_6, respectively. In case of total leaf chlorophyll content (TLCC), the maximum value was determined in T_4 (47 µmol m^{-2}), but the treatments were not significantly different from each other. The number of pod plant^{-1} (NPP) (23.7), pod length (PL) (18 cm), individual pod weight (IPW) (18 g), number of seed pod^{-1} (NSP) (45) and pod weight per plant^{-1} (PWP)(425 g) of okra were found to be highest in $T_{7,}$ followed by T_4 and T_6. The yield and yield contributing characters of okra showed significantly higher value for biochar treatments (T_2 - T_7) over to the control (T_0) and sole chemical fertilizer treatment (T_1). After the cultivation of okra, the highest pH value (7.2) was found in T_7, followed by T_6. The results of this study might contribute to enlarge the prospects of biochar application in the production of okra and other crops in both normal and less fertile soils.

Keywords: Tea waste; Sugarcane bagasse biochar; Soil conditioner; *Abelmoschus esculentus*; Plant growth and Yield; Sandy soil.

INTRODUCTION

Food insecurity and malnourishment have amplified intensely with the explicative growth in world human population (Pretty and Hine, 2001) and this population is projected to attain 960 crores by the year 2050 (U.N. Population Division, 2013). Key factor of food insecurity is the inadequate crop production due to soil infertility and degradation (Adaikwu *et al*., 2012). Approximately 43% of the entire land area of Bangladesh is affected by degradation in varying forms and grades. As being a vital part of degradation process, sandification of soil is a momentous matter owing to the growing rate of around 50,000 to 70,000 km^2 of area per year, and the predicted financial loss is around 42000 million USD (UNEP, 1997). In Bangladesh, most of the sandy soils typically occur in its northern region (FAO-UNDP, 1988). The sandy soils are particularly characterized by poor content of soil nutrients and organic carbon, low pH, and less water retention capacity (Laghari *et al*., 2015). To meet the challenge of producing enough crops to feed the huge population, we cannot help using synthetic fertilizers. Moreover, in case of less fertile soil chemical fertilizers are being used in high doses to retrieve required nutrient status to ensure desirable yield. But, if the lone application of inorganic fertilizers into crop fields continuous, eventually it degrades soil and decreases crop production accordingly. With the increasing environmental consciousness, the lone reliance on synthetic input-based crop cultivation is being shifted to method involving combined use of both organic and synthetic fertilizers, specifically in soils with poor fertility (Pan *et al*., 2018).

In recent times, biochar has been emerged as a promising soil conditioner that has the potential to challenge the growing need for more crop production (Ahmad *et al*., 2014). Biochar is carbon-rich material prepared by pyrolysing organic substances in less or oxygen-free ambiance at high temperature (Magnusson, 2015; Guo, 2020). Being recalcitrant in nature, biochar is capable to be a long-lasting organic source of carbon and other nutrients to soil (Spokas, 2010). Greater surface functionality and high porosity allow biochar to trap available soil nutrients and prevent nutrients to be leached out of the soil (Laird *et al*., 2010). Additionally, it has been established that by increasing the content of moisture, ventilation and the C/N ratio of the soil, biochar can build a suitable environment for microbial growth and activity (Lehmann and Joseph, 2015). In general, biochar is basic in reaction and thus can play effective role in attenuating acidity of soil and ensure favorable soil pH for better crop production (Randolph *et al*., 2017). Thus, biochar could be a promising option for improving soil health to support crop production especially in the problem soils.

Type and quality of biochar can be different depending on the pyrolysis temperature and raw material used. Tea is very popular as a beverage in the world, derived from the leaves of *Camellia sinensis* L. China is the global leader in tea production followed by India, Kenya, Sri Lanka, Vietnam, Turkey and Indonesia. Yearly tea production of Bangladesh is around 97 million kg (almost 2% of global production) from 172 commercial tea gardens (BTB, 2020). Consequently, a huge amount of tea wastes are being generated every day. Similarly, numerous sugar milling industries around the world release bagasse in huge amount as one of the byproducts. Mahamud *et al*. (2012) reported that sugarcane cultivation covers around 425,000 acres of land in Bangladesh producing about 7.5 million tons annually. While processing of sugarcane, along with sugar and molasses approximately 800,000 tons of bagasse is being generated every year. Unfortunately, most of the tea waste and sugarcane bagasse are disposed into environment unwisely causing emission of harmful greenhouse gases like CH_4 and CO_2. Both the tea waste and sugarcane bagasse are representing potential feedstock to be converted into biochar and can be used in crop production to improve yield as well as to increase soil fertility. To confirm a healthy fate of continuously producing organic residues as well as to increase soil fertility and crop yield in problem soils, maximum studies have targeted on crop straw or organic manure-derived biochars as soil amendments. In this context, it is very important to assess the impact of tea wastes and sugarcane bagasse biochar on growth and yield of popular crops and sandy soil properties.

Okra (*Abelmoschus esculentus* L.), member of Malvaceae family, is a high-value summer vegetable crop. It is known to be originated from Africa, but afterwards generalized in maximum portions of other continents of the world. Okra is widely consumed for is high nutritional and medicinal value since being rich in carbohydrate, protein, vitamins (A, B and C), minerals including Fe, Ca, K, Mg and I (Lee *et al.*, 2000) and some healthy fatty acids (Asare *et al*. 2016). According to BBS (2013), in the year 2012-2013, okra production in Bangladesh land area under okra cultivation was 26000 acres producing around 44000 metric tons okra with an approximate average yield of 4.6 t ha^{-1}, which is much lower in comparison to the yield (7-12 t ha^{-1}) in the top okra producing countries.

Keeping in mind the above issues, a pot trial was conducted with the under-mentioned goals to make available the information on the performance of tea waste biochar (TWB) and sugarcane bagasse biochar (SBB) in combination with inorganic fertilizers on okra (*A. esculentus*) production under sandy soil.

i) To quantify the influence of joint application of biochar (TWB and SBB) amendments and inorganic fertilizers on okra growth parameters.

ii) To evaluate the impacts of applied biochar treatments on yield and yield contributing indexes of okra.

MATERIALS AND METHODS

Experimental site and climatic attributes

The pot experiment was done at the net house and respective sample analysis was done at the laboratory of the Department of Agroforestry and Environmental Science, Sylhet Agricultural University, Sylhet during the period from the end of April 2021 to September 2022. Being under sub-tropical zone, this territory experiences heavy precipitation ranging from 246-968 mm $month^{-1}$ and high average temperature > 30°C during May - September whereas from October-April low precipitation occurs within the range from 0-22 mm $month^{-1}$ and mean temperature remains < 28°C.

Soil collection and Biochar preparation

Sandy soil was collected from riverbank area of Badhaghat, Sylhet. Primarilly soil samples were collected from different fifty (50) points (at 0-20 cm depth) of the collection site and the sub-samples were brought to the lab putting into separate 50 plastic sacks. Then the sub-samples were thoroughly mixed to prepare a composite sample and separated all the unwanted materials (plant debris, gravels, brick pieces etc.) followed by air-drying for one week. Tea wastes and sugarcane bagasse were collected from local tea stalls and sugarcane juice shops of Sylhet city, respectively.

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Collected biochar feedstocks were carried to the lab followed by air-drying (for one week) and oven-drying (at 45±2 ^{0}C for 72 hours). The oven-dried raw materials were pyrolised separately using a traditional biochar Kiln. Prepared tea waste biochar (TWB), sugarcane bagasse biochar (SBB) and some soil were then crushed and passed through 2 mm mesh sieve for further pot trial and lab analysis. Some basic physico-chemical characteristics of sandy soil, TWB and SSB were tested (Table 1).

Table 1. Basic characteristics of sandy soil, TWB and SBB.

Material	pH	Total Organic C (%)	Total N (%)	Available P (ppm)	Exchangable K (ppm)
Sandy soil	5.7	0.199	0.017	5.7	74.29
TWB	8.4	12.96	1.118	294.9	4301.0
SBB	8.8	11.97	1.032	530	2267.8

Experimental design and treatments for pot experiment

The pot trial was carried out in a randomized complete block design with three replications at the net house of the respective department. Eight (08) treatments for growing okra included as: (1) T_0 (CK- Control, no amendment), (2) T_1 (CF- Chemical fertilizers), (3) T_2 (2.5 % TWB + CF), (4) T_3 (5% TWB + CF), (5) T_4 (10% TWB + CF), (6) T_5 (2.5% SBB + CF), (7) T_6 (5% SBB + CF); and (8) T_7 (10% SBB + CF). The treatments were denoted as T_0, T_1, T_2, T_3, T_4, T_5, T_6 and T_7. Seven (7) kg of sandy soil and required amount of selected biochar were mixed to prepare pots. Urea, TSP, MP were applied in all treatment pots except the control (CK) pots at the rate of 150, 100 and 150 kg ha^{-1}, respectively. The total of the required TSP, ½ urea and MP were used at the time of during soil preparation in treatment pots excluding T_0. The rest of the ½ urea and MP was applied in three installments after 25, 35 and 65 days of seed sowing (BARC, 2018). Three (03) seeds of BARI Dherosh-1 were sown in each pot on 24 April 2022 by hand dibbling method at a depth of 4-5 cm and finally one healthy seedling were allowed to grow till the end. Before sowing, seeds were treated with Captain at the rate of 3g kg^{-1} seed. Tea waste and sugarcane bagasse biochars were applied in selected treatments at required doses. Polythene sheds were prepared to protect the seedlings from heavy rainfall. Mulching, weeding, irrigation etc. were done as and when necessary. Approximately 136 days after seed sowing, plants were uprooted and taken to lab for further data collection.

Measurement of growth and yield traits of okra

During growing period and harvesting time of okra, different growth indexes including plant height (PH), number of leaves plant^{-1} (NLP), leaf length (LL), plant fresh weight (PFW), stem diameter (SD), root length (RL), fresh root weight (FRW); and yield parameters such as pod length (PL), individual pod weight (IPW), pod diameter (PD), number of seed pod^{-1} (NSP), number of pod plant^{-1} (NPP), pod weight plant^{-1} (PWP) were recorded very carefully. The young non-fibrous pods were harvested several times throughout the whole growing period. The average yield as PWP by accumulating the weight of total number of pods collected from each single plant grown in each pot. PH, LL, RL and PL were measured using a measuring tape while weighing PFW, FRW, IPW and PWP was done by using digital balance. Measurement of SD and PD were taken using a digital vernier caliper whereas NLP, NSP, NPP was also recorded after being counted. Total leaf chlorophyll content (TLCC) (µmol m^{-2}) was detected using chlorophyll meter (SPAD-502).

Analysis of soil physico-chemical characteristics

Initial soil and biochar samples were subjected to lab analysis for pH, total organic carbon (TOC) %, total Nitrogen (TN) %, available phosphorus (AP) and exchangeable potassium (EK). Collected post-harvest soil samples were also analyzed for pH. pH of Soil samples (1:5 H_2O w/v) and biochars (1:10 H_2O w/v) was determined using pH meter. TOC (%) was quantified following the method adopted by Ahmod, *et al.* (2023). TN was measured using the Kjeldahl method (Soil Management Directorate, 2017), whereas AP and EK were estimated using the protocol developed by Murphy and Riley (1962) and Knudsen *et al.* (1983), respectively.

Statistical Analyses

All experimental data were subjected to One-way ANOVA using GraphPad Prism software (version 8.00, La Jolla, CA, USA). The treatment mean values were separated by the Tukey's HSD (honest significant difference) test performed at a 5% level of significance.

RESULTS

Effects of TWB and SBB on the morphological parameters of okra

Plant height (PH)

The highest PH of okra (107.33 cm) was recorded in treatment T_0 (Control), followed by T_6 (5% SBB + CF). The lowest height (81.33 cm) was found in T_5 (2.5% SBB + CF) (Table 2). Recorded data of PH of okra in the treatments were not significantly different.

Number of leaf plant^{-1} (NLP)

In the case of NLP, the maximum number of the leaves (20) was found in T_2 (2.5% TWB + CF), followed by the next value (19) in T_3 (5% TWB + CF) (Table 2). NLP values in the treatments were non-significant from each other.

Leaf length (LL)

The LL of okra was found to be highest (27.33 cm) in T_3 (5% TWB + CF) followed by T_2 (2.5% TWB + CF) (Table

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2). Regarding the LL, there was no discernible change between the treatments.

Plant fresh weight (PFW)

The highest PFW (110.67g) of okra plant was recorded in T_6 (5% SBB + CF), followed by T_7 (10% SBB + CF) (Table 2). Significant difference was absent among the treatments in case of PFW of okra.

Stem diameter (SD)

The highest SD (16.83 mm) was found in T_3 (5% TWB + CF), followed by treatment T_6 (5% SBB + CF) and the lowest SD (10.38 mm) was found in T_5 (2.5% SBB + CF) (Table 3). The SD of okra in all the biochar treatments (T_2-T_7) was not significantly different from the control.

Root length (RL)

The RL of okra was found to be significantly higher in T_0 (Control -Without fertilizer and biochar) and treatment T_1 (Chemical fertilizer dose) compared to T_5 (2.5% SBB + CF), where the RL was found to be lowest (Table 3). No significant differences were found among T_1, T_2, T_3, T_4, T_6 and T_7 treatments.

Fresh root weight (FRW)

The highest (FRW) (19.67g) of okra was recorded in T_3 (5% TWB + CF), which was significantly greater than the smallest FRW value (6.67g) found in T_5 (2.5% SBB + CF) followed by treatment T_7 (10% SBB + CF) (8 g) (Table 3). FRW values in the other treatments were not significantly different.

Total leaf chlorophyll content (TLCC)

The maximum chlorophyll content (47 µmol m^{-2}) of leaf was recorded when 10% TWB and CF (T_4) were applied to the soil, followed by applying 10% SBB and CF (T_7). The lowest chlorophyll content (47 µmol m^{-2}) was measured in the control treatment (T_0), as expected (Table 3). But no significant difference was found among the applied treatments.

Table 2. Effects of TWB and SBB on PH (cm), NLP, LL (cm), PFW (g) of okra.

Crop	Treatment	PH (cm)	NLP	LL (cm)	PFW (g)
Okra	T_0	107.33±21.13^a	15.33±3.06^a	20.33±0.58^a	89.67±28.29^a
	T_1	88.00±8.19^a	17.00±4.00^a	20.67±4.93^a	76.33±33.56^a
	T_2	82.33±8.14^a	20.00±7.94^a	22.00±3.61^a	75.33±27.97^a
	T_3	90.00±32.14^a	19.33±4.93^a	27.33±2.52^a	94.33±43.89^a
	T_4	81.67±6.51^a	18.67±6.43^a	19.33±6.66^a	83.00±40.26^a
	T_5	81.33±19.66^a	14.67±6.51^a	21.33±2.08^a	90.33±33.26^a
	T_6	104.33±9.71^a	13.67±4.73^a	21.33±10.21^a	110.67±28.45^a
	T_7	100.33±18.45^a	17.00±6.04^a	16.67±1.15^a	105.33±25.93^a

* Mean values bearing same letters are not significantly different. Mean values (± standard deviation) in the same followed by the different letters are significantly different from each other by the Tukey's HSD test at the 5% probability level ($p \leq 0.05$). *T_0 (CK, Control, no amendment), T_1 (CF, Chemical fertilizers), T_2 (2.5 % TWB (Tea waste biochar) + CF), T_3 (5% TWB + CF), T_4 (10% TWB + CF), T_5 (2.5% SBB (Sugarcane Bagasse biochar) + CF), T_6 (5% SBB + CF); and T_7 (10% SBB + CF).

Table 3. Effects of TWB and SBB on PFW (g), PD (mm), RL (cm), FRW (g) and TLCC (µmol m^{-2}) of okra.

Crop	Treatment	SD (mm)	RL (cm)	FRW (g)	TLCC (µmol m^{-2})
Okra	T_0	12.33±2.81^a	70.67±12.70^a	9.33±3.06^{ab}	38.08±4.69^a
	T_1	11.17±1.96^a	60.00±24.98^{ab}	11.00±4.58^{ab}	41.27±6.71^a
	T_2	12.30±1.05^a	56.33±5.51^{ab}	13.67±3.06^{ab}	42.59±7.42^a
	T_3	16.83±2.18^a	50.00±1.00^{ab}	19.67±3.06^a	46.18±1.51^a
	T_4	10.92±2.11^a	30.33±8.74^{ab}	10.00±5.00^{ab}	47.00±7.22^a
	T_5	10.38±2.01^a	22.33±6.66^b	6.67±2.89^b	43.69±6.61^a
	T_6	14.60±4.43^a	55.67±21.13^{ab}	11.67±6.51^{ab}	45.58±2.90^a
	T_7	13.25±1.58^a	53.00±19.08^{ab}	8.00±2.65^b	46.91±2.25^a

* Mean values bearing same letters are not significantly different. Mean values (± standard deviation) in the same followed by the different letters are significantly different from each other by the Tukey's HSD test at the 5% probability level ($p \leq 0.05$). *T_0 (CK, Control, no amendment), T_1 (CF, Chemical fertilizers), T_2 (2.5 % TWB (Tea waste biochar) + CF), T_3 (5% TWB + CF), T_4 (10% TWB + CF), T_5 (2.5% SBB (Sugarcane Bagasse biochar) + CF), T_6 (5% SBB + CF); and T_7 (10% SBB + CF).

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Impacts of TWB and SBB on the yield and yield contributing traits of okra

Number of pod/plant^{-1} (NPP)

The highest NPP (≈23) was recorded in T_7 (10% SBB + CF), which was significantly higher than the lowest NPP (15) found in T_1 (CF) (Table 4).

Pod length (PL)

In the case of PL, the maximum value (18 cm) was found in T_7 (10% SBB + CF), which was significantly greater than the minimum value recorded (5 cm) in T_0 (CK) followed by the next value (6 cm) in T_2 (2.5 % TWB) (Table 4).

Individual pod weight (IPW)

The largest IPW (18 g) was noted in T_7 (10% SBB + CF) compared to T_2 (6.33g) (2.5 % TWB), followed by both the T_1 (CF) and T_0 (CK). There was no significant difference among T_3, T_4, T_5 and T_6 treatments (Table 4).

Pod diameter (PD)

The maximum PD (20.75mm) was measured in T_5 (2.5% SBB + CF); and the minimum (8.55mm) was noted in T_0 (CK), which showed significant difference from all other treatments (Table 4).

Number of seeds pod^{-1} (NSP)

In T_7 (10% SBB + CF), the largest NSP (45) was counted, followed by T_6 (40) and T_4 (40). The smallest number of NSP (6) was noted in T_0 (CK), which was significantly different from all other treatments (Table 4).

Pod weight plant^{-1} (PWP)

The highest PWP (425g) was found in T_7 (10% SBB + CF), significantly different from all other treatments. The lowest value (105.7g) was recorded in T_2 (2.5 % TWB + CF), followed by T_1 (CF) (108.3g) and T_0 (CK) (118.3g) (Table 4).

Table 4. Effects of TWB and SBB on the yield and yield contributing characters of okra.

Crop	Treatment	NPP	PL (cm)	IPW (g)	PD (mm)	NSP	PWP (g)
Okra	T_0	17.00 ± 2.00^{bc}	5 ± 2.0^{d}	7.00 ± 0.50^{c}	8.55 ± 1.53^{c}	6.67 ± 3.06^{e}	118.3 ± 5.53^{d}
	T_1	15.33 ± 1.53^{c}	7 ± 0.0^{cd}	7.00 ± 1.00^{c}	16.85 ± 0.77^{b}	10 ± 2.65^{de}	108.3 ± 26.16^{d}
	T_2	16.67 ± 0.58^{bc}	6 ± 1.0^{d}	6.33 ± 1.04^{c}	16.35 ± 1.00^{b}	19 ± 2.00^{cd}	105.7 ± 18.95^{d}
	T_3	17.33 ± 0.58^{bc}	11 ± 1.0^{bc}	11.00 ± 2.00^{b}	17.0 ± 0.00^{b}	38 ± 6.08^{ab}	190.0 ± 29.61^{cd}
	T_4	21.67 ± 2.89^{ab}	14 ± 2.0^{ab}	14.00 ± 1.00^{b}	15.35 ± 0.65^{b}	40 ± 2.65^{a}	301.7 ± 22.55^{b}
	T_5	18.00 ± 2.65^{abc}	11 ± 0.0^{bc}	11.00 ± 2.00^{b}	20.75 ± 2.12^{a}	29 ± 3.46^{bc}	197.3 ± 40.08^{cd}
	T_6	19.00 ± 2.00^{abc}	14 ± 2.6^{ab}	14.00 ± 0.50^{b}	17.2 ± 2.13^{ab}	40 ± 2.65^{a}	266.3 ± 34.32^{bc}
	T_7	23.67 ± 3.51^{a}	18 ± 1.0^{a}	18.00 ± 1.00^{a}	17.7 ± 0.43^{ab}	45 ± 4.58^{a}	425.0 ± 56.31^{a}

* Mean values bearing same letters are not significantly different. Mean values (± standard deviation) in the same followed by the different letters are significantly different from each other by the Tukey's HSD test at the 5% probability level ($p \leq 0.05$). *T_0 (CK, Control, no amendment), T_1 (CF, Chemical fertilizers), T_2 (2.5 % TWB (Tea waste biochar) + CF), T_3 (5% TWB + CF), T_4 (10% TWB + CF), T_5 (2.5% SBB (Sugarcane Bagasse biochar) + CF), T_6 (5% SBB + CF); and T_7 (10% SBB + CF).

Influence of TWB and SBB on soil pH

The soil pH value was significantly affected by various treatments. After the cultivation of okra, the highest pH value (7.2) was found in T_7 (10% SBB + CF), followed by treatment T_6 (5% SBB + CF) and T_1 (CK) and no significant difference was found between these treatments (Figure 1). The lowest soil pH value (5.2) was found in T_2 (2.5 % TWB + CF) (Figure 1), and it showed a significantly lower value compared to other treatments.

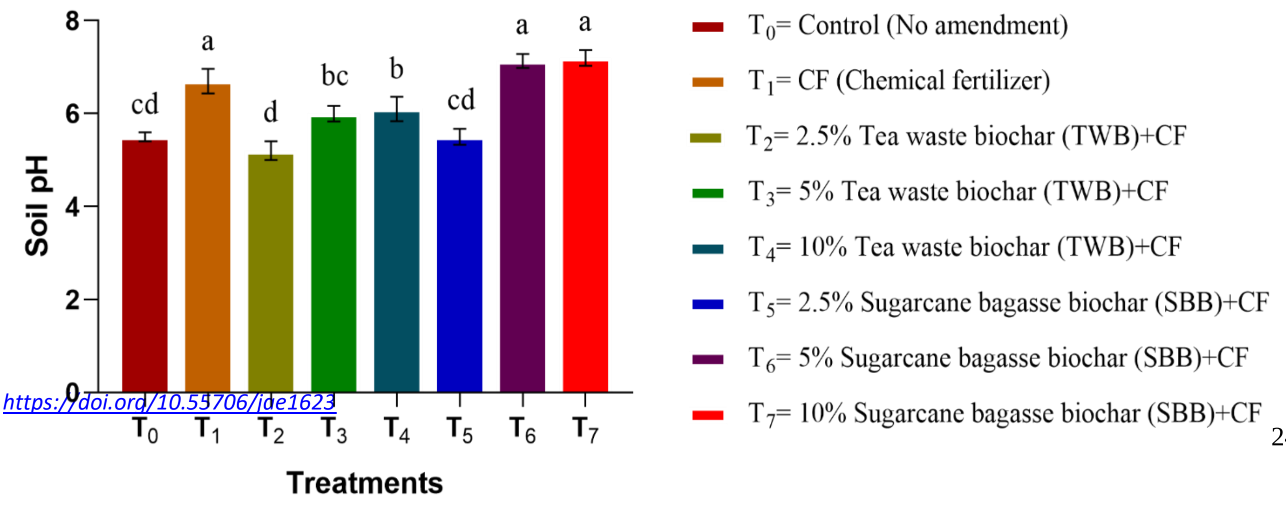

Figure 1. Effects of TWB and SBB on soil pH. *Same letters indicate no significant differences among mean values. Mean values (± standard deviation) in the same followed by the different letters are significantly different from each other by the Tukey's HSD test at the 5% probability level ($p \leq 0.05$).

DISCUSSION

As we observed in our experiment, except RL and FRW, other growth indexes parameters showed non-significant differences among the treatments. But in all measured characters, improvement occurred after applying different treatments comprising biochar and synthetic fertilizers especially in treatments having higher biochar levels. These results are supported by many previous researches where positive effects on okra growth traits were reported (Onwuka and Nwangwu, 2016; Adamu and Junaidu, 2021; Reddy, *et al*., 2022; Oluleye, *et al*., 2023). Interestingly, both the PH and RL were found to be the highest (107.33 cm and 70.67 cm, respectively) in T_0 (CK, no amandment). This is might be due to the poor nutrient content and water holding capacity which triggered plant to extend root for searching necessary water and nutrients. Although biochar treatments in combination with fertilizers could not affect significantly in morphological parameters, expected positive results were obtained in yield and yield contributing indexes. Okra yield and all the yield contributing characters were positively affected by the applied biochar plus chemical fertilizer treatments. And particularly, treatments having the highest level of biochars showed significant improvement over both the T_0 (control) and T_1 (only chemical fertilizer). Findings of Many other studies also reported significant increase in yield and yield related parameters of okra after application of various biochars at different levels that corroborates to our results (Yakubu, *et al*., E. 2020; Dimande, *et al*., 2023; Acharya, *et al*., 2023). Correlating to yield and yield indexes, soil pH was also positively influenced by biochar treatments. Being basic in nature biochar can positively alter soil pH and it has been proved by many study results. Corroborating to previous findings (Smebye *et al*., 2016 and Si *et al*., 2018; Sial, *et al*., 2019; Dimande, *et al*., 2023), we also observed that both TWB and SSB applied at 5% and 10% caused significant amplification in soil pH. Altered pH might have facilitated nutrient availability in soil and caused better yield of okra in biochar plus fertilizer treatments (Artiola *et al*. 2012).

CONCLUSION

The current study revealed that application of TWB and SBB did not pose significant effect on different growth traits of okra including PH, NLP, LL, PFW, SD, RL, FRW and TLCC. Significant effects of TWB and SBB application were observed on the yield and yield contributing characteristics of okra. The NPP (23.7), PL (18 cm), IPW (18 g), NSP (45) and PWP (425 g) of okra were found to be highest in T_7, followed by T_4 and T_6. Similarly, the soil pH was significantly affected by the application of biochar treatments particularly T_6 and T_7 in comparison to T_0 (control) and T_1 (Only chemical fertilizer). Therefore, the findings will encourage the crop growers to use the biochar combined with chemical fertilizers to enhance crop production in sandy soils. Moreover, these findings will also lead to making the commercial production of biochar to be used as an agricultural input, for better carbon source and carbon sequestrations in problem and normal soils, which might be helpful for sustainable crop production and food security in Bangladesh.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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