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Research article

Effect of different levels of nitrogen and charcoal on growth and yield traits of chili (*Capsicum annuum* L.)

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ABSTRACT

Nitrogen and carbon sources are important for the growth and yield of chili. A combination of nitrogen and charcoal shows the potential to increase the availability of nutrients and stimulate plant performance. Therefore, an experiment was conducted to investigate the influence of different levels of nitrogen and charcoal on the growth and yield of chili. A pot experiment was carried out at Lamjung Campus, Lamjung, Nepal from 2019 to 2020. The experiment was carried out using two-factor Completely Randomized Design (CRD) with five replications. Twelve treatments consisted of three levels of nitrogen (0, 50 and 100 kg N ha^{-1}) and four levels of charcoal (0, 2.5, 5 and 7.5% by soil weight) were used in the experiment. Nitrogen and charcoal showed a significant effect on different growth and yield parameters. Nitrogen application at the rate of 100 kg N ha^{-1} showed significantly the maximum number of primary branches (8.25), plant height (52.62 cm), leaf area (54.33 cm^2), number of fruits per plant (42.95), fruit length (6.97 cm), yield per pot (97.14 g) and root length (29.87 cm). The application of 2.5% charcoal by soil weight showed a significant effect on plant height (53.60 cm), fruit length (7.12 cm) and yield per pot (77.55 g), while the application of 5% charcoal by soil weight produced the maximum number of fruits per plant (31.93). The combined level of nitrogen @ 100 kg N ha^{-1} and charcoal @ 2.5% by soil weight produced the yield per plot (127.1 g). This study suggests that chili production can be maximized by applying such a combined level of nitrogen and charcoal in the Lamjung.

1. Introduction

Chili is one of the important fruit vegetable or condiment (spice) belongs to the family Solanaceae. Nepal has a total area of 9687 ha allocated to chili cultivation, with a production of 100,344 metric tons and a productivity of 10.35 MT/ha [1]. It is an integral component of every Nepalese kitchen. Because of the pungency, pleasant flavor as well as of medicinal importance, fruit of pepper are in high demand thus it has attained the status of a high-value crop. Hot peppers are also used in industries for the manufacture of various products like chips, chilly powered, sauces etc. In addition to this, chili have antioxidant, antimutagenic, and hypo-cholesterolemic properties [2]. Globally, chili act as a source of revenue for farmers resulting in poverty alleviation and improvement

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of women's social status [3]. Similarly, vegetable farming including chili has been widely adopted by the people across all parts of Nepal including Lamjung as a part of their employment as well a way of life for rural farmers.

Nitrogen occupies conspicuous place in plant metabolic system and is the most important nutrient for plants to perform well. In the soil, it exists in two forms: organic and inorganic nitrogen. Most of the organic nitrogen is transformed to inorganic ammonium and nitrate, which plants use [4]. Nitrogen is also a key component of proteins, nucleic acids, and chlorophyll. The use of nitrogen fertilizer is crucial for improving the fruit production in chili [5]. According to numerous studies [6,7], the buildup of too much nitrate can lower agricultural yield because it inhibits photosynthesis and enzyme activity. Uptake and utilization of potassium, and phosphorous, which is also important nutrients for the growth and yield of chilies, can be enhanced by nitrogen and regulates the overall growth and development of plant [8,9].

When a chemical fertilizer is put into the soil, it is quickly depleted, either through leaching or degradation into a different form. Similarly, manure or compost can be drained from the soil, putting farmers under further financial strain. To provide food security for the growing population, agricultural production must be intensified in particular. It is only possible to sustain high quantities of soil organic matter by using carbonized materials derived from the incomplete combustion of organic compounds, such as charcoal [10], which is a carbon-rich solid and porous substance with excellent water and air retention properties that is made by heating biomass in an oxygen-depleted environment. The use of charcoal as a soil additive is analogous to the "slash-and-burn" method of fertilization. Humans began producing and using charcoal around 2500 years ago, according to archeological data. The first proof was discovered in South America's Amazon Basin [11], where Terra Preta conferred three times higher soil organic matter and nutrient levels [12]. The largest percentage of charcoal was employed as a soil supplement in agricultural land in Japan [13]. More importantly, using charcoal as a soil supplement has been shown to improve bioavailable water, soil organic matter, and increase the population of beneficial microorganisms due to the physical refuge given by the charcoal [14]. The potential of charcoal in soil act as suitable soil amendments for plant growth due to its ability to boost soil fertility and soil quality by raising soil pH, increasing moisture-holding capacity, improving cation exchange capacity (CEC), and retaining nutrients in the soil [15, 16]). Many studies have found that applying charcoal to soil improves soluble nitrogen adsorption [17,18,19,20,21].

Furthermore, growers' haphazard nitrogen administration causes deficiency or toxicity in crops, resulting in a considerable drop in crop yield. Moreover, most farmers are unaware of the optimal utilization of nitrogen fertilizer and charcoal effect. In these circumstances, fertilizer in combination with charcoal might be more beneficial. [22] discovered a similar correlation between enhanced peanut yield and increased pH, accessible nitrogen/phosphorus, and CEC. Many plants and soil scientists advise using charcoal to increase soil quality and plant growth [23]. Given the importance of the crop in the area, soil nutrient depletion, and a lack of adequate recommendations, a study is required to make recommendations for economically practical fertilizer application. With the help of this research, farmers will be able to learn about the importance of an adequate amount of nitrogen on the growth and yield parameters of chili, as well as the substantial importance of charcoal on the growth production of chili. Hence, the objective of the experiment was to investigate the effect of different levels of charcoal and nitrogen on and yield traits in chili.

2. Materials and methods

2.1. Experimental location

A pot experiment was conducted at the Horticulture Farm of the Institute of Agriculture and Animal Science (IAAS), Lamjung, Nepal from August 2019 to January 2020. The farm is located at 28.13°N latitude, 84.42°E longitude and 630 m altitude. The pot experiments was conducted outdoors. The meteorological data during the experiment is given in Fig. 1. The initial soil properties were analyzed at National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal for soil physicochemical analysis. The physical and chemical properties of the experimental site is given in Table 1 [24].

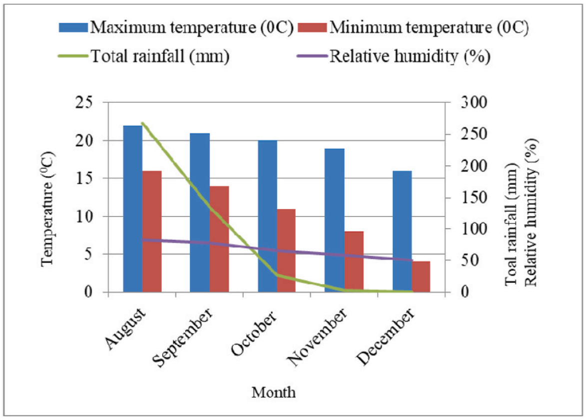

Fig. 1. Meteorological data of the experimental location in 2019–2020.

2.2. Description of experimental materials

Variety "NS 1701" of chili was grown in this experiment. This variety can be cultivated in the Lamjung district of Nepal. The seeds were obtained from Dawadi Agrovet, Narayangarh, Chitwan, Nepal. The source of the nitrogen fertilizer was urea (46% N). The urea, single super phosphate (SSP), muriate of potash (MOP) and charcoal were obtained from the same Agrovet. The farmyard manure (FYM) used in this experiment was cattle FYM. It was matured after 5 months of decomposition.

2.3. Experiment design, treatment details and cultural practices

The experiment was carried out using a two-factor completely randomized design with 12 treatments and five replications. The two factors include nitrogen and charcoal where, nitrogen was one factor with three different levels 0, 50 and 100 kg N ha^{-1} (=0, 2 and 4 g per pot) and charcoal was another factor at the rate of 0, 125, 250 and 375 g charcoal per pot (=0, 2.5, 5 and 7% by soil weight) were applied in the experiment (Table 1). Twelve treatments were replicated five times, thus there were altogether 60 pots in an experiment where a single pot was considered an experimental unit. Pot has a capacity of 5 kg soil with a top diameter of 22.5 cm, base diameter of 16.5 cm, and height of 18 cm was filled with 5 kg of forest soil and mixed uniformly with FYM viz. 10 t ha^{-1} (180 g per pot). Nitrogen in the form of urea was applied as per the treatments in three different doses *viz.* 0 kg N ha^{-1}, 50 kg N ha^{-1}, and 100 kg N ha^{-1} whereas phosphorous and potassium in the form of SSP and MOP were applied as per the recommended dose (100:100 kg P_2O_5:K_2O ha^{-1}) [1] (Table 2). Variety "NS 1701" of chili was planted on first week of August 2019 at the depth of 4–5 cm in a plot of 1 m × 1 m. After the appearance of 3–4 leaves, healthy, robust, and uniform seedlings were transplanted on September 6, 2019 during evening time, and light irrigation was applied immediately. Drip irrigation was applied to pots in this experiment. Pots were watered to field capacity. The fertilizer requirement per pot was calculated according to the required spacing of chili (60 cm × 30 cm). A full dose of P (11 g $plant^{-1}$) and K (3 g $plant^{-1}$) was applied while half of the urea *viz.* 2 g per plant (0, 1, and 2 g $plant^{-1}$) at the basal dose and remaining urea was applied at two split doses viz. (0, 0.5, and 1 g $plant^{-1}$) and (0, 0.5 and 1 g $plant^{-1}$) at 25 days and 55 days respectively as per treatment. The charcoal consists of lignin, resin, pectin, and volatile materials [25,26]. It was collected in a pit, and a fire was started in it then another layer of wood was applied to limit oxygen. Water was sprinkled over it when it became a dark reddish color up to which it had been cooled down and grounded into a powder and was applied to the pot as per treatment. Then, to promote a healthy crop's growth in accordance with the need, the conventional agronomical practices—such as irrigation, cross-cultural activities, and insecticide application—were implemented. To protect chili plants from aphids, insecticide 'Roger' at the rate of 2 mL L^{-1} of water was applied and to supply micronutrient, Agroliv at the rate of 2.5 mL L^{-1} of water was applied. Harvesting was done when the fruit of chili achieved dark green color, where the first harvesting was done at 32 DAT (Days After Transplanting). The light irrigation was given in pots just after seed sowing and continued at 7–10 days interval. Furrow irrigation was provided 20 days after transplanting.

2.4. Data collection and observations

Data were collected for all traits from ten plants chosen at random from each experimental plot. Data collection and observation were done for the number of primary branches, plant height (cm), leaf area (sq. cm), the number of fruits per plant, fruit length (cm), yield per plant (g), and root length (cm).

2.5. Statistical analysis

Data were recorded and entered into MS-Excel 2016. Outliers are removed and data was processed so that it follows normal distribution. The data were analyzed using R-Studio (version February 1, 5033). Completely randomized design two-way ANOVA was used to analyze data. LSD test were used for any significant differences at the $p < 0.05$ level between the means.

Table 1
Soil physical and chemical properties of experimental site.

Soil Component	Values	Remarks
pH	5.93	Acidic
N%	0.18	Medium
P (kg ha^{-1})	35.5	Medium
K (kg ha^{-1})	1098.8	High
OM	3.63	Medium
Sand	56	
Slit	29.7	
Clay	14.3	
Soil texture	Sandy Loam	

(Source: [24]

Table 2a
Details of factors used in treatments in the experiment

Factor A (Nitrogen levels)	Factor B (Charcoal levels)
N1: 0 kg N ha-1 = 0 g pot-1 (Control)	C1: 0% by soil weight = 0 g charcoal pot-1(Control)
N2: 50 kg N ha-1 = 2 g pot-1	C2: 2.5% by soil weight = 125 g charcoal pot-1
N3: 100 kg N ha-1 = 4 g pot-1	C3: 5% by soil weight = 250 g charcoal pot-1
	C4: 7.5% by soil weight = 375 g charcoal pot-1

Where soil weight = 5 kg soil of pot.

Table 2b
NPK application at basal and split-dose for pot experiment of chili.

Fertilizers	Basal dose (g)	Split dose (g)
Urea	0, 1 and 2g pot^{-1}	At 25 days (0,0.5 and 1 g pot^{-1}) At 55 days (0, 0.5 and 1 g pot^{-1})
SSP	11 g pot^{-1}	_
MOP	3 g pot^{-1}	_

SSP: Single Super Phosphate and MOP: Muriate of Potash.

3. Results

3.1. *Effect of nitrogen and charcoal levels on growth traits*

The results of the experiment conducted at given soil and climatic parameters of Lamjung Campus, Lamjung, Nepal from 2019 to 2020 was given in Tables 3–5. The nitrogen levels produced significant ($p < 0.001$) differences for the number of primary branches (Table 3). The highest number of primary branches (8) was found with the application of 100 kg N ha^{-1} followed by 50 kg N ha^{-1} (7). These two results were at par with each other, and the lowest number of primary branches (6) was observed with the application of 0 kg N ha^{-1}. In general, the number of primary branches increased with an increasing level of nitrogen. However, the application of charcoal and the interaction between nitrogen and charcoal did not bring any changes in the number of primary branches (Tables 4 and 5).

The application of nitrogen levels gave significant ($p < 0.01$) differences for the plant height. The highest plant height (52.62 cm) was found with the application of 100 kg N ha^{-1}, which was statistically at par with 50 kg N ha^{-1} (49.93 cm), whereas the smallest pant height (45.75 cm) was found with the application of 0 kg N ha^{-1} (Table 3). Similarly, the application of charcoal produced significant ($p < 0.01$) differences for plant height. Plant height varied from 53.60 cm to 45.42 cm. The application of 2.5% charcoal by soil weight gave the maximum plant height (53.60 cm), whereas the shortest plant height (45.42 cm) was found with the application of 0% charcoal by soil weight (Table 4). However, plant height remained unchanged for interaction between nitrogen and charcoal levels (Table 5).

Leaf area significantly varied with nitrogen levels**.** A higher plant spread (54.33 cm^2) was obtained with the application of 100 kg N ha^{-1} followed by 50 kg N ha^{-1} (42.87 cm^2) while the minimum plant spread (32.5 cm^2) was found with the application of 0 kg N ha^{-1} (Table 3). However, charcoal and the combined effect nitrogen and charcoal levels did not bring any significant difference on the plant spread of chili (Tables 4 and 5).

Root length increased with increasing levels of nitrogen and was found the maximum (29.85 cm) with the application of 100 kg N ha^{-1} and the minimum (25.11 cm) with the application of 0 kg N ha^{-1} (Table 3). However, the application of different levels of charcoal and its interaction with nitrogen did not bring any significant difference in the root length (Tables 4 and 5).

Table 3
Effects of different levels of nitrogen on number of primary branches, plant height, leaf area, number of fruits per plant, fruit length, yield per pot, and root length of chili at Lamjung, Nepal in 2019–2020.

Nitrogen Levels (kg/ha)	Number of primary branches	Plant height (cm)	Leaf area (cm^2)	Number of fruits per plant	Fruit length (cm)	Yield per pot (g)	Root length (cm)
N1 (0 kg N ha^{-1})	6.05b	45.75b	32.5c	12.10c	6.07b	27.26c	25.11b
N2 (50 kg N ha^{-1})	7.75a	49.93a	42.87b	30.65b	6.85a	66.67b	29.35a
N3 (100 kg N ha^{-1})	8.25a	52.62a	54.33a	42.95a	6.97a	97.14a	29.85a
Mean	7.35	49.43	43.25	28.56	6.63	63.69	28.11
F test	***	**	***	***	***	***	*
LSD (0.05)	1.01	3.99	5.5	6.08	0.42	10.62	3.83

*Significant at 0.05 level of significance, ** Significant at 0.01 level of significance, *** Significant at 0.001 level of significance. LSD: Least Significant Difference. Means followed by the same letters in the same column are not significantly different at the 0.05 level of probability.

Table 4
Effects of different levels of charcoal on number of primary branches, plant height, leaf area, number of fruits per plant, fruit length, yield per pot, and root length of chili cultivated at Lamjung, Nepal in 2019–2020.

Charcoal levels (%/soil weight)	Number of primary branches	Plant height (cm)	Leaf area (cm^2)	Number of fruits per plant	Fruit length (cm)	Yield per pot (g)	Root length (cm)
C1 (0% charcoal by soil weight)	7.7	45.42c	44.41	22b	6.16c	49.94c	29.44
C2 (2.5% charcoal by soil weight)	7	53.60a	45.99	31.2a	7.12a	77.55a	29.16
C3 (5% Charcoal by soil weight)	7.4	50.74 ab	40.26	31.93a	6.68 ab	59.70bc	27.34
C4 (7.5% charcoal by soil weight)	7.2	47.98bc	42.34	29.13a	6.55bc	67.56 ab	6.5
Mean	7.35	49.43	43.25	28.56	6.63	63.69	28.11
F test	NS	**	NS	*	**	***	NS
LSD (0.05)	1.17	4.61	6.35	7.02	0.48	12.27	4.42

NS: Not significant, *Significant at 0.05 level of significance, ** Significant at 0.01 level of significance, *** Significant at 0.001 level of significance. LSD: Least Significant Difference. Means followed by the same letters in the same column are not significantly different at the 0.05 level of probability. Soil weight: 5 kg soil of pot.

Table 5
Interaction effect of different levels of nitrogen and charcoal on number of primary branches, plant height, leaf area, number of fruits per plant, fruit length, yield per pot, and root length of chili at Lamjung, Nepal in 2019–2020.

Treatments (Nitrogen × Charcoal levels)	Number of primary branches	Plant height (cm)	Leaf area (cm^2)	Number of fruits per plant	Fruit length (cm)	Yield per pot (g)	Root length (cm)
$N_1 \times C_1$	6.4	44.26	31.83	10.2	5.92	26.70i	23.28
$N_1 \times C_2$	5.8	51.78	37.59	14.8	6.74	36.59h	26.76
$N_1 \times C_3$	6.8	44.98	29.21	13.2	5.84	22.83j	26.44
$N_1 \times C_4$	5.2	41.98	31.58	10.2	5.78	22.91j	23.96
$N_2 \times C_1$	7.8	47.14	40.74	26.4	6.14	63.55f	31.06
$N_2 \times C_2$	6.6	53.76	45.97	32	7.24	68.98d	31.24
$N_2 \times C_3$	8.6	51.02	44.13	29.8	7.14	64.89e	29.38
$N_2 \times C_4$	8	47.82	40.65	34.4	6.88	69.25d	25.74
$N_3 \times C_1$	9	44.86	60.67	29.4	6.44	59.58g	34
$N_3 \times C_2$	8.6	55.28	54.42	46.8	7.4	127.1a	29.5
$N_3 \times C_3$	6.8	56.22	47.43	52.8	7.06	91.36c	26.2
$N_3 \times C_4$	8.6	54.15	54.8	42.8	7	110.5b	29.8
Mean	7.35	49.43	43.25	28.56	6.63	63.69	28.11
SD	1.88	7.36	12.40	16.35	0.82	35.86	6.27
F test	NS	NS	NS	NS	NS	**	NS
LSD (0.05)	2.02	39.44	11	12.16	0.84	0.49	7.67

NC: Nitrogen × Charcoal. NS: Not significant, ** Significant at 0.01 level of significance. SD: Standard deviation, LSD: Least Significant Difference. Means followed by the same letters in the same column are not significantly different at the 0.05 level of probability.

3.2. *Effect of nitrogen and charcoal levels on yield and yield attributing traits*

The application of nitrogen levels produced significant ($p < 0.001$) differences for the number of fruits per plant (Table 3). Significantly the maximum number of fruits per plant (42.95) was found with the application of 100 kg N ha^{-1}, followed by 50 kg N ha^{-1} and the minimum number of fruits per plant (12.10) was found at control. Additionally, a significant ($p < 0.05$) result was observed for the number of fruits per plant with the application of different levels of charcoal (Table 4). The application of 5% charcoal gave the maximum number of fruits per plant (31.93) which was statistically at par with the application of 2.5% charcoal and 7.5% charcoal, whereas the least number of fruits per plant was found at control. However, no significant interactive effect was observed for number of fruits per plant (Table 5).

The application of nitrogen levels significantly ($p < 0.01$) affected the fruit length of chili. The longest fruit length (6.97 cm) was found with the application of 100 kg N ha^{-1} which was statistically at par with 50 kg N ha^{-1}. The minimum value of fruit length (6.07 cm) was found at control (Table 3). Generally, the fruit length increased with the increment of nitrogen levels. Moreover, a significant difference was observed for fruit length with the application of different levels of charcoal (Table 4). Fruit length varied from 7.12 cm to 6.16 cm. The application of 2.5% charcoal produced the longest fruit length (7.12 cm) which was statistically at par with 5% charcoal and 7.5% charcoal. However, the shortest fruit length (6.16 cm) was found at control which was statistically at par with 7.5% charcoal. An interactive effect of nitrogen and charcoal levels was found non-significant for fruit length (Table 5).

The yield per pot varied significantly ($p < 0.001$) with different levels of nitrogen (Table 3). The maximum yield per pot (97.14 g) was found with the application of 100 kg N ha^{-1} followed by 50 kg N ha^{-1} (66.67 g) while the minimum yield per pot (27.26 g) was found with the application of 0 kg N ha^{-1}. The results revealed that yield per pot increased with an increment in nitrogen levels applied. Similarly, the application of different levels of charcoal produced significant ($p < 0.001$) differences for yield per pot. Yield per pot varied from 77.55 g to 49.94 g. The application of 2.5% charcoal gave the maximum yield per pot (77.55 g) which was statistically at par with 7.5% charcoal and 5% charcoal. However, the minimum yield per pot (49.94 g) was found with the application of 0% charcoal by soil weight which was statistically at par with 5% charcoal (Table 4). Additionally, a combined effect of nitrogen and charcoal levels showed highly significant ($p < 0.01$) results for yield per pot (Table 5). The maximum yield per pot (127.1 g) was found with the application of 100 kg N ha^{-1} and 2.5% charcoal which was significantly different among other treatment. However, the minimum yield per pot (22.83 g) was found with the application of control nitrogen and 5% charcoal.

4. Discussion

4.1. Effects of nitrogen levels on growth and yield of chili

Nitrogen is an important nutrient for plants since it is a component of chlorophyll and a building block for amino acids and protein. It boosts potassium and phosphorus uptake and utilization while also regulating plant growth and development [27]. As a result, it is involved in practically every metabolic process. The nitrogen level of 100 kg ha^{-1} resulted in the greatest number of primary branches of chili in our study. These findings corroborate those of [28], who discovered that adding nitrogen increased the number of branches significantly because nitrogen stimulates vegetative growth. Furthermore, enhanced cell division and tissue formation improve the plant's vegetative development, resulting in a long-term improvement in yield. Similarly, the height of the chili plants in our study increased as the amount of nitrogen increased. The results appear to be comparable to those of [29]. Because nitrogen aids in vegetative growth, the number of branches increases, and more branches imply more fruits. [30] discovered that the highest nitrogen amount produced the most fruit. It indicated maximum leaf area due to nitrogen's role in cell division and cell expansion, similar to discovery of [31]. The presence of the essential supplement N in the soil helped to sustain better fruit length, and its application in large quantities helped to improve fruit length. According to our research, the longest chili fruit and chili yield per plot was found at the maximum nitrogen content (100 kg ha^{-1}). It could be because nitrogen helps to build high-quality foliage and plays an important role in carbohydrate synthesis via photosynthesis, resulting in better plant yield. Nitrogen is a part of chlorophyll, which functions as a plant's factory for photosynthesis. Nitrogen has a major influence in the production of leaf area, the duration of leaf area, and the net assimilation rate, all of which are directly related to increased yield [32].

4.2. Effect of charcoal levels on growth and yield of chili

Plant height, number of fruits per plant, fruit length, yield per pot, and average fruit yield were all significant in our study). According to our research, 2.5% charcoal provided the best results for plant height, fruit length, yield per pot, and average fruit yield, though it was comparable to 5% and 7.5% charcoal. [33] inferred that low percentage of charcoal (2% in volume) into composting improved the humidified organic carbon. However, high rate of biochar application reduced the concentrations of nitrate, ammonium, and orthophosphate in the first sampling season of soil water solution in turfgrass system, which lasted an extra year for the nitrate concentration [34].

4.3. Interaction effect of nitrogen and charcoal levels on growth and yield of chili

According to our research, combining charcoal with nitrogen resulted in a considerable increase in yield per pot. The reason for this could be that the use of charcoal in conjunction with fertilizer resulted in a large increase in nutrient uptake [35]. Biochar boosts soil microbial activity improves N availability, and boosts crop output [36], whereas microorganisms play a key part in the nitrogen cycle [37].

[38] found that the chemical groups on the surface of charcoal are responsible for nitrogen adsorption. Negatively charged acid functional groups, such as carboxylic, hydroxyl, lactone, and lactol, are effective at binding to NH_4+ via electrostatic attraction. Basic functional groups on biochar, such as chromes, ketones, and pyrones, can also improve NO_3-adsorption [39]. The adsorption of nitrogen on biochar, on the other hand, is dependent on the process time and temperature. Biochar-based fertilizers, for example, have been shown to increase the productivity of green pepper, cabbage, and rice by increasing Nitrogen Use Efficiency (NUE) [40,41,42,43]. The discovery of an increase in production owing to the addition of nitrogen to charcoal is similar to the findings of [44]. Furthermore, [45] found that pepper and tomato plants were less susceptible to two contagious diseases (*Botrytis cinerea* and *Leveillula Taurica*), and pepper to a foliar mite, when grown (*Polyphagotarsonemus latus*). Similarly, a charcoal adjusted mixture shared root-associated bacterial isolates such as Pseudomonas, Mesorhizobium, Brevibacillus, Bacillus, and Streptomyces strains that operate as either/or both plant growth promoters and biocontrol agents against a variety of plant diseases [46]. According to Ref. [47]; 1% biochar combined with lower fertilizer doses can successfully boost wheat growth, yield, nutritional content, and absorption. When compared to merely fertilizer application, the synergistic effect of charcoal plus fertilizer treatments enhances yield [48].

5. Conclusion

The application of nitrogen @ 100 kg ha^{-1} increased the growth and yield of chili, whereas 2.5% charcoal produced significant increments for plant height, fruit length, and yield per. The combination of nitrogen @ 100 kg ha^{-1} and 2.5% charcoal by soil weight gave the maximum yield of chili and was found non-significant for remaining growth and yield parameters. Therefore, the application of combination of nitrogen @ 100 kg ha^{-1} +2.5% charcoal by soil weight was found to be the optimum level for the cultivation of chili.

Author contribution statement

Puja Subedi, Prayusha Bhattarai, Babita Lamichhane, Amit Khanal: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jiban Shrestha: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

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