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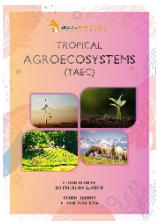

RESEARCH ARTICLE

EFFECT OF DIFFERENT DOSES OF BIOCHAR ON SOIL PROPERTIES, GROWTH PARAMETERS AND YIELD ATTRIBUTES OF TOMATO (SOLANUM LYCOPERSICUM MILL) IN KHOTANG, NEPAL

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ABSTRACT

This study was carried out from Feb to June, 2023 with an objective to assess the optimum dose of biochar for growth and yield of tomato in Khotang district. The experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments replicating four times. Biochar treatments significantly improved plant height, stem diameter, leaf and flower number, fruit count, size, and overall yield compared to the control. $BC_{6t/ha}$ +RDF treatment exhibited the highest number of flowers and fruits, indicating biochar's positive influence on improving soil properties and nutrient availability for better growth, flowering and fruiting in tomato plants. Larger fruit size in the $BC_{6t/ha}$ +RDF treatment indicates enhanced nutrient uptake and water retention. The overall improvement of plant vegetative and reproductive attributes is resulted best at $BC_{6t/ha}$ +RDF treatment level followed by $BC_{8t/ha}$ +RDF. However, $BC_{8t/ha}$ +RDF showed the highest yield of tomato. Thus, this study recommends $BC_{8t/ha}$ +RDF as optimum application of biochar as sustainable soil amendment for tomato production.

KEYWORDS

Biochar, amendment, tomato, effect, soil properties

1. INTRODUCTION

Tomatoes are flowering plant belonging to nightshade family Solanaceae and staple in different cuisines around the world for its edible fruits (Klee, Harry J et al.,2020 and Britannica, 2024). It is native to South America where it was named from Spanish tomate which is derived from Nahuatl word 'tomatl' (Douglas, 2024). As it is a relatively short-duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily (Bose, T.K., and Som, M.G., 1986). World tomato production in 2001 was about 105 million tons of fresh fruit from an estimated 3.9 million ha. The largest producer of tomato is China (One quarter) followed by India and the United States (FAO, FAOSTAT, 2016). The tomato plant is an annual that is harvested after just one growing season and can reach a height of 0.7 to 2 meters (2.3 to 6.6 feet) (plantvillage.psu.edu). Certain varieties of tomato plants are compact and upright, but most are heavily branched, spreading 60–180 cm (24–72 inches), and somewhat trailing while fruiting (Britannica, 2024). The tomato plant yields a spherical fruit (berry) with smooth, meaty skin that can be red, pink, purple, brown, orange, or yellow, as well as yellow flowers that can grow into a cyme of three to twelve (Atherton, J.G., and Rudich, J., 1986).

Tomatoes can be prepared in a variety of ways and come in a variety of sizes which consist of soups, liquids, purees, raw tomatoes, stewed tomatoes, and cherry tomatoes (Motamedzadegan and Tabarestani, 2011). Numerous health-promoting substances, including vitamin C, vitamin E, carotenoids (lycopene and b-carotene), and phenolic compounds are abundant in tomatoes that have gathered a lot of attention due to their antioxidant activity and protective functions in preventing chronic diseases like cardiovascular disease and cancer (Petruccelli, et al., 2015). Tomato juice is known as a great sport drink to restore from sleepiness and fatigue (Bhowmik et al., 2012).

Tomato is widely adapted in various agro-climatic conditions of Nepal and can be produced year around. It covers 180 ha with a total production of 1,800 Mt in Khotang district and 5,131 ha area with a total production of 1,31,970 Mt in Koshi province (MOALD, 2077-78). Nepal is still behind to meet its fruits and processed good demand as only minor portion of 4.875 Mt. costing Rs. 200 Thousand is exported and majorly 596.053 Mt. costing Rs. 24 Million is being imported in Nepal (Customs, 2019/20). Due to lack of proper knowledge and judicious application of fertilizers, Khotang district has comparatively lower productivity than national average and province average productivity. Annually, 2 to 105 Mt/ha of soil gets eroded from agricultural land of Nepalese hill, where 5 Mt/ha soil loss equivalents to loss of 75 kg/ha of Organic Matter (OM), 3.8 kg/ha of Nitrogen (N), 10 kg/ha of Potassium (K) and 5 kg/ha of Phosphorous (P) in mid hills situation (Tripathi, 2019). Furthermore, the ability of hilly agricultural land to retain fertilizer is low because of the shallow soil layer, low to high degree of slope, and runoff. It follows that farming must be conservative and focus on soil improvement, especially in these vulnerable areas (Dahal et al., 2018). Thus, Soil degradation and poor fertility status of soil is the vital cause for lower productivity of various agricultural products in Nepal.

Regarding the above-mentioned difficulties faced, the potential advantages of biochar application for crop production, soil fertility, and

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carbon sequestration have led to its increasing use in agriculture and increased research interest worldwide. Biochar is a fine-grained, porous, carbon-rich material that is created when biomass is thermally decomposed at low temperatures (less than 700 °C) and with limited oxygen. It is necessary to apply this material to the soil intentionally for energy production, waste valorization, and soil improvement in agriculture and the environment (Manya, Azuara, and Manso, ,2018). Global warming and climate change have negative effects on the entire world (IPCC, 2021). The manufacture of biochar and its application in agriculture can significantly reduce the effects of climate change and enhance the management and quality of waste products originating from forestry and agriculture. Applying biochar to soil can improve soil quality and agricultural yield while lowering gas emissions and increasing soil carbon sequestration (Alburquerque, et al., 2013).

Utilizing biochar improved crop yields, reduced soil acidity, increased soil capacity to hold water and nutrients, reduced greenhouse gas emissions from the soil, and stimulated nutrient uptake (Sohi et al., 2009). The soil status of Khotang district is acidic in nature. Thus, pyrolytic biochar seems to be beneficial in this condition due to its acidic soil reclamation property and also improves soil fertility and aid in carbon sequestration (Chintala et al., 2014). Moreover, Biochar can boost photosynthesis, improve carbon sequestration, decrease greenhouse gas emissions, minimize soil erosion, and increase the effectiveness of polluted soil removal (Alori et al., 2023).

This suggests that biochar can serve as alternative for synthetic fertilizer as it becomes scarce and polluting. Conversely, several studies have shown a decrease in plant growth when biochar is applied, and they have also revealed various causes for this drop phenomenon. Therefore, it is still unclear if biochar will eventually help plants by supplying nutrients or hinder their growth by sequestering them. So, this research will facilitate the optimal application of biochar, disclosing the proper combination of biochar and chemical fertilizer in ratio, examining the impact of biochar on soil, and recognizes the benefits and drawbacks of using biochar

2. Materials and Methodology

2.1 Experimental Site

The field experiment was conducted at Rupakot Majhuwagadhi-06, Khotang, Nepal (figure 1). It lies in the lower region of subtropical mid hill in Khotang, Koshi province within latitude 27°13'23'' N and longitude 86° 48'50'' E at the height of 1200 masl. The preceding crop was potato and the situated site has suited for tomato cultivation all year round. The research was carried out from 12th March, 2023 to 22nd June, 2023. During the research period, the mean temperature and precipitation recorded on the field was 25.6°C and 2.3-16.2mm respectively.

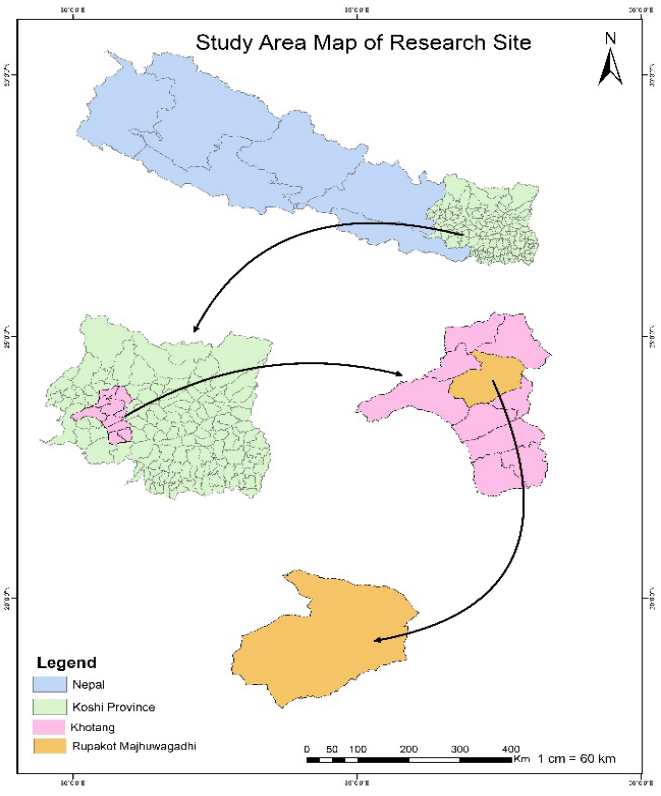

Figure 1: Study Area Map of Research Site

2.2 Experimental Design and Method

The experiment was laid out in Randomized Complete Block Design (RCBD) with five treatments and each replicated four times. Each plot was 1.8 ×2.25 m² having three rows at spacing of 60 cm and each contain 5 plants at distance of 45 cm in row. Each experimental plot area was 4.05 m² and the space between each plot, block and in border was 65 cm, 1 m and 50 cm respectively. Hence, gross experimental field area was 156 m².

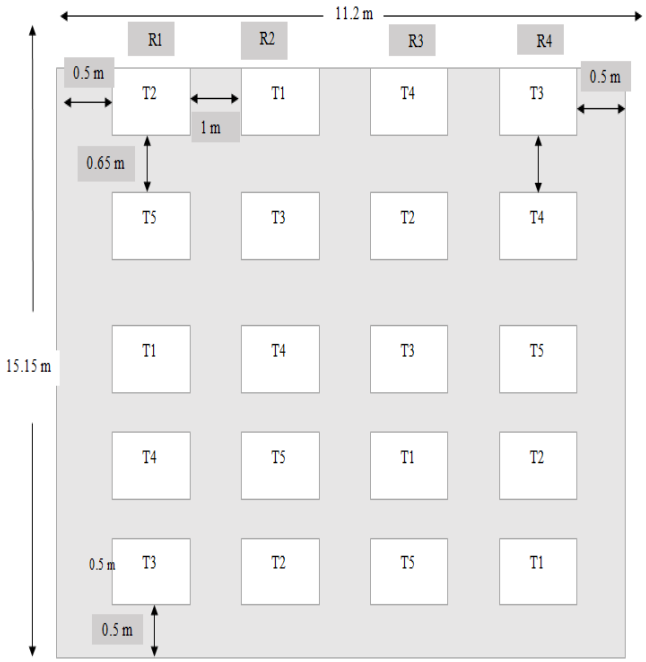

Figure 2: Research Field Layout

2.3 Variety and Treatment description

The B.L-410 determinant variety of tomato was cultivated for the research study due to its capacity to tolerate hail and drought with higher storage life. This variety was grown in the open field condition. The cultivar was sown on March 8, 2023 and transplanted on April 8, 2023. Total of five treatments were made for the study according to application of different amount and doses of biochar as a soil amendment keeping uniform application of FYM and RDF (N, P, K). The treatments details and biochar applied accordingly is given.

Table 1: Treatment details and biochar applied according to treatment

Treatment types	Notation	Biochar applied per plot(kg/4.05m²)	Biochar applied per ha(Mt.)
Control	T1	0	0
2 t/ha Biochar + RDF of NPK	T2	0.810	2
4 t/ha Biochar + RDF of NPK	T3	1.620	4
6 t/ha Biochar + RDF of NPK	T4	2.430	6
8 t/ha Biochar + RDF of NPK	T5	3.240	8

2.4 Preparation and application of Biochar

Biochar was prepared from various locally sourced feed stocks including *Eupatorium* adenophorum, dry banana leaves, *Pinus* roxburghii, Schima wallichii, Alnus nepalensis, and rice husk. The biomass underwent pyrolysis in a controlled oxygen environment at atmospheric pressure within a V-shaped pit. For biochar production, different feed stocks were burnt in the pit, with the surface being partially covered to maintain low oxygen conditions. The burning required a considerable duration, resulting in approximately 50% of the biomass being transformed into biochar after a cooling period of one hour.

Biochar was mixed into the soil one week before of transplanting tomatoes to improve soil fertility and structure. The different doses of biochar was applied variably in experimental plots according to treatment. This can help retain moisture and nutrients in the soil, which can benefit plant growth and yield.

2.5 Field Operations

Research land having soft, well-drained and well-aerated soil was selected for growing tomato. The soil was made deeply ploughed and harrowed until completely free of weed roots. Experimental plot was raised at 15cm height was made on the field and urine charged biochar was incorporated a week before transplanting as soil amendment according to treatment design.

The seeds were sown on trays having growing medium of soil, coco-peat and vermin-compost at 2:1:1 ratio and the seedlings were ready for transplanting between 4-5 weeks after seeding in beds. Seedlings were hardened before transplanting them.

Due to adequate moisture requirement of tomato during its growing period it was immediately irrigated after transplanting followed by small, frequent watering on daily basis. The fertilizers were applied according to recommended dose of 30 ton/ha, 200 kg/ha, 180 kg/ha and 100 kg/ha for FYM, Nitrogen, Phosphorus and Potassium respectively. All the fertilizers were incorporated into the field before transplanting except N source which was split into two halves at basal and top dressing. Along with that hand weeding was done twice at 30 DAT and 50 DAT.

In determinate cultivars, fruits can be normally harvested after 70 days of transplanting depending on the environmental condition. Fruit harvesting was done at the right stage, which depends upon the purpose of fruit utilization.

2.6 Data Collection

For the evaluation of effect of different dose of biochar in soil properties, growth parameters, yield and yield attributes of tomato, data was collected from the randomly selected five sample plants among 15 plants of each plot. Data was collected after 14 DAT followed by 14 days of interval. Bio-morphological characters of five tagged plants were recorded while collecting data and yield was recorded after final harvest. Plant height was measured by using measuring scale ranging from soil surface to top of growing point of sample plants. Leaves number, flowers per plant and fruits per plant were measured by randomly counting. While Vernier calipers was used to measure main stem diameter and fruit diameter of sample plants. The average productivity of tomato was recorded by weighing the fruit weight per plot via weighing machine for accurate result. Soil samples was collected from the field before biochar application and at the end of the experiment to evaluate the soil properties. The evaluated soil properties will be soil P^H, Organic Matter, Nitrogen, Phosphorus and Potassium.

2.7 Statistical Analysis

The data collected was refined and entered in MS-Excel sheet and was analyzed to draw meaningful interferences by using statistics software R-STUDIO Version 4.3.1. (Installing GVLMA and Agricolae Package) Mean comparison of analyzed parameters was done using DMRT (Duncan's Multiple Range Test) at 5% level of significance to find out the significance difference among the various means.

3. Results

3.1 Plant Height

Plant height was found significant at 14 DAT, 42 DAT, 56 DAT and 70 DAT observation while non-significant at 28 DAT (Table 2). BC_{6t}+RDF showed the highest plant height at 14 DAT, 42 DAT, 56 DAT and 70 DAT having observation of 14.80 cm, 46.85 cm, 67.725 cm and 72.3 cm respectively. Among all treatments, Cultivation without biochar application C_0 showed significantly lowest plant height in different observation days which was statistically at par with $BC_{8t/ha}$ +RDF also at 14 DAT.

Table 2: Plant height of tomato influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	Plant height at 14 DAT (cm)	Plant height at 28 DAT (cm)	Plant height at 42 DAT (cm)	Plant height at 56 DAT (cm)	Plant height at 70 DAT (cm)
C_0	11.78^{d}	25.45^{a}	42.65^{b}	56.325^{d}	63.175^{d}
$BC_{2t/ha}$+RDF	13.53^{b}	26.10^{a}	43.85^{b}	61.60^{c}	66.650^{c}
$BC_{4t/ha}$ +RDF	13.35^{bc}	25.35^{a}	43.45^{b}	65.725^{ab}	70.025^{ab}
$BC_{6t/ha}$ +RDF	14.80^{a}	26.25^{a}	46.85^{a}	67.075^{a}	72.300^{a}
$BC_{8t/ha}$ +RDF	12.43^{cd}	27.65^{a}	42.75^{b}	63.625^{bc}	68.275^{bc}
LSD(0.05)	1.094	3.80	2.11	2.30	2.40
SE_m(+-)	0.15	0.55	0.30	0.33	0.34
F-probability	***	NS	**	***	***
CV(%)	5.40	9.45	3.13	2.37	2.28
Grand Mean	13.18	26.16	43.91	62.87	68.085

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.2 Stem Diameter

Stem diameter was found significant at 28 DAT and 70 DAT among different doses of biochar (Table 3). C_0 (0.72 cm) and $BC_{4t/ha}$ +RDF (1.58 cm) significantly showed the thickest stem diameter at 28 DAT and 70 DAT respectively. In contrary, $BC_{4t/ha}$ +RDF (0.58 cm) and $BC_{2t/ha}$ + RDF (1.36 cm) recorded the thinnest stem diameter significantly at 28 DAT and 70 DAT respectively with statistical equivalent with other remaining treatments.

Table 3: Stem diameter was found significant at 28 DAT and 70 DAT among different doses of biochar

Treatment	Stem diameter at 14 DAT (cm)	Stem diameter at 28 DAT (cm)	Stem diameter at 42 DAT (cm)	Stem diameter at 56 DAT (cm)	Stem diameter at 70 DAT (cm)
C_0	0.36	0.72^{a}	1.05^{a}	1.28^{a}	1.40^{b}
$BC_{2t/ha}$+ RDF	0.39	0.66^{ab}	1.07^{a}	1.15^{a}	1.36^{b}
$BC_{4t/ha}$ +RDF	0.38	0.58^{c}	0.92^{a}	1.16^{a}	1.58^{a}
$BC_{6t/ha}$ +RDF	0.35	0.62^{bc}	1.05^{a}	1.26^{a}	1.38^{b}
$BC_{8t/ha}$ +RDF	0.37	0.69^{a}	1.11^{a}	1.24^{a}	1.41^{b}
LSD(0.05)	0.057	0.063	0.195	0.212	0.091
SE_m(+-)	0.008	0.0092	0.028	0.030	0.013
F-probability	NS	**	NS	NS	**
CV (%)	10.22	6.31	12.21	11.32	4.14
Grand Mean	0.366	0.65	1.037	1.217	1.428

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.3 Number of Leaves

Among treatments only at 42 DAT, there is a significant difference among treatments on leaves number (table 4). At 42 DAT, $BC_{8t/ha}$ +RDF (44.65)

resulted significantly the highest no. of leaves. In contrary, $BC_{6t/ha}$ +RDF (27.80) resulted the lowest no. of leaves followed by other treatments.

Table 4: Leaves number of tomatoes influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	No. of leaves at 14 DAT	No. of leaves at 28 DAT	No. of leaves at 42 DAT
C_0	5.60[a]	14.75[a]	35.75[b]
$BC_{2t/ha}$+RDF	5.60[a]	14.10[a]	36.00[b]
$BC_{4t/ha}$ +RDF	5.25[a]	12.50[a]	35.05[b]
$BC_{6t/ha}$ +RDF	5.25[a]	13.80[a]	27.80[c]
$BC_{8t/ha}$ +RDF	5.80[a]	15.65[a]	44.65[a]
LSD(0.05)	0.99	4.58	3.82
SE_m(+-)	0.144	0.66	0.55
F-probability	NS	NS	***
CV(%)	11.76	21.03	6.93
Grand Mean	5.5	14.16	35.85

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.4 Number of Flowers

The number of flowers counted at 42 DAT and 56 DAT showed the significant difference among different treatments (Table 5). The highest number of flowers were counted by $BC_{6t/ha}$ +RDF treatment 12.27 and 44.22 at 42 DAT and 56 DAT respectively which was significantly higher than the flower number of other treatments. In contrary, $BC_{4t/ha}$ +RDF (4.35) and C_0 (24.05) resulted significantly lower no. of leaves at 42 DAT and 56 DAT respectively was statistically at par with $BC_{2t/ha}$ +RDF(4.35).

Table 5: Number of flowers in tomatoes influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	No. of flowers at 42 DAT	No. of flowers at 56 DAT
C_0	8.80[b]	24.05[c]
$BC_{2t/ha}$+ RDF	5.75[c]	28.92[bc]
$BC_{4t/ha}$ +RDF	4.35[c]	34.65[b]
$BC_{6t/ha}$ +RDF	12.27[a]	44.22[a]
$BC_{8t/ha}$ +RDF	6.95[bc]	33.05[b]
LSD(0.05)	2.65	6.27
SE_m(+-)	0.38	0.91
F-probability	***	***
CV(%)	22.56	12.34
Grand Mean	7.625	32.98

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.5 Number of Fruits

There is a significant difference among treatments on fruit number at 56 DAT and 70 DAT as indicated by Table 6. $BC_{8t/ha}$ +RDF (59.675) and $BC_{6t/ha}$ +RDF (65.05) resulted significantly the highest no. of fruits at 56 DAT and 70 DAT respectively. In contrary, $BC_{4t/ha}$ +RDF (31.30) and $BC_{2t/ha}$ +RDF (40.85) resulted the lowest no. of fruits.

Table 6: Number of fruits in tomatoes influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	No. of fruits at 42 DAT	No. of fruits at 56 DAT	No. of fruits at 70 DAT
C_0	4.45[a]	42.80[b]	55.22[ab]
$BC_{2t/ha}$+RDF	3.40[a]	38.70[bc]	40.85[b]
$BC_{4t/ha}$ +RDF	1.75[a]	31.30[c]	50.25[ab]
$BC_{6t/ha}$ +RDF	3.85[a]	44.02[b]	65.05[a]
$BC_{8t/ha}$ +RDF	3.20[a]	59.675[a]	61.15[a]
LSD(0.05)	2.86	9.13	13.79
SE_m(+-)	0.41	1.32	2.00
F-probability	NS	***	*
CV (%)	55.76	13.69	16.42
Grand Mean	3.33	43.3	54.50

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.6 Fruit Size

Among treatments, 56 DAT and 70 DAT showed significant difference on fruit size Table 7.

The highest fruit size was produced by $BC_{6t/ha}$ +RDF as 3.07 cm and 3.72 cm at 56 DAT and 70 DAT respectively. In contrary, $BC_{8t/ha}$ +RDF and C_0 showed the lowest fruit size at both observations.

Table 7: Fruit size of tomatoes influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	Fruit diameter at 42 DAT (cm)	Fruit diameter at 56 DAT (cm)	Fruit diameter at 70 DAT (cm)
C_0	1.14[ab]	2.58[b]	3.18[b]
$BC_{2t/ha}$+RDF	1.13[ab]	2.89[a]	3.31[b]
$BC_{4t/ha}$ +RDF	0.63[b]	2.96[a]	3.31[b]
$BC_{6t/ha}$ +RDF	1.22[a]	3.07[a]	3.72[a]
$BC_{8t/ha}$ +RDF	1.20[a]	2.56[b]	3.21[b]
LSD(0.05)	0.50	0.27	0.29
SE_m(+-)	0.073	0.084	0.089
F-probability	NS(.)	**	*
CV(%)	30.90	6.35	5.66
Grand Mean	1.061	2.815	3.34

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.7 Yield of Tomatoes

There is significant differences seen for yield of tomatoes due to the effect of different doses of biochar (table 8). On appraising the effect of different doses of biochar on yield of tomatoes, $BC_{8t/ha}$ +RDF (17.99 t/ha) resulted the highest yield which was significantly difference over other treatments. In contrary, the lowest yield was obtained by C_0 (10.95 t/ha) which is statistically at par with $BC_{2t/ha}$ +RDF (12.15 t/ha) and $BC_{4t/ha}$ +RDF (12.85 t/ha).

Table 8: Yield of tomatoes influenced by the different doses of Biochar at Diktel Rupakot Majhuwagadhi-06, Khotang during 2023

Treatment	Yield of tomatoes (Mt/ha)
C_0	10.95^{c}
$BC_{2t/ha}$+RDF	12.15^{c}
$BC_{4t/ha}$ +RDF	12.85^{bc}
$BC_{6t/ha}$ +RDF	15.05^{b}
$BC_{8t/ha}$ +RDF	17.99^{a}
LSD(0.05)	2.33
SE_m(+-)	0.71
F-probability	***
CV(%)	10.99
Grand Mean	13.8

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

3.8 Soil Properties

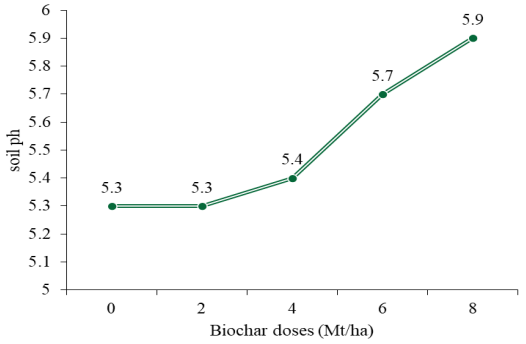

Figure 1: Soil pH as influenced by the different doses of Biochar application at Diktel Rupakot Majhuwagadhi-06, Khotang, Nepal (2023).

The effect of different doses of biochar shows, biochar added treatments improves the soil properties as increases in the doses of biochar application as shown in Table 9. The effect of treatment on soil organic matter, nitrogen, phosphorus and potassium was highly significant and found to be increased with increased rate of application (Table 9).

3.8.1 Soil pH

The effect of biochar application on soil pH at the time of tomato harvesting was not significant among the treatments but it was increased with higher rates of biochar application (figure 5).

3.8.2 Soil Organic Matter

The highest soil organic matter was obtained from $BC_{8t/ha}$ +RDF (3.42%) which was statistically similar ($p<0.001$) with $BC_{6t/ha}$ +RDF (3.07%) and it was the lowest (2.20%) from no biochar application (Table 9).

3.8.3 Nitrogen Content in Soils

*The highest nitrogen content (0.*17%) was found from 8 Mt ha^{-1} and 6 Mt ha^{-1} biochar application which was statistically similar with other treatments. The lowest nitrogen content (0.12%) was obtained from 2 Mt ha^{-1} biochar application and without biochar amended soil (Table 9).

3.8.4 Phosphorus Content in Soil

The highest phosphorus content was found from $BC_{8t/ha}$ + RDF (93.22 kg/ha) and it was statistically similar to $BC_{4t/ha}$ +RDF (89.40 kg/ha) and $BC_{6t/ha}$ + RDF (89.30 kg/ha) but was significantly higher than $BC_{2t/ha}$ + RDF (84.72 kg/ha) and C_0 (75.45 kg/ha).

3.8.5 Available Potassium Content in Soil

The highest available potassium content in soil was found from $BC_{6t/ha}$ +RDF (445.07 kg/ha) which was statistically similar with $BC_{8t/ha}$ +RDF (439.92 kg/ha) but significantly higher ($p<0.001$) than other treatments. The lowest available potassium content was found from $BC_{2t/ha}$ +RDF (341.10 kg/ha) it was significantly ($p<0.001$) lower than other treatments.

Table 9: Effects of different doses of biochar application on different soil properties during tomato harvest at Diktel Rupakot Majhuwagadhi-06, Khotang, Nepal (2023)

Treatment	Soil Organic Matter (%)	Soil P^H	Nitrogen Content (%)	Available Phosphorus(kg/ha)	Available Potash(kg/ha)
C_0	2.20^{c}	5.3^{a}	0.12^{a}	75.45^{c}	360.15^{c}
$BC_{2t/ha}$+RDF	2.68^{b}	5.3^{a}	0.12^{a}	84.72^{b}	341.10^{d}
$BC_{4t/ha}$ +RDF	2.86^{b}	5.4^{a}	0.15^{a}	89.30^{ab}	413.50^{b}
$BC_{6t/ha}$ +RDF	3.07^{ab}	5.7^{a}	0.17^{a}	89.40^{ab}	445.07^{a}
$BC_{8t/ha}$ +RDF	3.42^{a}	5.9^{a}	0.17^{a}	93.22^{a}	439.92^{a}
LSD(0.05)	0.3951	0.57	0.075	6.55	10.93
SE_m(+-)	0.0405	0.083	0.010	0.95	1.58
F-probability	***	NS	NS	***	***
CV(%)	9.007	6.71	32.89	4.92	1.77
Grand Mean	2.8475	5.52	0.14	86.42	399.95

*,** and *** represent significant at 5%, 1% and 0.1% level of significance respectively, NS=Non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based DMRT test.

4. Discussion

Adding biochar to soil improved the soil properties such as organic matter, pH, nitrogen, available phosphorus, and potassium content, as reported by (K. Y.A. Chan et al., 2008). In our experiment, all the measured soil properties were improved which is similar result with Hazman's findings. The outcomes pertain to an increase in the proportion of soil organic matter, which improves soil's ability to hold onto water, boosts cation-exchange capacity (CEC), lowers bulk density, and reduces loss of nutrients and other agricultural chemicals in soil runoff (Hazman et al., 2022). Although the shift for chicken litter biochar on acidic soils was as large as from pH 4.8 to 7.8, the average pre-amendment soil pH for the experimental trials used in the meta-analysis on plant productivity was 5.3, and the average post-amendment soil pH was 6.2, the study which supported our findings(Verheijen et al.,2010). In our research experiment, the soil P^H value increases as the doses of biochar aided to the experimental plots which did not have significantly differences in results. Biochar treatments led to increased plant height, with similar effects on stem diameter and the number of leaves, especially after 42 DAT (days after transplanting). At 28 DAT, there was no significant difference in plant height, but at later stages (42, 56, and 70 DAT), biochar treatments significantly outperformed non-biochar treatments. The increase in plant height may be due to biochar's moisture retention, improved nutrient retention, and its synergetic effect with mineral fertilizers, enhancing soil fertility (Hazman et al., 2022). If biochar enhances nitrogen levels, it could promote canopy, leaf, stem, and lateral branch growth (Millard and Mackerron, 1986). There were no significant differences in the number of leaves and stem diameter at the early growth stages, consistent with Hazman et al.'s findings. While biochar had no effect on tomato plant height in freshwater conditions, it increased the number of leaves in saltwater. Similarly, a analysis found no significant differences in plant

height and branch numbers in biochar-amended potato crops in Canada.Tomato yields were significantly higher in the $BC_{8t/ha}$ + RDF (recommended dose of fertilizer) treatment compared to other treatments Mawof et al.,2021). Yield increased with higher biochar application rates, consistent with previous studies is study which found that increasing biochar application enhanced radish Total Dry Matter (TDM) (K.Y.A. Chan et al., 2008). A research observed a 42% increase in radish TDM at 10 t/ha, rising to 96% at 50 t/ha, while the study reported that applying 5 or 10 tons of biochar per hectare improved tomato yield and quality, with yields ranging from 10 to 13 tons/ha. In this study, biochar from diverse sources showed varying results in tomato fruit size. $BC_{6t/ha}$ + RDF produced the largest fruit, but fruit size decreased as biochar doses increased with $BC_{8t/ha}$ + RDF(Chan et al.,2008). This aligns with a research who found that the source of biochar feedstock affected fruit weight in maize plants(Almaroai and Eissa .,2020). The number of flowers significantly increased with higher biochar doses, similar to findings a analysis who reported increased flower numbers with biochar addition. Unlike the results in this study found that a biochar rate of 10 t/ha produced lower radish yields compared to no biochar(Hazman et al., 2022.,Chan et al. 2007). This variation could be attributed to differences in crop type, climate, feedstock, pyrolysis conditions, and soil fertility (Biederman and Stanley Harpole, 2013).

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