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Research Article

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Investigating the Effects of Banana-Derived Biochar and Straw Residues on Growth and Yield of Maize (Zea Mays L.) Crop

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Abstract

Biochar application with straw residues can enhance their rate and increase the availability of nutrients for maize crop under field conditions. Therefore, this present study was primarily aimed at exploring the combined effect of banana derived biochar and straw residues application on the biomass production and the yield components of maize crop. The experimental study was consisting of six treatments: T-1 control, T-2 Biochar (40 ha^{-1}), T-3 12.5 tons ha^{-1} straw residues, T-4 25 tons ha^{-1} straw residues, T-5 40 tons ha^{-1} biochar + 25 tons ha^{-1} straw residues, T-6 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} straw residues. Results displayed that combine application of Biochar (40 tons ha^{-1}) and straw residues (25 tons ha^{-1}) enhanced the shoot fresh biomass (208%), Root fresh biomass (85%), Root length (85%), Number of grains per cob (262%), Seed index (68%), cob length (79%), grain yield (120%) and leaf area (80 %) as compared to control. While, 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} straw residues increased shoot fresh biomass (197%), root fresh biomass (57%), root length (41%), number of grains per cob (220%), seed index (37%), cob length (69%), grains yield (103%) and leaf area (64%) in comparison to control. Most of the growth parameters were positively correlated with yield components. Similarly, correlation coefficient indicated significant association among different morphological characteristics when subjected to these combined applications of biochar and straw residues. Hence, this study concluded that combine application of banana biochar and straw residues promoted the grain growth and yield of the maize crop under field condition.

Keywords: Banana biochar, Grain yield, Growth components, Straw, Maize

Introduction

Maize is an important cereal crop and staple food to meet the dietary conditions of the world's population (Javed *et al*., 2021), with calculated total annual production recorded as being higher than wheat and rice crops (Wang *et al*., 2019). Maize has gotten popularity to meet the global food demands due to the maximum production per unit hectare relative to other major staple food crops grown throughout the globe (Roohi *et al*., 2022). In the Pakistan, the maizeis fourth major growing crop after rice, cotton and wheat plant. In Pakistan maize crop cultivated over one million hectares and production is around 3.5 million metric tons (Arian, 2013; Kakar *et al*., 2021). In assessment of its enhancing position for fodder as well as the grains, development on the maize has excellent significant consideration in the world (Ahsan & Mehdi, 2000; Rafiq *et al*., 2010). The maize is a noteworthy crop in Pakistan's current cropping method because it is a short-term seasonal crop that delivers a high economic yield to farmers. It is cultivated in different regions of the country for fodder, feed and food purpose with an average production of 6.4 tons per hectare (FAO, 2023). During the year 2022-23 the production of maize in Pakistan was 10.5 million tons and it was cultivated on approximately 1.6 million hectares (FAO, 2023).

The integration of banana derived biochar and press mud in agricultural practices has gained attention as a potential solution to address the challenges faced by the scientific community in feeding the world's growing population. Unfertile agricultural land, including those affected by salinization, desertification, and soil contamination, can be brought into the agricultural production system through the use of these organic amendments (Young *et al*., 2021; Kubar *et al*., 2023). Rainfed agriculture, which covers 80% of the world's cultivated land and contributes to about 60% of total crop production globally (Khan *et al*., 2022), often faces low productivity in arid and semi-arid regions due to degraded soil fertility and limited inputs of soil water and nutrients. Water availability is a crucial limiting factor for crop yield promotion, particularly in dryland farming ecosystems that hinder crop growth and productivity (Lobel *et al*. 2008; Khan *et al*., 2022). In this context, maximizing the production of major crops while also exploring fallow fertile lands can help meet current challenges related to food demands. The integrated application of banana derived biochar and press mud offers a promising approach to enhance soil fertility, water retention capacity, nutrient availability, and overall crop yield and growth components. By utilizing these organic amendments effectively in rainfed agricultural systems, it is possible to improve agricultural productivity on unfertile soils while mitigating environmental issues associated with conventional farming practices.

Crop straw is a frequent waste product of agricultural industry with a considerable annual output (Gu *et al*., 2018; Abbas *et al*., 2020). The incorporation of straw into soil increases crop biomass production (Kubar *et al*., 2020). Xu *et al*. (2019) reported that straw return increased the crop yield stability in wheat-maize systems. According to Getahun *et al*. (2018), the incorporation of straw residues into soil had beneficial effects on root development and thus affected aboveground biomass production. Straw residues can significantly decrease soil loss began by rain on the ground surface. Because of its polycyclic aromatic structure, biochar, which is similarly made from agricultural remaining, is chemically and physiologically constant (Yan *et al*., 2019; Li *et al*., 2021). It has a significant number of organic macromolecules with multi-pore architectures and, as a result, may readily form aggregates with soil particles, increasing soil structure. The adsorptive ability of biochar enhances soil adsorption and hence the retention of soil nutrient ions, notably NH_4^+ (Zhou *et al*., 2020). Biochar moreover has an effect on crop nutrient absorption, improving plants' capacity to use available nutrients. Several studies have demonstrated that using biomass charcoal enhances soil nitrogen, phosphorus, and potassium absorption in wheat (Van *et al*., 2010), maize (Liu *et al*., 2009; Kubar *et al*., 2022), and radish (Chan *et al*., 2007) within a limited range. An increasing amount of data indicates that biochar has an effect on plant development and yield Gu *et al*., 2018; Taghizadeh-Toosi *et al*., 2022). Still, the causes and rise or changed in development and yield and processes after these variations are unknown. Most studies have shown gains in crop income for soils modified with the straw biochar when likened to control soils; nevertheless, there are some occurrences of reductions (Singh *et al*., 2022; Wang *et al*., 2022).

Little or less research has been conducted on the effect of organic improvements on maize (Zea mays L.) production and growth when combined with biochar. We hypothesized that the combine use of the biochar and straw incorporation will improve the growth biomass and yield components of the maize crop as compared to the use of straw or biochar alone. To the best of our knowledge, combine use of the banana derived biochar along with the straw incorporation is rarely studied in the arid dry environment. Keeping these facts in mind, the following objectives were determined: (1) to explore the combine effects of banana derived biochar and straw residues incorporation on the biomass production of maize. (2) To evaluate the combine effects of banana derived biochar and straw residues incorporation on the yield components of maize crop (3) To find out the relationship of grain yield with biomass attributes of the maize crop.

Materials and methods

Outline of the study area: This current study was carried out at Lasbela University of Agriculture and Water Marine Sciences Uthal (25.84159°N 66.62302°E), District Lasbela, in Balochistan province the district's topography is primarily a large sandy plain with hilly sections combined throughout. The climate in the Environment and Natural Resources District of Lasbela is symbolic of a tropical dry, hot environment. The annual maximum and minimum temperatures are around 17 ^{0}C and 3 ^{0}C, respectively, and above 38 ^{0}C and 24 ^{0}C in June, the district's temperature is normally hot in the summer and moderate in the winter. The weather in Uthal is often random with little rain (20 cm annually), arid, temperate, and moist in the coastal areas.

Experimental design and Treatments details: A field research was conducted at the Department of Soil Science, Lasbela University of Agriculture, Water and Marine Sciences, Uthal Lasbela to measure the effects of the Banana derived biochar and straw management on the yield and growth element of Maize crop. The trial was arranged available with six treatments and replicated three times in a randomized complete block design (RCBD). The portion of all plot will be 4 m × 5 m = 20 m^2 and prepared in a randomized block design with three replicates. The maize variety "Akbar" was grown in autumn season 10th August, 2021. Maize row arrangement was 60 cm with plants spread out 40 cm apart. Maize was fixed at 52,000 plants ha^{-1}. Following treatments were arranged for this study.

Treatments details:

T1= Control

T2= Biochar recommended dose (40 tons ha^1)

T3=12.5 tons ha^{-1} Straw residues.

T4= 25 tons ha^{-1} Straw residues.

T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} Straw residues

T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} Straw residues.

Biochar and Straw application: Biochar was prepared from banana waste material in a locally made furnace. Banana waste was collected from the surrounding of the Lasbela University of agriculture water and marine science Uthal Balochistan, later banana waste were washed to remove dust and other impurities, sun-dried to remove moisture, and crushed into 2-5 mm sized particles for biochar preparation.

The method described by Abbas *et al*. (2020) was followed for biochar preparation in which crushed banana leaves were filled in 2 litter capacity Pyrex flask that could bear up to 1000℃. During pyrolysis, 15 ℃ per minute increase in temperature, and 30 minute residence time will be adjusted after attaining a maximum 350℃ temperature. The furnace was permitted to cool down until the temperature dropped to 20 ℃. Then the lid was removed, and biochar was stored in a plastic bag for further analysis. However, in the straw residues plots, straw of banana leaves was chopped into 5–8 cm lengths and incorporated the soil. The straw was equally incorporated as per treatment in the field to reduce variations between treatments, straw was manually applied in the treatments before sowing of the maize crop.

Fertilizer application and agronomic practices: Recommended dose of the inorganic chemical fertilizers was applied as basal dose during the sowing time of maize crop. Fertilizer was broadcasted earlier sowing with maize getting basal amounts of NPK at 150 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O respectively. The nitrogen was supplied as urea (46% N) while phosphorus (P) as diammonium phosphate, (DAP, 18% N and 46% P_2O_5) and Potassium was supplied as Sulphate of potash (50% K). All the P and K, along with N was supplied to the crop by broadcasting to the soil and then thoroughly mixed. All other agronomic management observes such as weed control, irrigation, disease control was done using conventional systems used in Balochistan Province.

Observation of Parameters: Maize was harvested at maturity stage. In this experiment different growth and yield parameters were recorded. Following parameters were measured. Shoot fresh biomass: At ripeness, maize crop was harvested and then plant fresh shoot was weighed without cobs through digital balance. Root fresh biomass: At maturity of crop, maize plant roots were collected, air dried than fresh root was recorded with the help of digital balance. Shoot dry biomass: At maturity, maize crop was harvested. After taking fresh weight plants were dried at 80 ^{0}C for 24 hours in oven and then dry plant shoot weight was noted with help of balance. Root dry biomass: At maturity of crop, maize roots were collected and were dried at 80 ^{0}C for 24 hours in oven and then root dry weight was noted with the help of balance. Number of leaves per plant: Number of leaves per plant was counted by selecting 10 healthy plants per square meter. Leaf area: Leaf area (cm^2) was measured by determining the leaf length and width of plant from different positions. Average was recorded through width multiply by the length of leaf. Plant height: The plant height was measured from surface of soil to top of tassels in centimeter (cm) with help of measuring tape. Root length: Root distance was measured top to bottom in centimeter (cm) with help of measuring tape. The number of grains per cob: It is presented that number of grains per cob. Number of grains per cob were counted and noted for calculating yield parameter. Seed index (100 seed weight): Data for seed index was measured as by counting 100 grains and then weighed by using electronic balance machine. Cob length: Data for cob length was measured by means of measuring tape which was expressed in centimeters (cm). Grain yield: It is totally dependent on yield contributing parameters i.e., cob length as well as cob weight.

Statistical Analysis: Experimental data was analysed by the SPSS 20.0 software package and Microsoft Office Excel 2010. One way analysis of variance (ANOVA) was conceded out to define the variances among the measured parameters for dissimilar treatments. Least significant difference (LSD) at ($p<0.05$) was used to explain significant different. Pearson correlation coefficients was measured to define the association of the grain yield with other growth and biomass parameters.

Results and discussion

Shoot Fresh Biomass and root fresh biomass (g): Significant differences in shoot fresh biomass was documented between treatments (Figure 1a). Combine application of the biochar and straw residues improved the fresh shoot weight of maize plants up to 97% as against control. Based on the mean performance results, maximum shoot fresh weight 46.70 g was noted under biochar 40 ton ha^{-1} and straw residues 25 tons ha^{-1} followed by biochar 40 tons ha^{-1} and straw residues 12.54 tons ha^{-1} was (45 g) and straw residues 12.5 tons ha^{-1} (21.20 g). However, minimum results were recorded in control (15.14 g) followed by biochar 40 tons ha^{-1} **(**18.14 g). The increase in maize shoot fresh biomass in response to the application of biochar and straw residues from banana extracts is attributed to the fact that they contain nutrients, which are released into the soil for maize plants, as opposed to no treatment. Masood *et al*. (2014) confirmed our findings where they noted that shoot biomass increased apparently when subjected to more treatment of biochar. Similarly, in our research work, best maize performance under treatment biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} was owing to improved soil conditions as a result of this treatment. Biochar treatment may have improved plant physiological processes, nutritional availability, and soil characteristics, resulting in an increase in biomass (Jeffery *et al*., 2011). Our outcomes are in line by the outcomes of Sarfraz *et al*. (2017) in which they recounted after application of biochar, shoot fresh weight was significantly affected in maize plant. Straw residues derived from crops are common waste materials obtained from the production of agricultural stuff with huge number of annual returns (Abbas *et al*., 2020).

Significant differences in root fresh biomass was documented between treatments (Figure 1b). Combine application of the biochar and straw residues improved the fresh root weight of maize plants up to 85% as against control. Based on the mean performance results can be drawn where maximum root fresh weight was noted in biochar 40 ton ha^{-1} and straw residues 25 tons ha^{-1} is (4.30 g) followed by biochar 40 tons ha^{-1} and straw residues 12.54 tons ha^{-1} and biochar 40 tons ha^{-1} with values of (3.70 g) for both treatments. However, minimum results for the said parameter were recorded in control as well as 12.55 tons ha^{-1} with mean results of (2.30 g). This was attributable to the waste products from banana extracts enhancing organic matter. Masood *et al*. (2014) supported our work by claiming that increment in maize root fresh biomass in comeback to the use of biochar is attributed to the fact that they contain nutrients, which are released into the soil for maize plants. Similarly, best maize performance for root fresh biomass under in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} was owing to improved soil conditions as a result of this treatment. This rise in greater root biomass could be attributed to nutrient availability and soil properties (Jeffery *et al*., 2011). Improved bulk density, which is recognized to decrease root elongation on little nutrient availability, contributed to the little presentation in the no manure use plots (Adekiya and Ojeniyi, 2002), which adversely declined uptake of water and nutrients and therefore low yield.

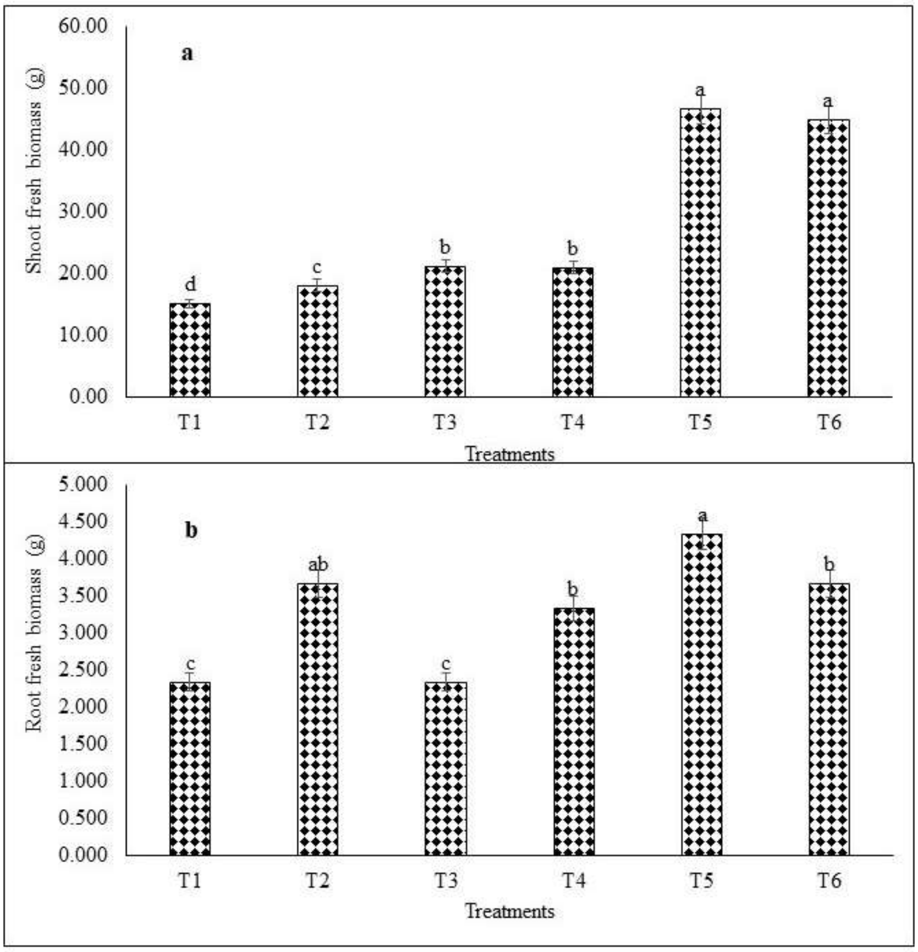

Figure 1. (a) Effects of the biochar and straw residues on the shoot fresh biomass and (b) Effects of the biochar and straw residues on root fresh biomass of maize crop**.** T1= Control, T2= Biochar recommended dose (40 tons ha^{1}), T3=12.5 tons ha^{-1} Straw residues, T4= 25 tons ha^{-1} Straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} Straw residues, T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} Straw residues.

Shoot dry biomass and root dry biomass (g): Significant differences in shoot dry biomass was documented between treatments (Figure 2a). Combine implementations of the biochar and straw residues amended the dry shoot weight of maize plants up to 90% as against control. Based on the mean performance results, maximum shoot fresh weight was noted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} **(**11.32 g) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (9.30 g) and 25 tons ha^{-1} straw residues (7.90 g). However, minimum results for the said parameter were recorded in control (5.60 g) followed by 12.54 tons straw residues (5.80 g). Improved nutrient application below the combined usage of organic and inorganic nutrients could explain the better maize production and shoot dry mass. Banana derived biochar and straw residues may have improved nutritional availability and soil characteristics which resulted in increased in shoot biomass (Jeffery *et al*., 2011). Similarly, in our research work, best maize performance under **in** biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} was owing to improved soil conditions as a result of this treatment. Masood *et al*. (2014) confirmed our findings where they noted that shoot dry biomass increased significantly when subjected to more levels of biochar application. Our results confirm the results of Rajkovich *et al*. (2012) where they noted similar findings for shoot dry biomass under banana derived biochar application. The addition of organic manures clearly boosted shoot growth (Hirzel *et al*., 2007) this may be due to better availability of nutrient in soil (Marschner, 2011)

Significant difference in root dry biomass were documented between treatments (Figure 2b). Combine implementation of the straw residues and biochar amended the dry root weight of maize plants as against control. Based on the performance of different levels of treatment applied, results can be drawn where maximum root dry weight was noted in biochar 40 ton ha^{-1} (1.67g) followed by biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (1.57g) and 12.5 ton ha^{-1} straw residues with value of (1.33g). However, minimum results for the said parameter were recorded in control (0.77g) followed by 25 ton ha^{-1} straw residues with mean result of (0.83g). Masood *et al*. (2014) supported our work by claiming that increment in maize root dry biomass in rejoinder to the implementation of biochar is attributed to the detail that they contain nutrients, which are on the loose into the soil for maize plants. Similarly, best maize performance for root fresh biomass under biochar 40 ton ha^{-1} was owing to improved soil conditions as a result of this treatment. This rise in greater root biomass could be attributed to nutrient obtainability and soil quality (Jeffery *et al*. 2011). Improved bulk density, which is recognized to decrease root elongation at little nutrient availability, contributed to the low presentation in the no manure application plots (Adekiya and Ojeniyi 2002), which adversely declined uptake of water and nutrients and therefore low yield. The addition of organic manures clearly boosted root growth (Hirzel *et al*. 2007) this may be due to better availability of nutrient in soil (Marschner 2011).

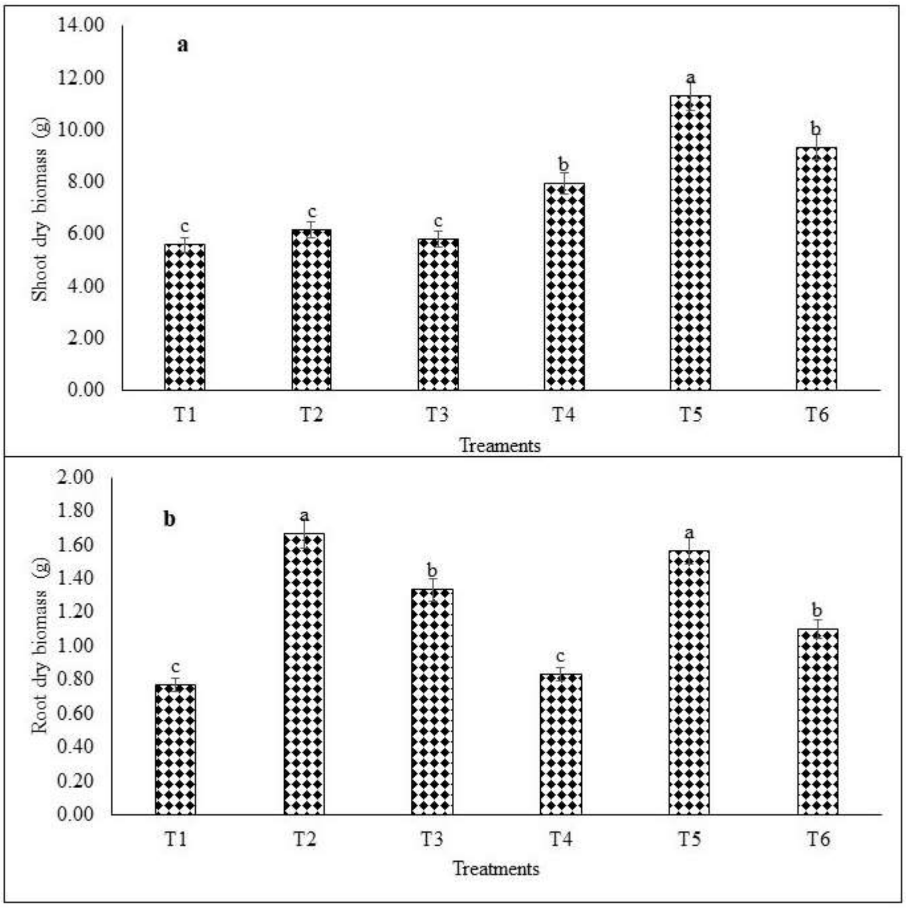

Figure 2. (a) Effects of the biochar and straw residues on the shoot dry biomass and (b) Effects of the biochar and straw residues on root dry biomass of maize crop. T1= Control, T2= Biochar recommended dose (40 tons ha^{1}), T3=12.5 tons ha^{-1}

Straw residues, T4= 25 tons ha^{-1} Straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} Straw residues, T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} Straw residues.

Number of leaves per plant and leaf area (cm^2): Significant difference in number of leaves per plant was documented between treatments (Figure 3a). Combine application of the biochar and straw residues improved the number of leaves per plant of maize plants up to 5% as against control. Based on the performance of different levels of treatment applied, results can be drawn where maximum number of leaves were counted in biochar 40 ton ha^{-1} (7.33) and 25 ton ha^{-1} straw residues (7.35) followed by 12.5 ton ha^{-1} straw residues (6.35). However, minimum results for the parameter mentioned above were recorded in biochar 40 ton ha^{-1} and straw residues 12.5 tons ha^{-1} (5.3) followed by control with mean results of (6). With higher pyrolysis temperatures, biochar is responsible for improved leaf growth, whilst others induce decreased growth, which is purely dependent on the concentration applied. Therefore, temperature of pyrolysis is still a significant factor in improving biochar effectiveness for soil fruitfulness organize (Makoto *et al*., 2011). Similarly, leaves from sugar cane developed with biochar completed from bagasse or bio solids had very different responses (Chen *et al*. 2010). Number of leaves produced by biochar derived after plant leftovers such as hazelnut shells, pine, and oak showed minimal development (Lehmann *et al*., 2003). Increased number of leaves by organic manure claim has too been informed by (Muhammad & Khattak 2009). However, an implementation of press mud and poultry manure resulted in higher maize shoot growth with leaves than that of farm yard manure (Aziz *et al*. 2010) which could be due to extra inorganic nutrients being unconfined from the press mud, although FYM also discharges nutrients and stimulates soil microbial weight when it decomposes. Khan *et al*., (2022) stated that number of leaves per plant was not affected significantly when dissimilar regimes of treatment applied which supports the findings of our work. Various biochar characteristics and their possible effects on maize growth were not examined in leaves, nevertheless they might have influenced development.

Significant differences in leaf area were documented between treatments (Figure 3b). Combine application of the biochar and straw residues improved the leaf area 80% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where highest leaf area was noted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (89.32 cm^2) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^1 (81.20 cm^2). However, minimum results for the parameter mentioned above were recorded in 12.5 tons ha^{-1} straw residues (48.80 cm^2) followed by control and biochar 40 tons ha^{-1} with mean results of (49.30 cm^2) and (51 cm^2) respectively. Khan *et al*. (2022) reported that leaf area was significantly affected when different regimes of treatment applied which supports the findings of our work. The fact that biochar and straw residues from banana extracts contain nutrients which are issue to the soil for plant growth as likened to control (Akande *et al*., 2010). This improved production could be owed to improved leaf nutrient accumulation and uptake, as well as an improvement in the overall physical and chemical condition of the soil, following the addition of banana extracts. When this specific parameter was reviewed further it was established by the outcomes of Khan *et al*. (2022) where they stated that leaf area was significantly different under biochar application.

Plant height and root length (cm): Significant differences in plant height were documented between treatments (Figure 4a). Combine application of the biochar and straw residues improved the plant height 86% as against Control. Based on the mean performance results, maximum plant height was noted in biochar 40 ton ha^{-1} (104 cm) followed by control (97 cm) and 25 tons ha^{-1} straw residues (93 cm). However, minimum results for the said parameter were noted in 12.5 tons ha^{-1} straw residues and biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} with mean performances of 86 cm under both treatments. Further vegetative improvement, which outcome in enhanced joint shadowing and intermodal delay, could explain the rise in plant height due to more biochar and straw application. Such increment in plant height due to higher rates of biochar applied and straw residues derived from banana extracts have been inveterate by the earlier results of (Sarfraz *et al*., 2017; Akbar *et al*., 2002). As a result of the mutual shadowing effect, plant height rose at larger plant masses owing to competing for light. Furthermore, plant height of maize crop was importantly pretentious by cooperative outcome of nitrogen rates and biochar levels. Likewise outcomes were originate by (Kakar *et al*., 2021; Masood *et al*., 2014) in which they studied plant height under the influence of banana leaf-based amendments to estimate the response of maize plant where they found non-significant difference in plant height. However, Sarfraz *et al*. (2017) reported a 73.4 percent increase in plant height over control when biochar rates were combined with nitrogen fertilizers. The contradictory results on maize plant height under biochar additions can be attributed to the manufacture of biochar from different feedstocks utilizing varied pyrolysis temperatures, as well as diverse soil types and, most importantly, the rates of biochar applied.

Significant differences in root length was documented between treatments (Figure 4b). Combine application of the biochar and straw residues improved the root length 85% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where highest root length was noted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (15 cm) followed by 25 tons ha^{-1} straw residues and biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (15 cm) followed by 25 tons ha^{-1}with an average value of (14 cm) and (13 cm). However, minimum length of root was measured in control (9.4 cm) followed by biochar 40 tons straw residues with mean result of (12 cm). The best performance of maize plant for root length under Treatment biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} was due to improved soil state resulting from higher rates of straw residues applied. Improved bulk density, which is identified to decrease root elongation at low availability of nutrients, contributed to the little presentation in the no manure implementation plots which adversely reduced nutrient and water approval and therefore low yield (Adekiya and Ojeniyi, 2002). It is obvious that amended root growth by accumulation of organic manures (Hirzel *et al*., 2007) strength remain qualified to better nutrient obtainability of the soil (Marschner, 2011). When this specific parameter was reviewed further it was established by the results of (Khan *et al*., 2022; Rasheed *et al*., 2004) where they reported that root length was significantly different under biochar application.

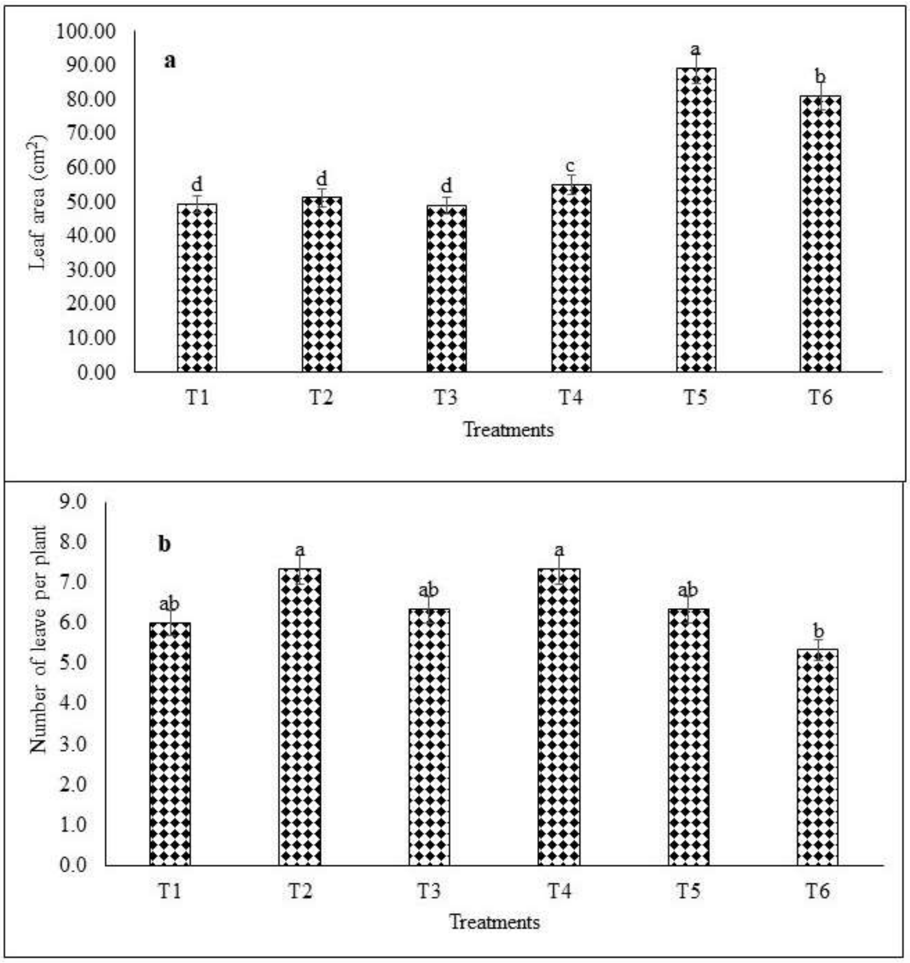

Figure 3. (a) Effects of the biochar and straw residues on the leaf area and (b) Effects of the biochar and straw residues on number of leaves per plant of maize crop**.** T1= Control, T2= Biochar recommended dose (40 tons ha^{1}), T3=12.5 tons ha^{-1} Straw residues, T4= 25 tons ha^{-1} Straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} Straw residues, T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} Straw residues.

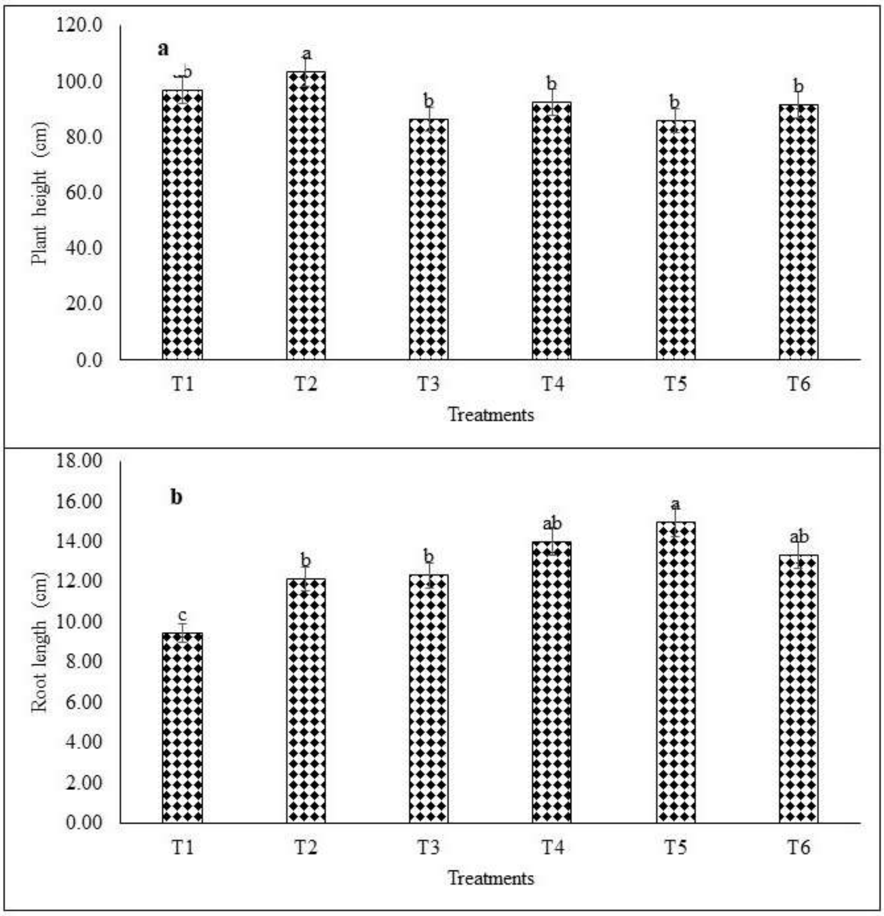

Figure 4. (a) Effects of the biochar and straw residues on the plant height and (b) Effects of the biochar and straw residues on root length of maize crop T1= Control, T2= Biochar recommended dose (40 tons ha^{1}), T3=12.5 tons ha^{-1} straw residues, T4= 25 tons ha^{-1} straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} straw residues, T6= 40 tons ha-^{1} biochar + 12.5 tons ha^{-1} straw residues.

Seed Index and number of grains per cob: Significant differences in number of grains per cob was documented between treatments (Figure 5a). Combine application of the biochar and straw residues improved the number of grains per cob 262% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where maximum number of grains were counted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (113) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (100) and straw residues 25 tons ha^{-1} **(**73). However, minimum results for the parameter mentioned above were recorded in control (31) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} with mean results of 50 and 55 respectively. It is evident that improved number of grains by addition of organic manures (Hirzel *et al*. 2007) capacity be qualified to enhance nutrient obtainability of the soil (Marschner 2011). Masood *et al*. (2014) supported our findings where they applied different levels of plant-based biochar and found the significant difference in number of grains per cob.

Significant differences in seed index was documented between treatments (Figure 5b). Combine application of the biochar and straw residues improved the seed index 68% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where maximum seed index was noted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (16 g) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (13 g) and biochar 40 tons ha^{-1} with value of (12.70 g). However, minimum results for the said parameter were recorded in control (9.67 g) followed by and straw residues 25 tons ha^{-1} with mean result of (11.67 g). Our results for seed index are in link by the conclusions of Masood *et al*. (2014) where they stated that claim of biochar improved the nutrient application of the soil which affected seed index in a positive way as biochar application significantly improved N, P, and K approval in maize crop. Additionally, the growing volume of biochar will too reduce nutrient percolating, particularly N and K (Zwieten *et al*., 2010). Seed index, also known as 1000 grain weight, is an important yield element, which pays to ultimate final yield of maize crop. Khan *et al*. (2022) reported that seed index was significantly affected when different regimes of treatment applied which supports the findings of our work.

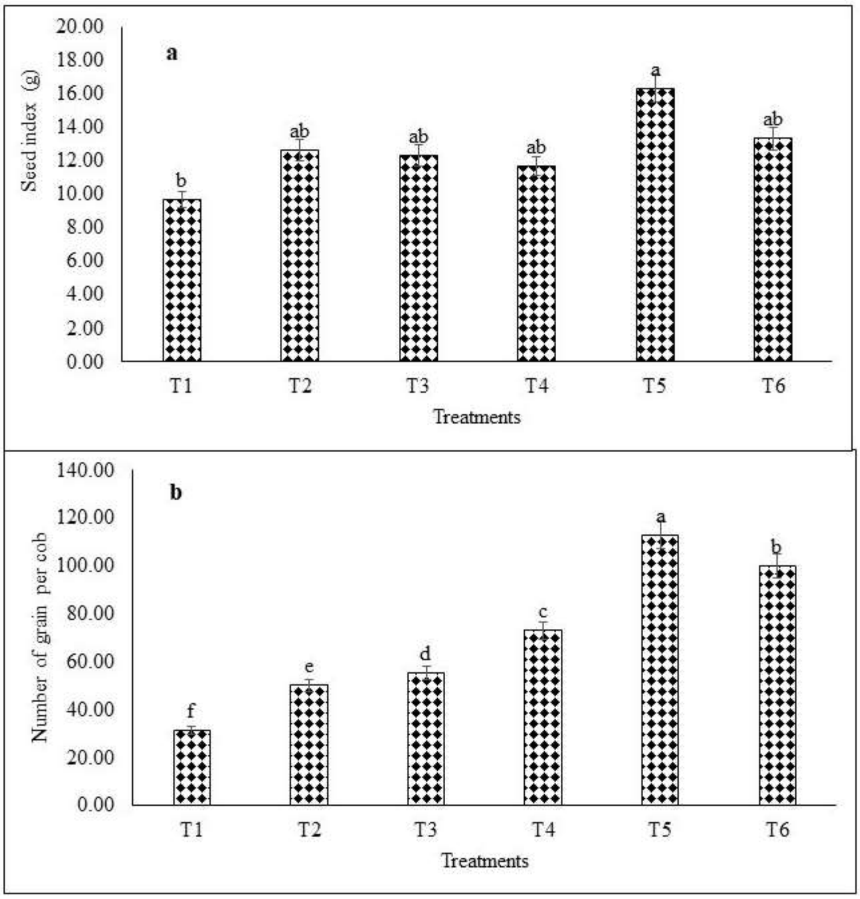

Figure 5. (a) Effects of the biochar and straw residues on seed index and (b) Effects of the biochar and straw residues on the number of grains per cob of maize crop. T1= Control, T2= Biochar recommended dose (40 tons ha[1]), T3=12.5 tons ha^{-1} straw residues, T4= 25 tons ha^{-1} straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} straw residues, T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} straw residues.

Cob length (cm) and grain yield (g): Significant differences in cob length were documented between treatments (Figure 6a). Combine application of the biochar and straw residues improved the cob length 78% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where max cob length was noted in 25 tons ha^{-1} straw residues and biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} with average value of (11.30 cm) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (10.77 cm). However, minimum length of cob was measured in control (6.30 cm) followed by straw residues 12.5 tons ha^{-1} and biochar 40 tons ha^{-1} with mean result of (8.70 cm) and (10.30 cm) respectively. The best performance of maize under Treatments 25 tons ha^{-1} straw residues and biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} was payable to improved soil disorder resultant from this application. Biochar can seriously affect soil carbon dioxide emissions which boosted yield components in maize plant (Wu *et al*., 2013). Improve in maize yield components in rejoinder to the application of banana derived biochar and straw residues are adduced to the fact that they contain nutrients which are unconfined to the soil for maize crop likened with no implementation of the treatments (Shirani *et al*., 2002). Our results for cob length are in link through the outcomes of Masood *et al*. (2014) where they stated that different levels of biochar application affected cob length in maize plant.

Significant differences in grain yield were documented between treatments (Figure 6b). Combine application of the biochar and straw residues improved the grain yield 120% as against Control. Based on the performance of different levels of treatment applied, results can be drawn where maximum grain yield was noted in biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} (25 g) followed by biochar 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1} (23 g) and straw residues 25 tons ha^{-1} with value of (21 g). However, minimum results for the said parameter were recorded in control (11 g) followed by straw residues 12.5 tons ha^{-1} with mean result of (16 g). The compliance of biochar augmented maize development and yield in comparison with the control. A likewise result of biochar on grain income as a product of soil P obtainability was also experiential by Asai *et al*. (2009) where maize grain yield was meaningfully improved in plots with low obtainable P as a product of amplified plant available P after the accumulation of biochar. Different mechanisms have been suggested for increment in grain yield after the application of plant-based biochar. Comparable outcomes were stated by Omara *et al*. (2020) who recorded 17 and 13% increase in maize grain yield when nitrogen-biochar combination (NBC) integrated with 50 and 100 kg N ha^{-1}. More leaf nutrient buildup and nutrient uptake, as well as an improvement in overall soil physical and chemical condition after the addition of banana extracts, could explain the increase in grain yield. As one group of researchers reported 150% increase in maize grain yield when added 15 t ha^{-1} plant-based biochar under acidic sandy soil (Uzoma *et al*., 2011). However, short routine in the no manure implementation plots was payable to improved bulk density, which is recognized to decrease root elongation at little water content (Adekiya and Ojeniyi 2002), this will unfavorably decrease nutrient and water application and therefore little grain yield.

Different levels of biochar and straw residues significantly affected grain yield which was confirmed from previous studies carried out by Rafiq *et al*. (2010) where it was noted that grain yield of maize crop was pretentious significantly ($p<0.05$) when different stages of fertilizer applied. Furthermore, (Masood *et al*., 2014; Khan *et al*., 2022)) stated that grain income was significantly affected when different regimes of treatment applied which supports the findings of our work.

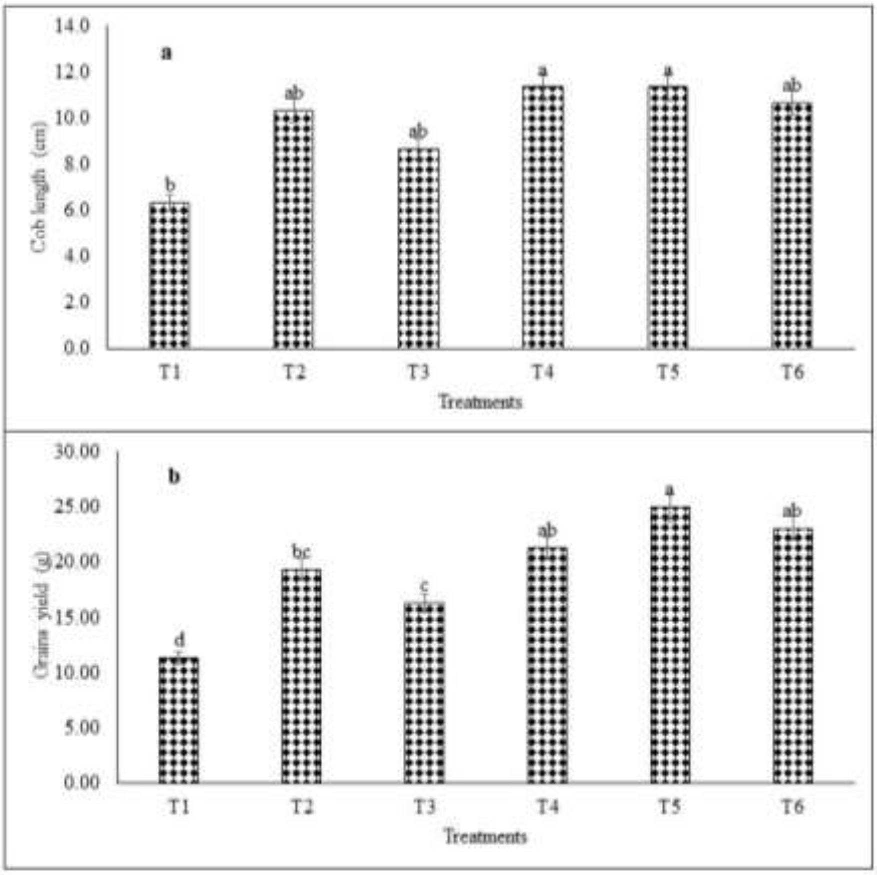

Figure 6. (a) Effects of the biochar and straw residues on the Cob length and (b) Effects of the biochar and straw residues grains yield of maize crop. T1= Control, T2= Biochar recommended dose (40 tons ha^1), T3=12.5 tons ha^{-1} straw residues, T4= 25 tons ha^{-1} straw residues, T5= 40 tons ha^{-1} biochar + 25 tons ha^{-1} straw residues, T6= 40 tons ha^{-1} biochar + 12.5 tons ha^{-1} straw residues.

Relationship of grain yield with biomass traits of maize: Correlation coefficients was derived among these parameters at probability level (p<0.001) (Table 2). Shoot fresh biomass was significantly connected with grain yield (r=0.77), leaf area (r=0.97), number of grains per cob (r=0.94) and seed index (r=0.72). Moreover, leaf area was significantly connected by grain yield (r=0.77), number of grains per cob (r=0.93) and seed index (r=0.71). On the other hand, root length was significantly connected by grain yield (r=0.80), number of grains per cob (r=0.80) and cob length (r=0.72). In addition to this, number of grains per cob were significantly associated with grain yield (r=0.90) and seed index (r=0.74) whereas, seed index was significantly connected only by grain yield (r=0.72).

In addition to this, when correlation coefficient was derived at 99% confidence level, shoot fresh biomass was also positively correlated with root length (r=0.63) whereas root fresh biomass was significantly associated with grain yield (r=0.68) and root dry mass (r=0.64). Moreover, leaf area was too definitely connected only by root length (r=0.61) at significant level (p<0.01). Optimistic plant rejoinder in plant development due to biochar improvement was too experiential by Hossain *et al*. (2010). Reported increase in plant yield later biochar submission and credited this rise to the increase in soil obtainable nutrients. There were important optimistic effects of biochar level on overall height and number of leaves at dissimilar development phases of maize crop (Uzoma *et al*., 2011). Biochar amount also presented a significant result on over-all grain yield of maize. Furthermore, when correlation coefficient was derived among growth and yield parameters at probability level (p<0.05), it was concluded that shoot fresh weight was correlated by cob length (r=0.48) and root fresh weight (r=0.48). Nevertheless, root fresh biomass was also positively correlated with leaf area (r=0.53), number of grains per cob (r=0.56), cob length (r=0.49) and seed index (r=0.49). Moreover, shoot dry biomass was significantly associated by number of grains per cob (r=0.40) and root length (r=0.47) whereas, root dry biomass was significantly associated with root fresh biomass (r=0.64) as well as seed index (r=0.46). Similarly, leaf area was correlated only with cob length (r=0.47) whereas, root length was correlated with only seed index (r=0.53). In addition to this, number of grains per cob was definitely correlated only with cob length (r=0.64) whereas, seed index was also completely correlated with cob length (r=0.53) as well as with root fresh biomass (r=0.49) at 95% confidence level. Variances in the number of leaves crosswise the dissimilar growth phases were also comparable to that of height. Respectable plant height and number of leaves are actual significant because they are imperative for photosynthesis which eventually distress yield. Rafiq *et al*. (2010) claimed that plant height was absolutely correlated by grain yield. Biochar has gained a tremendous momentum in agriculture sustainability and environment safety in the current era. Banana derived biochar and straw residues cheap bulk density and temperature and improved moistness content and permeability likened by the control. Growth inspiration has been practical concluded organic materials in the biochar such as carboxylic acids and phenols or shifts in microbial inhabitants near recognized growth supporting microorganisms (Graber *et al*. 2010)

Table 1. Relationship of grain yield with other growth parameters of maize crop.

	GRY	LA	NGR	NL	PHT	RDM	RFM	RTL	SDM	SFM	SI
LA	0.77***										
NGR	0.90***	0.93***									
NL	0.03ns	-0.33ns	-0.18ns								
PHT	-0.06ns	-0.23ns	-0.28ns	0.14ns							
RDM	0.30ns	0.14ns	0.15ns	0.01ns	0.11ns						
RFM	0.68**	0.53*	0.56*	0.18ns	0.08ns	0.64**					
RTL	0.80***	0.61**	0.80***	0.12ns	-0.27ns	0.04ns	0.37ns				
SDM	0.37ns	0.37ns	0.40*	0.07ns	-0.26ns	-0.03ns	0.34ns	0.47*			
SFM	0.77***	0.97***	0.94***	-0.34ns	-0.27ns	0.14ns	0.48*	0.63**	0.39ns		
SI	0.72***	0.71***	0.74***	-0.16ns	-0.04ns	0.46*	0.49*	0.53*	0.06ns	0.72***	
CL	0.72***	0.47*	0.64*	0.33ns	0.00ns	0.08ns	0.49*	0.72***	0.06ns	0.48*	0.53*

*=significant (p<0.05), **=significant (p<0.01), ***=significant (p<0.001), ns=non-significant (p>0.05). Grain yield (GRY), Leaf area (LA), Number of grains (NGR), Number of leave (NL), Plant height (PHT), Root dry biomass (RDM), Root fresh biomass (RFM), Root length (RTL), Shoot dry biomass (SDM), Shoot fresh biomass (SFM), Seed index (SI), Cob length (CL).

Conclusion

Co-application of the biochar with straw residues significantly affected the growth and yield components of maize crop. Overall, shoot fresh biomass, root fresh biomass, root length, number of grains per cob, seed index, cob length, grain yield and leaf area were increased under biochar 40 tons ha^{-1} and straw residues 25 tons ha^{-1} followed by 40 tons ha^{-1} and straw residues 12.5 tons ha^{-1}**.** Correlation coefficient indicated that significant association among different morphological characteristics when subjected to these combined applications of biochar and straw residues were studied. Most of the growth parameters were positively correlated with yield components which indicated that improvement of any of the growth trait will directly or indirectly enhance yield components. This study concluded that biochar and straw residues application on a level of 40 t ha^{-1} and 25 tons ha^{-1} was optimal to enhance maize development and grain yield. Future studies are wanted to evaluate the slong-term studies of biochar along with straw residues and its performance in maize grown fields.

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