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Corn biochar influences yield attributes of two varieties of chili (*Capsicum annuum*) in the coastal region

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Abstract

A solid biomass pyrolysis byproduct is biochar. The most important uses of this carbon-rich, porous substance are soil enhancement, remediation, and pollution management. Biochar improves soil fertility, water retention, and fertilizer efficiency. Biochar stores plant nutrients, reduces salinity and drought, and neutralizes soil acidity. This component is environmentally favorable. It reduces chemical fertilizer and irrigation as well as lowers farmer costs. Green chili benefits greatly from organic fertilizer. Biochar must pay more attention to this economically valued crop despite its importance. Under a randomized complete block design (RCBD) with 3 replications, a field experiment determined the best dose to boost chili plant yield. Thus, to determine how two green chili varieties—Bangladeshi local hybrid 'Anal 1701 DG F1' (V_1) and Indian hybrid 'Bijlee Plus F1' (V_2)—react to different corn biochar doses. The treatments included T_1 (Control), T_2 (0.1kg/m^2), T_3 (0.3kg/m^2), T_4 (0.5kg/m^2), and T_5 (0.7kg/m^2). Using biochar significantly (*$p<0.05$) increased yield characteristics. Bijlee plus F1 had the highest yield and yield-related parameters above Anal 1701 DG F1. The combination of treatments and varieties yielded the maximum (2.40 ton/ha) in T_5V_2, while the lowest (0.3134 ton/ha) was in T_1V_1. Most yield-related characteristics (fruit number per plant, single fruit weight, mature chili length, diameter, and total yield) were achieved from T_5 treatment and T_5V_2 interaction. Corn biochar performed well on green chili varieties and yield-related parameters. The investigation proposed using Bijlee plus F1 variety and 0.7kg/m^2 corn biochar (T_5) dose to maximize chili production. This is an excellent recommendation for the farmers of coastal areas.

Keyword: *Capsicum annuum;* Corn biochar dose; Yield parameters; Chili variety

1. Introduction

In Bangladesh, chilies are the most extensively grown as a spice crop in both winter and summer [1]. Originally from South America, chilies (*Capsicum annuum* L.), the members of the nightshade family (Solanaceae), get their name from the Nahuat language via the Spanish term "chili" [2]. It is used as a spice in every cuisine because of its pungency, colour, and flavor. The green variety of chili is frequently added to salads and other prepared foods [3]. Chili contains significant amounts of vitamin C, other vitamins like vitamin A, vitamin B6, and vitamin K, and minerals like calcium, magnesium, folate, potassium, thiamin, iron, copper etc. [4]. It contains a lot of "capsaicin," a crystalline, colourless component with a strong flavor [5]. This pungent substance (capsaicin) has a variety of biological effects. It functions as an analgesic to manage pain. Due to chili's nutritional and pharmacological benefits, it is highly demanded in foreign markets. Both domestic and international markets are becoming increasingly dependent on chilies [6]. There are many known types and variations of chilies, but only a few are consistently cultivated and marketed in the marketplace [9]. With an annual production of 18,828 thousand tones, the chili plant occupies 1450,000 hectares globally [7]. The Bangladesh Bureau of

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Statistics (BBS) reports that production for the economic year 2020–21 was just shy of 0.5 million tons, compared to an annual demand for green chilies in Bangladesh of 0.45–0.5 million tones.

One of the main problems in managed tropical soils is soil deterioration. This issue lowers agricultural output and the ecological services the ground provides [8]. The leading cause of Bangladesh's soil fertility issues is the overuse of synthetic or chemical fertilizers during intense crop cultivation. In such circumstances, biochar should be a miraculous solution for increasing soil carbon content, enhancing soil health, and ensuring sustainable agriculture. The scientific community has established a strong belief in it [9]. Although biochar is not a new concept, its importance and potential have lately gained attention [10]. It also goes by the name "Black Gold" [9]. Biochar is created by the pyrolysis process. It possesses a high amount of aromatic carbon, is carbon-rich, and exhibits excellent chemical and biological stability [11]. To create biochar material, pyrolysis is a thermal conversion carried out in an environment with little or no oxygen [12]. Different crop wastes like cassava residues, corn cobs, rice husks, sawdust, coffee husks, and peanut shells can be used to make biochar [13]. The source type and pyrolysis temperature have the most significant impact on the properties of biochar [11]. However, pyrolysis could produce biochar, which has agronomic and environmental advantages [13]. The advantageous effects of biochar on soil quality and fertility indicators have already been noted in several studies [12]. In addition to storing carbon, biochar also serves as a fertilizer. This sparks interest, and a lot of recent research has focused on using biochar in various applications. The correct biochar doses would activate soil microorganisms, resulting in nutrient release and fertilization, and contribute carbon content for a decade to the soil carbon pool [14]. Additionally, biochars can sorb or otherwise lessen the bioavailability of phytotoxic soil pollutants, such as metals and lingering pesticides [15][16]. Applying biochar to soil also stimulates plant growth and yield [17]. Realizing new agricultural techniques that boost yields, protect soils, and concentrate on marginal farmer households' food security and nutrition is difficult [18]. In these conditions, biochar has the potential to increase agricultural productivity at a low cost and as a way to restore lost soil fertility [19]. To better marginal and poor communities, particularly tribal ethnic communities, the Christian Commission for Development in Bangladesh (CCDB) established the biochar technique in Bangladesh [20]. Research on using biochar to improve soil is of great interest to environmental and soil scientists. However, some biochar research has been done in Bangladesh [9]. The effects of biochar application are frequently researched at laboratory dimensions, but much research still needs to be done on the impact of biochar application on the decomposition of crop wastes at field scales [21]. Therefore, a thorough investigation of biochar research is required to highlight its use's value, potential, and opportunities in Bangladeshi soil [9]. Taking these facts into consideration, a field experiment titled "Corn biochar on yield and yield-related parameters of two different varieties of chili (*Capsicum annuum*) in the coastal region" was carried out at the Agriculture Research Field, NSTU, Noakhali in Bangladesh during Rabi season 2022 to evaluate the effective dose of biochar that is the best for the yield of chili for this zone as well as varietal response to biochar including interactions.

2. Material and methods

2.1. Study period

A field investigation named "Corn biochar influences yield and yield related parameters of two varieties of chilies (*Capsicum annum*) in coastal region" that was carried out from 24 December 2021 to 24 April 2022 (Rabi Season).

2.2. Experimental site

The research was conducted in an open field of Noakhali Science & Technology University situated in Noakhali-3814, Bangladesh. The place located in 22°47′31″N latitude and 91°06′07″E longitude. The land had been allocated to the "Young Meghna Estuarine Floodplain" in the coastal region's Agro-ecological Zone (AEZ)-18. Field had a medium height. Average annual rainfall was 7.36 mm, and temperatures ranged from 25 to 29 degrees. The Weather Station Maijdee in Noakhali specified monthly records of temperature, relative humidity, and total rainfall during the experimental period from November to April.

2.3. Experimental details

2.3.1. Factors

Two factors included in the experiment. They were as follows -

Factor A: Treatment (doses of corn biochar)

- $T_{1(Control)}$ = 0 kg/m^2
- T_2 = 0.1 kg/m^2

- T_3 = 0.3 kg/m^2
- T_4 = 0.5 kg/m^2
- T_5 = 0.7 kg/m^2

Reference [22]

Factor B : Two varieties of chili

- V_1: Anal 1701 DG F1
- V_2: Bijlee plus F1

So, the treatment and variety combinations were (Factor A × Factor B)

- $T_1 \times V_1$ (Control × Anal 1701 DG F1)
- $T_1 \times V_2$ (Control × Bijlee plus F1)
- $T_2 \times V_1$ (0.1 kg/m^{2}biochar × Anal 1701 DG F1)
- $T_2 \times V_2$ (0.1 kg/m^{2}biochar × Bijlee plus F1)
- $T_3 \times V_1$ (0.3 kg/m^{2}biochar × Anal 1701 DG F1)
- $T_3 \times V_2$ (0.3 kg/m^{2}biochar × Bijlee plus F1)
- $T_4 \times V_1$ (0.5 kg/m^{2}biochar × Anal 1701 DG F1)
- $T_4 \times V_2$ (0.5 kg/m^{2}biochar × Bijlee plus F1)
- $T_5 \times V_1$ (0.7 kg/m^{2}biochar × Anal 1701 DG F1)
- $T_5 \times V_2$ (0.7 kg/m^{2}biochar × Bijlee plus F1)

2.4. Soil Characteristics of the experimental site

The soil of the experimental site was sandy loam in texture with medium-high land. Physio-chemical composition of soil such as pH-7.42, moisture -1.56%, EC- 111 µS/cm, total organic carbon 1.37% and total organic matter 2.36%. All properties were tested by SRDI before conducting this experiment.

2.4.1. Layout

Each experimental plot was 0.6561m^2 (0.81m × 0.81m) with four holes in each corner of the plot, whereas the seedlings were transplanted. Each block contained 4 seedlings. The net experimental field measurements were 36.015m^2 (6.86m×5.25m). The space between plots was 0.2 m, and between replication blocks was 0.35 m. About 0.35 m was left around the field. In total, 60 plots with 3 replication blocks were arranged on the site.

2.4.2. Land preparation

Two ploughing by power tiller initially prepared the experimental field to make it even on 10th January. The corners of the land spaded well. Weeds and stubbles were removed by using hand and hand racks. The plot was prepared using a spade and hand hoe and labeled with hands and bamboo. The drainage channel was prepared around the land and between the blocks for the easy movement of drainage water. Finally, the land was ready on 13th January 2021, ten days before transplanting. To maintain soil fertility status, the recommended Urea, TSP, and MOP rates were mixed with the soil.

2.4.3. Soil Sample collection and analysis

Initially, the soil samples with a 0-15 cm depth from nine locations of the research field were randomly collected and placed on brown paper for air drying. The air-dried soil samples were then grounded and passed through a 2 mm sieve. The sieving soil samples were kept in a plastic container and examined by the Soil Resource Development Institute (SRDI), Noakhali, Bangladesh, to know their physical and chemical properties.

2.4.4. Biochar application

Different types of biochar are available in markets. The corn biochar was used in this experiment. Corn biochar was collected from an NGO named CCDB (Christian Commission for Development in Bangladesh).

At first, the doses of corn biochar as per treatments were weighed and packed. Then, these doses are mixed with the soil of the plots according to treatments. Corn biochar was incorporated on 15 January 2021, eight days before the transplanting of seedlings. Then, a minimal amount of water was sprinkled over the plot once.

2.4.5. Management of manures and fertilizers

Manures and fertilizers were applied with gentle care. Cow dung was used 45 kg/decimal 5 days before land preparation. A total of 1.20 kg/decimal urea was involved in two installments; there was 0.7 kg/decimal during land preparation and 0.5 kg/decimal during 35 DAT. 1.7kg/decimal TSP and 1.20 kg/decimal MOP were applied fully during land preparation.

2.4.6. Transplantation & intercultural operations

4 holes were made at each corner of each plot. Then, the seedlings were transplanted by maintaining a plant-to-plant space of 30 cm. Then, bamboo sticks were placed to support the plant growth.

2.4.7. Irrigation

Chili requires less soil moisture for its growth. It was maintained by pre-transplanting sprinkler irrigation. Further irrigations were given at 3-5 days except during intermittent rains.

2.4.8. Weeding

Regular weeding was carried out on the field to prevent crop weed competition, infestation of pests and diseases, and ensure maximum crop growth. The first weeding was done after 10 days of land preparation, and another was carried out at 5-day intervals.

2.4.9. Plant protection

Plant protection was carried out, such as hand picking of insects and disease-affected plant parts and plants in the experimental plots when needed. To prevent insect infestation, "Aktara 25WG" insecticide was sprayed once.

2.4.10. Picking of fruits

The fruits were picked manually when they were green tender and at marketable size. The picked fruits were weighed and subjected to other observations immediately after each picking.

2.4.11. Sampling and harvesting

The harvesting time is significant for chili because its fruit maturity time differs. Before applying treatment, the plants were tagged separately plot-wise. Three sample plants were randomly selected from each plot and tagged for recording necessary data. Fruits were harvested till 70 days from the experimental plot for analysis purposes.

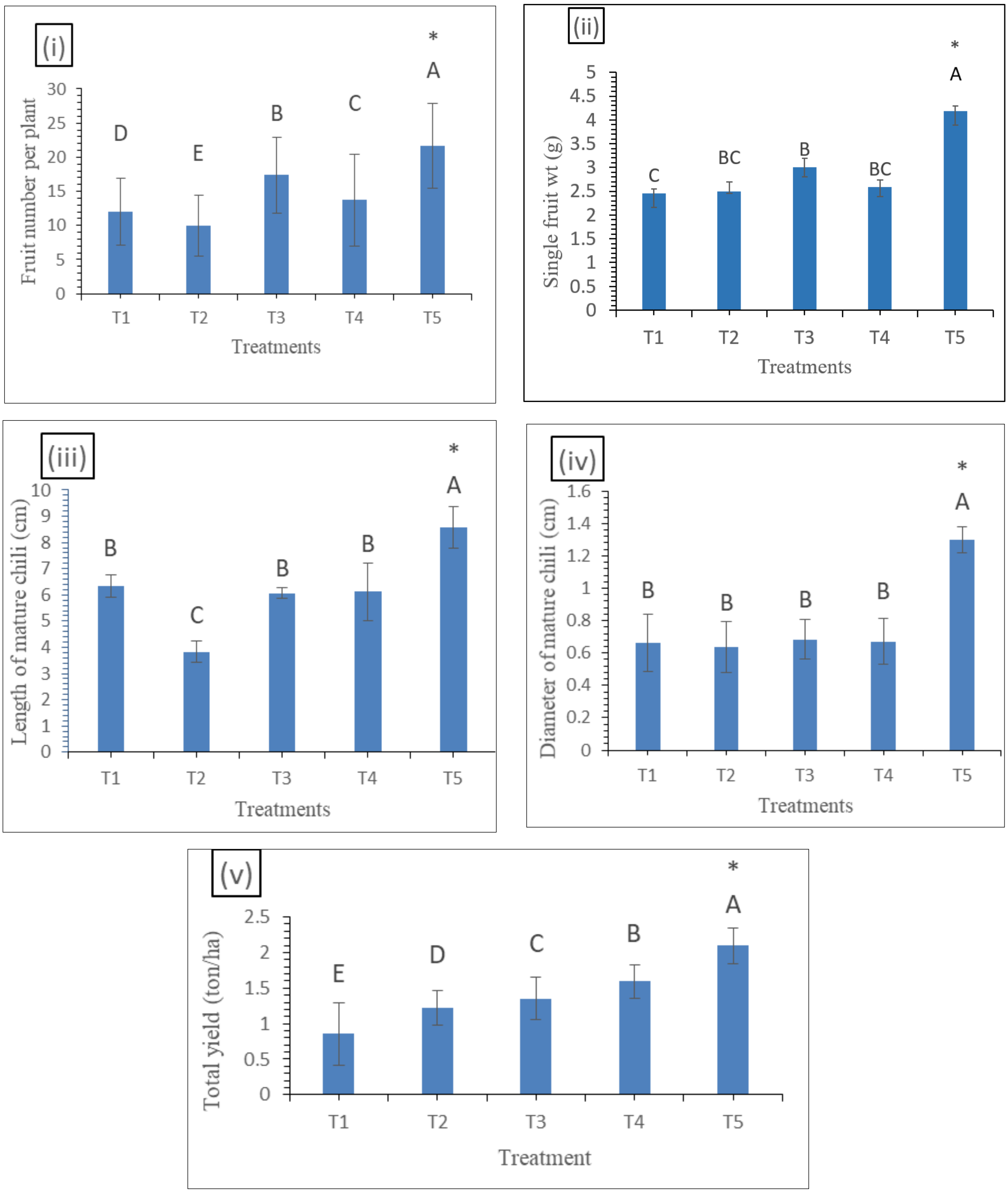
2.5. Data collection and analysis

Data on different parameters were collected, including fruit number per plant, weight of mature fruit, length of mature fruit, diameter of mature fruit, and total yield. Data were recorded on yield and yield attributes and then analyzed using "Statistix10" statistical program and Microsoft Office Excel 2016 to determine the significance or non-significance within treatments and varieties. The means were calculated at a 5% probability level.

3. Results and discussion

3.1. Effect of treatments

The result of Tukey HSD of the post-hoc analysis showed that treatment had a very significant effect on parameters of fruit number per plant, single fruit weight (g), length of mature chili (cm), diameter of mature chili(cm), and total yield (ton/ha). T_5 treatment influenced mostly and resulted in the highest 21.678 fruit per plant, 4.1817 g single fruit weight, 8.5787 cm fruit length, 1.30 cm diameter of mature chili, and total yield of 2.0935 ton/ha were obtained from this biochar dose in comparison to control T_1. The lowest fruit number was collected from the T_1 treatment. Similarly, the least fruit weight of single fruit (2.4502 g) and total yield (0.8562 ton/ha) resulted from T_1. However, T_2 revealed the shortest fruit of 3.833 cm and the narrowest fruit diameter of 0.6375 cm, where T_2 was statistically similar to T_1, T_3, and T_4 treatments (**Figure 1**). An experiment on tomato plants under the Solanaceae family noted that the maximum fruit number per plant was produced from higher doses of biochar application in soil. In that case, biochar application increased the fruit number (9.40) per plant, and single fruit weight (66.12 g) depicted a similar result [23]. Another study on the cucumber plant revealed that date palm biochar increased the length of fruit (16.24 cm) and diameter of fruit (35.15 mm), which supported the influential result of this study [24]. Correspondingly, an experiment found the highest total fruit yield (14.6 tons/ha) from the red chili plant's biochar-treated plot. That result showed that biochar application increases the total yield [25].

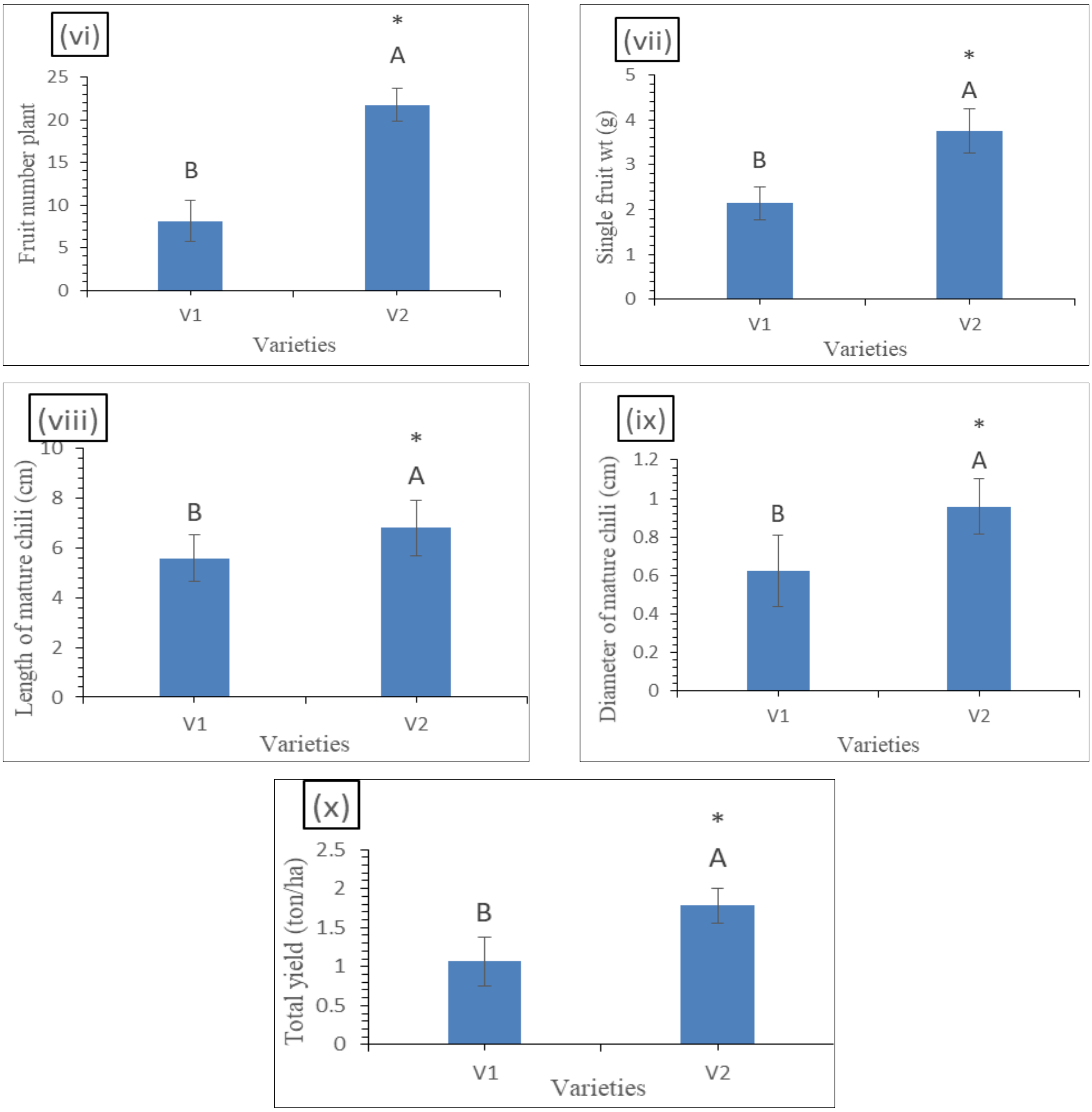


T_1 = Control; T_2 =0.1kg/m^2 corn biochar, T_3 = 0.3kg/m^2 corn biochar; T_4 = 0.5kg/m^2 corn biochar; T_5 = 0.7kg/m^2 corn biochar. Alteration of fruit number per plant (i), single fruit weight (ii) , length of fruit (iii), diameter of fruit (iv) and total yield (v). Data are the averages of three replicates ± SEM (standard error mean). The values with different characters (A, B, C, D, E) indicate significant difference (*$p<0.05$) over control

Figure 1 Effect of Corn biochar doses

3.2. Effect of varieties

Better performances were statistically identified from the V_2 variety. The elevated result in fruit number of 21.742, single fruit weight of 3.7437 g, 6.8039 cm long fruit length, 0.9577 cm fruit diameter, and total yield of 1.7815 ton/ha revealed in the case of Indian hybrid variety Bijlee plus F1(V_2) that was statistically different from the local hybrid variety Anal 1701 DG F1 (V_1) variety. The local hybrid variety V_1 showed minimal effect on all yield parameters of the chili plant statistically in coastal areas (**Figure 2**). This aligns with the idea that superior types possess higher qualities than local ones [26]. Some scientists determined in research that the Lado F1 chili variety resulted in the highest fruit number (198) and potential crop yield (15.64 tons/ha), where the variety is a foreign hybrid variety [27]. Another study on chili variety and more extended fruit size (13.95 cm), breadth or diameter (5.32 cm), and single fruit weight (11.38 g) compared to the local check variety obtained from Binamorich-2(IndoCF-25) [28]. The Lado F1 and Binamorich-2 share similar traits with the Bijlee plus F1 foreign (Indian) chili variety.

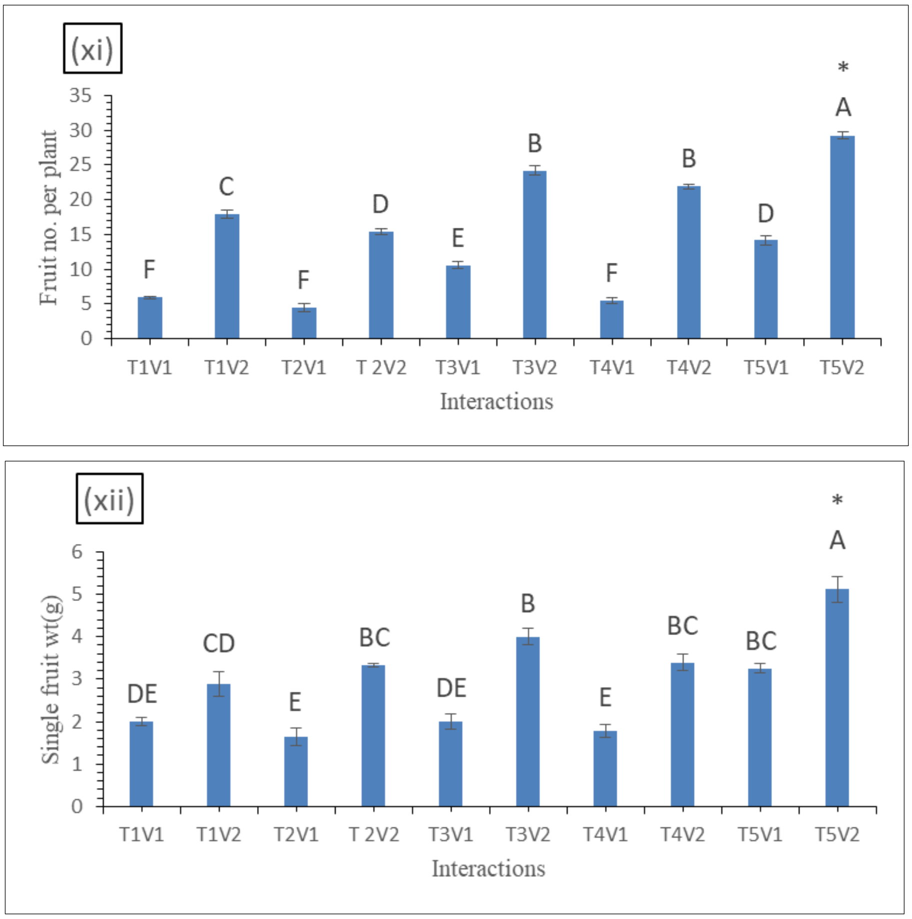


V_1= Anal 1701 DG F1; V_2 = Bijlee Plus F1. Alteration of fruit number per plant (vi), single fruit weight (vii), length of fruit (viii), diameter of fruit (ix) and total yield (x). Data are the averages of three replicates ± SEM (standard error mean).The values with different characters (A, B) indicate significant difference (*p<0.05) over control

Figure 2 Effect of chilli varieties

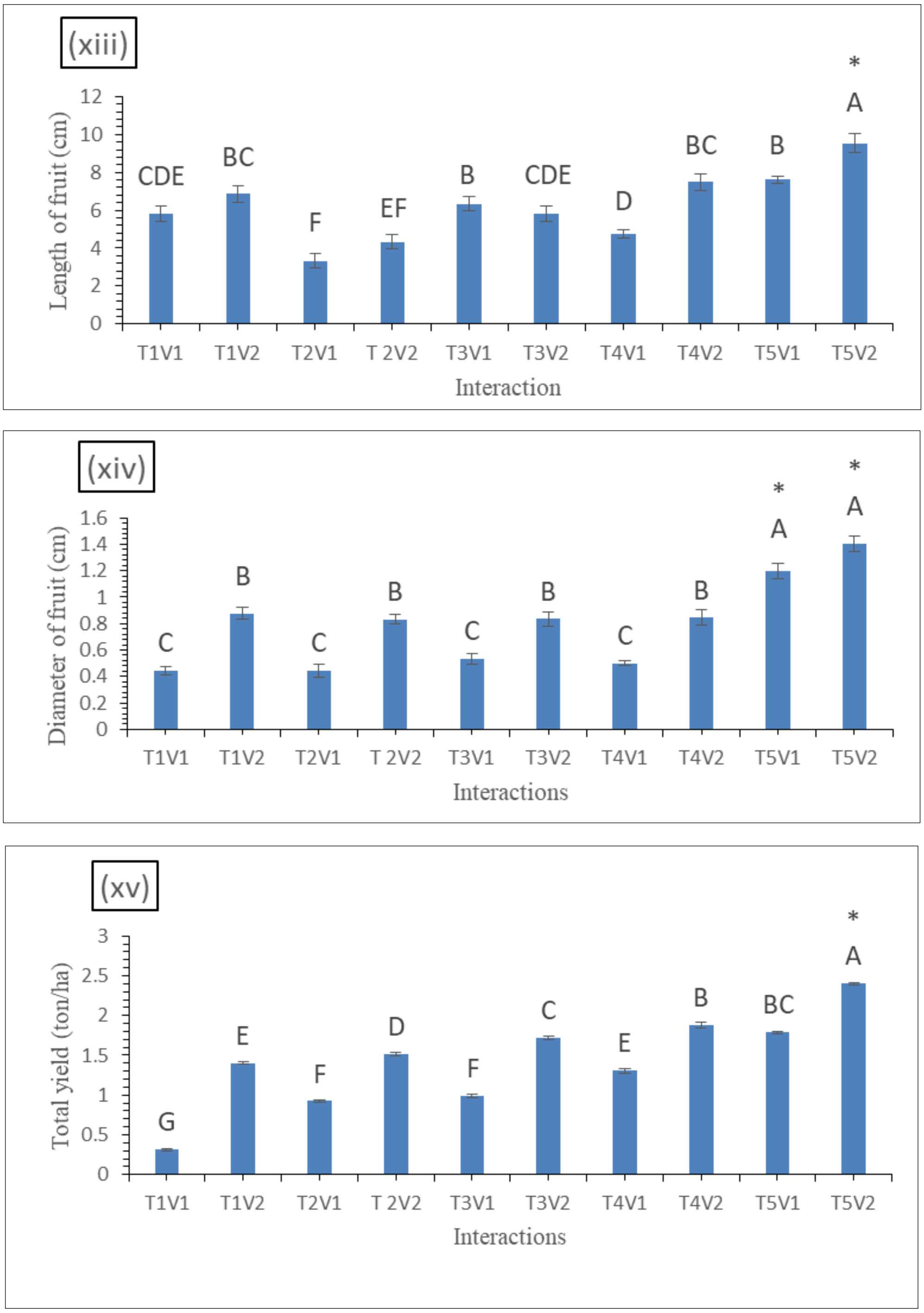
3.3. Effect of treatment-variety interactions

A significant contribution to the different yield parameters of chili was determined by treatment and variety combinations. Clearly, the maximum amount of fruits (29.222) and single fruit weight (5.113 g) were picked from T_5V_2 interaction, and a minimum fruit number of 4.445 were found from T_2V_1, which was statistically similar to T_4V_1 and T_1V_1. However, the lightest chili was 1.6447 gm from T_2V_1 (statistically equal to T_4V_1). The longest (9.5423 cm) chili was found from T_5V_2, which was statistically opposite to the result of T_2V_1 for 3.333 cm. In the diameter of mature chili, the widest chili measured from T_5V_1 was 1.40 cm, statistically identical to 1.20 cm of T_5V_2, which was reversed to T_2V_1. Nevertheless, the total yield was maximized with 2.3984 ton/ha by the combination of T_5V_2, where the lowest total yield (0.3134 ton/ha) weighed from T_1V_1. Overall, T_5V_2 interaction led to better results in the Tukey HSD test (**Figure 3**).



.T_1V_1 (Control & Anal 1701 DG F1); T_1V_2(Control & Bijlee plus F1); T_2V_1 (0.1 kg/m²biochar & Anal 1701 DG F1) ;T_2V_2 (0.1 kg/m²biochar&Bijlee plus F1); T_3V_1 (0.3 kg/m² biochar& Anal 1701 DG F1) ;T_3V_2 (0.3 kg/m²biochar&Bijlee plus F1) ;T_4V_1 (0.5 kg/m²biochar&Anal 1701 DG F1) ;T_4V_2 (0.5 kg/m²biochar & Bijlee plus F1); T_5V_1 (0.7 kg/m²biochar & Anal 1701 DG F1) ;T_5V_2 (0.7 kg/m²biochar & Bijlee plus F1). Alteration of fruit number per plant (xi), single fruit weight (xii). Data are the averages of three replicates ± SEM (standard error mean). The values with different characters (A, B, C, D, E, F) indicate significant difference (*$p<0.05$) over control.

Figure 3 Effect of treatment-variety interactions



.T_1V_1 (Control & Anal 1701 DG F1); T_1V_2(Control & Bijlee plus F1); T_2V_1 (0.1 kg/m^{2}biochar & Anal 1701 DG F1) ;T_2V_2 (0.1 kg/m^{2}biochar&Bijlee plus F1); T_3V_1 (0.3 kg/m^2 biochar& Anal 1701 DG F1) ;T_3V_2 (0.3 kg/m^{2}biochar&Bijlee plus F1) ;T_4V_1 (0.5 kg/m^{2}biochar&Anal 1701 DG F1) ;T_4V_2 (0.5 kg/m^{2}biochar & Bijlee plus F1); T_5V_1 (0.7 kg/m^{2}biochar & Anal 1701 DG F1) ;T_5V_2 (0.7 kg/m^{2}biochar & Bijlee plus F1). Alteration of length of fruit (xiii), diameter of fruit (xiv) ,and total yield (xv). Data are the averages of three replicates ± SEM (standard error mean). The values with different characters (A, B, C, D, E, F) indicate significant difference (*$p<0.05$) over control.

Figure 4 Effect of treatment-variety interactions

4. Conclusion

Chilies' development and yield depend on nitrogen supply, soil quality, spacing, and cultural practices. Carbon-based biochar can replace chemical and artificial fertilizers. It supplies additional nutrients to Earth. The current study examined "Anal 1701 DG F1" and "Bijlee plus F1" chili cultivars because of their varied growth and yield characteristics.

Regular coastal plants have many environmental stressors. Not all fertilizers are modifiable here. There are solutions, though. Coastal regions are increasingly using corn biochar as a fertilizer. It delivers nutrients to the soil without harming the environment. This study found that corn biochar improved two coastal chili varieties' yield-related attributes. This study found that corn biochar doses, varieties, and treatment-varietal interactions boosted significantly chili yield ton/ha, single fruit weight, length, and diameter. This study reported that T_5 (0.7kg/m^2) corn biochar increased yield parameters, including number of fruits per plant, total yield ton/ha, single fruit weight, fruit length, and fruit diameter. However, "Bijlee plus F_1" was superior to the other chili variety. T_2V_5 (0.7 kg/m^2 biochar and Bijlee plus F_1 variety) significantly drove up yield parameters in treatment-varietal interactions.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have conducted this research and written the article and have no conflicts of interest, financial, personal or otherwise, with any other person or entity.

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