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Research Article

Effects of Biochar and Compost Application on Soil Properties and on the Growth and Yield of Hot Pepper (*Capsicum annuum* L.)

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Improper depositions of organic waste threaten the environment. On the other hand, intensive soil cultivation, inappropriate utilization of inorganic fertilizers, and inadequate soil management practices in the study area resulted in soil fertility reduction and poor crop growth. The addition of organic fertilizers from organic waste (biochar and compost) to soil can be considered an environmental-friendly and climate-smart practice able to improve soil properties and the yield of crops. Thus, this study aimed at evaluating the potential of organic amendment with coffee pulp compost (CPC), coffee pulp biochar (CPB), and their combination (CPC_CPB) on selected soil properties and hot pepper yield. The field experiment was conducted in the 2020 and 2021 growing seasons by adopting a randomized complete block design with a factorial experiment using CPC, CPB, and CPC_CPB treatments in different application rates. Results indicated that, in both years, the maximum dose (4 t/ha) of biochar significantly improved the yield of hot pepper and some soil chemical properties such as pH, OC, TN, P, K, Ca^{2+}, Mg^{2+} contents, and CEC. When 2021 is compared with the 2020 growing season in terms of hot pepper yield, the treatments 4 CPB, 10 CPC, and 7 CPC_CPB increased the yield by 4.61, 1.62, and 1.55%, respectively. Thus, an application rate of CPB at the rate of 4 t/ha is considered suitable to improve hot pepper yield and soil properties. Therefore, the highest dose of CPB, followed by CPC_CPB and CPC can be considered as suitable to improve both soil fertility and hot pepper yield.

1. Introduction

Intensive soil cultivation, improper utilization of inorganic fertilizers, and inappropriate management of soil fertility in the country resulted in a reduction of soil fertility, mainly the degradation of physical, chemical, and biological properties of soil, and pressure on agricultural production and affected the livelihoods of millions of rural households in Ethiopia [1]. Hence, the application of organic amendments is a promising and sustainable solution to improve soil fertility and the yield of agricultural production.

Organic fertilizers, such as compost, biochar, or their mixture, are important in improving soil properties and play an essential role in long-term soil conservation by maintaining or restoring its fertility. Moreover, these organic amendments have the potential to increase organic matter and N, P, and K content of soil [2], improve soil structure, and absorb toxins [1].

Numerous studies have been conducted by several researchers using different organic fertilizers to improve soil fertility and yield of crops. Among them, Kiran et al. [3] reported that biochar produced from cow manure reduces the accumulation of heavy metals on the soil surface; biochar derived from poultry litter improves soil properties and reduces the emission of greenhouse gases [4]. Compost prepared by mixing cow dung with paddy straw showed higher total organic matter, a higher C/N ratio, and higher phosphorus, nitrogen, zinc, and manganese in comparison with inorganic fertilizers [5]. Compost enrichment with urea, phosphate, zinc, iron, copper, and manganese at various stages of composting in chaffed cotton stalks and farm wastes reduces the C/N ratio and lignin but increases other nutrients [6]. Compost produced from poultry litter showed higher phosphorus, potassium, calcium, and magnesium compared to fresh manure [7]. To improve soil fertility, enhance sustainable crop production, and reduce environmental problems, research has progressed considerably [1].

Although many researchers have studied the use of biochar and compost on soil properties and yield of crops, the type of waste for organic fertilizer production, its effects on soil properties and yield of crops, the optimum rate of application, and kinds of organic fertilizer are highly varying among farmers [8, 9]. Moreover, there are very few studies on a comparative evaluation of biochar and compost potential on selected soil properties and yield of vegetable crops, such as hot pepper. There is also little information documented on ameliorating the effect of the combined application of biochar and compost on organic matter content, nutrient status, and yield of hot pepper. Furthermore, there is a need for research to turn coffee pulp waste into biochar and compost fertilizer and minimize environmental problems. Thus, this study aimed at evaluating the potential of coffee pulp biochar and compost on selected soil properties and on the yield of hot pepper (*Capsicum annuum* L.).

2. Materials and Methods

2.1. Description of the Study Area. The experiments were carried out in Wonago district, Gedeo Zone, Southern Nations, Nationalities, and People's Regional State (SNNPRS), Ethiopia, in the 2020 and 2021 seasons. It is geographically located at 60 19′ 05″ North latitude and 380 15′ 36″ East longitude with an altitude of 1754 m.a.s.l. and found at 376 south of Addis Ababa. The district is characterized by 1001–1800 mm of annual rainfall and a temperature range of 12–25°C. The study area is suitable for cereals, vegetables, fruits, coffee, enset, and other horticultural crops. Twenty coffee processing industries in the area are engaged in wet and dry processing that could produce huge amounts of coffee pulp waste. There was also immense animal manure waste available due to potential animal production in the area.

2.2. Compost and Biochar Preparation. Coffee pulp and animal manure were collected from the coffee processing sites of Gedeo Zone and the College of Agriculture farm of Dilla University, Ethiopia, respectively. The collected fractions were manually separated from inorganic materials and ready for the production of compost and biochar. Coffee pulp compost was prepared using a 3 : 1 ratio of coffee pulp to animal manure in a heap composting method. For the compost preparation method, the heaps were turned on days 0, 3, 5, 7, 10, and 15 and thereafter at 15-day intervals until the composting period of 90 days [10] to improve the O_2 level inside the heap and to increase the population of aerobic microorganisms. The composting unit was constructed from wooden poles with a base area of 2 m by 2 m. The composter sides and base were covered with a polyethylene fabric sheet to control water seepage. In the base, a drainage pipe was built for the collection of leachate samples from the composter in the container. Fans were installed in a composting method with steady air circulation within the composter. During the composting process, the temperature was measured daily within the heap using a thermoelement. The prepared compost heap was air-dried under shade, crushed, screened through a 2 mm sieve, and applied to the experiment.

Biochar from the coffee pulp was produced in an oxygen-limited atmosphere using an electrically heated pilot-scale pyrolysis reactor. This technology is considered the most suitable technology for biochar production as it maximizes the biochar yield [11]. The pyrolysis temperature was adjusted at 500°C with a 3 h retention time [12, 13]. The biochar was ground into small granules, sieved to pass a 2 mm mesh, and analyzed for chemical properties.

2.3. Experimental Design and Treatments. The treatments adopted each year (2020 and 2021) are reported in Table 1. The experimental design was a factorial experiment completely randomized block design (RCBD) and replicated three times.

In the 2020 growing season, seeds of an improved hot pepper (*Capsicum annuum* L.) variety, namely, Markofana, were obtained from the Melkassa Agricultural Research Center of the Ethiopian Institute of Agricultural Research Center. The Markofana variety was raised in well-prepared seed beds. Seeds were drilled in rows with 10 cm row spacing and were covered lightly with fine soil and mulched with dried grass until emergence. Weeding was accomplished as deemed necessary. Seedlings were thinned at the first true leaf stage to allow sufficient distance within the seedlings. Proper management (weeding and watering) practices were carried out to produce healthy seedlings. Finally, vigorous, strong, and healthy seedlings were transplanted to a well-prepared experimental field in the late afternoon to reduce the risk of poor establishment and shock caused by intense heat in the daytime [14]. This procedure of raising seedlings in the nursery site was also repeated in the second experimental year (2021).

Each year, the experimental land was cleared and plowed manually, and then the bed was leveled, smoothed, and divided into thirty plots. Each plot size was 1.2 m × 2.4 m (2.88 m^2). Once per year, the selected organic fertilizer treatments were applied two weeks before transplanting seedlings. Uniform application over the surface and incorporation were done to the depth of 10 cm with a traditional hoe each year. The seedlings with four pairs of true leaves were transplanted to well-prepared experimental plots at a spacing of 30 cm and 60 cm between the plant and rows, respectively. Proper irrigation, weeding, and other good agronomic practices were applied.

2.4. Soil, Compost, and Biochar Collection and Laboratory Analysis. In both growing seasons, before treatments, CPC, CPB, and CPC_CPB samples were collected from the top, middle, and lower layers for analysis. Soil samples were collected for analysis in 2020. Each year, a composite

Table 1: Experimental treatments used in the study.

Treatment	Description
Control	No amendment
5 CPC	5 t/ha coffee pulp compost
7.5 CPC	7.5 t/ha coffee pulp compost
10 CPC	10 t/ha coffee pulp compost
2 CPB	2 t/ha coffee pulp biochar
3 CPB	3 t/ha coffee pulp biochar
4 CPB	4 t/ha coffee pulp biochar
3.5 CPC_CPB	3.5 t/ha combination of coffee pulp compost and biochar
5.25 CPC_CPB	5.25 t/ha combination of coffee pulp compost and biochar
7 CPC_CPB	7 t/ha combination of coffee pulp compost and biochar

sample of approximately one kilogram was collected from each treatment at five spots of the entire plot at a depth of 20 cm, and then, it was analyzed for physicochemical properties.

Soil texture was determined by a hydrometer method. The pH was determined by the H_2O (soil-H_2O) 1 : 2.5 soil-to-solution ratio using a pH meter. The electrical conductivity was measured by a conductivity meter after saturating the samples with distilled water and extracted by vacuum suction, and the extracts were filtered [15]. Organic carbon was determined using the Walkley and Black wet oxidation method [16]. The total *N* of the soil and compost was determined by the wet-oxidation procedure of the Kjeldahl method [17]. Determination of available phosphorous and available potassium (K) was carried out by the Olsen method, using sodium bicarbonate (0.5M $NaHCO_3$) as an extraction solution [18]. Exchangeable bases (Ca and Mg) in the soil were estimated by the ammonium acetate (1M NH_4OAc at pH 7) extraction method. In this procedure, the soil samples that were extracted were more than NH_4OAc solution, and Ca and Mg in the extracts were determined by an atomic absorption spectrophotometer, while a flame photometer was used to determine the contents of exchangeable K as described by Rowell [19]. Organic amendment samples were also analyzed for some chemical properties using the methods described above. After harvesting the hot pepper, soil samples were collected from each treatment plot and characterized.

2.5. Agronomic Data Collection. In each harvesting year (2020 and 2021), agronomic data were randomly collected from each replication to determine the growth and yield parameters of hot pepper. The plant height was measured from ground level to the tip of the plant at the mature fruit stage in centimeters. The average number of leaves per plant was counted in each treatment. Fresh biomass weight was recorded through a digital balance. The yield was also calculated using the following equation:

$$\text{yield (tons per ha)} = \frac{\text{subplot yield (ton)} * 10000\text{m}^2}{\text{subplot area}\left(\text{m}^2\right) * 1000}. \quad (1)$$

2.6. Statistical Data Analysis. The experiment was subjected to analysis of variance, and data were analyzed using the R-program (version 4.11.2021). To determine the significant difference between treatment means, Fisher's range test at a 5% significance level ($P < 0.05$) was applied.

3. Results and Discussion

3.1. Soil Characteristics. The soil texture of the experiment sites (Table 2) was sandy loam. The soil had high bulk density and was slightly acidic, with low organic matter content [20].

Thus, the soil was considered critically low in fertility for TN, available P, and available K contents [21]. According to the rating of FAO [22], the soil had low cation exchange capacity (CEC), calcium (Ca^{2+}), and magnesium (Mg^{2+}).

3.2. Characteristics of Organic Amendments. The physical and chemical properties of CPC, CPB, and CPC_CPB are listed in Table 3. The pH value of all amendments was alkaline. Electrical conductivity (EC) of CPC, CPB, and CPC_CPB was 0.09, 1.2, and 0.08 dS cm^{-1}, respectively.

As reported in Table 3, CPB had the highest values of TOC (35.2%), TN (2.05%), available P (1.34%), and available K^+ concentration (1.74%) compared to CPC and CPC_CPB. On the other hand, the observed values of calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations were high for CPC_CPB, followed by CPB and CPC. The result indicated that the determined values of TOC, TN, available P, available K^+ calcium, (Ca^{2+}), and magnesium (Mg^{2+}) concentrations recorded were high [22].

3.3. Effects of Treatments on Soil Physical and Chemical Properties. The effects of the various treatments on soil physical and chemical properties in the 2020 and 2021 growing seasons are presented in Table 4.

The result, in Table 4, revealed the effect of year had a significant ($P < 0.001$) difference in soils treated with organic amendments of CPB, CPC_CPB, and CPC than the control in the 2020 and 2021 experimental years. In the 2020 experimental season, the highest soil pH was recorded in the 4 CPB treatment (6.73 ± 0.02), followed by 7 CPC_CPB (6.69 ± 0.02) and 10 CPC (6.63 ± 0.02), while the lowest value was recorded in the control (6.25 ± 0.03). In the 2021 research season, the highest pH (6.89 ± 0.04) was observed in soils treated with 4 CPB, followed by 7 CPC_CPB (6.84 ± 0.01) and 10 CPC (6.79 ± 0.03). The result of individual factors and years showed a significant effect ($p < 0.001$) on soil pH. The result showed the mean pH value was higher in 2021 compared to the 2020 growing season. There was also a significant ($P < 0.05$) difference observed in the interactive effect of treatment and years ($T \times Y$).

The soil pH in the application of 4 CPB might have increased due to the accumulation of ash content and the porous nature of the amendment. Furthermore, the rise of the soil pH in CPB could be attributed to the release of biochar into the treatment soil. The findings agreed with those of Nigussie et al. [23] and Zhang et al. [24], who indicated that biochar application improved soil quality by increasing soil pH. Furthermore, Luo et al. [25] pointed out

Table 2: Physicochemical properties of the soil before the field study in 2020.

Property	2020
Sand (%)	64
Clay (%)	6
Silt (%)	30
Textural class	Sandy loam
Bulk density(g cm^{-3})	1.5
pH(1 : 2.5 H_2O)	6.1
EC (dS/cm)	2.05
%OC	1.25
%TN	0.37
Avail. P (mg·kg^{-1})	0.80
Avail. K (meq 100 g^{-1})	0.55
Ca^{2+} (meq 100 g^{-1})	10.2
Mg (meq/100 g)	1.45
CEC (cmol (+)/kg)	11.45

Table 3: Physical and chemical properties of biochar and compost before field study in 2020.

Property	CPC	CPB	CPC_CPB
pH (H_2O)	7.65	8.5	8.27
EC (dS/m)	0.09	1.2	0.08
TOC (%)	24.25	35.2	32.70
TN (%)	1.55	1.95	2.05
Available P (%)	0.94	1.34	1.23
K^+ (%)	1.25	1.74	1.62
Ca^{2+} (%)	2.99	3.45	3.60
Mg^{2+} (%)	0.55	0.75	0.81

CPC = coffee pulp compost, CPB = coffee pulp biochar, and CPC_CPB = coffee pulp compost, and coffee pulp biochar.

that the accumulation of ash content and basic oxide cations in biochar might have increased the soil pH of treated plots. Nigussie et al. [23] also attributed the increase in soil pH found in biochar-amended soils to the high surface area and porous nature of biochar increased the cation exchange capacity (CEC) of the soil, which binds Al and Fe to the soil exchange sites.

Results of the application of organic amendments on soil bulk density (BD) are shown in Table 4. Individual and combined applications of biochar and compost in both years had a significant ($P < 0.001$) difference in soil BD in organic amendments than the control. In the first year, the bulk density reduced from 4 CPB, 7 CPC_CPB, and 10 CPC by 24.16%, 23.15%, and 17.45%, respectively, compared with the control treatment. The highest reduction of bulk density of treatments in the second year, as compared to the control treatment, was 31.13%, 26.49%, and 25.83%, respectively. The results of individual factors and years showed significant ($p < 0.001$) differences for soil BD. The result showed that the mean value of BD decreased in the second-year growing season over plants grown in the first year. There was a significant difference ($p < 0.05$) observed in the interactive effect between treatment and years ($T \times Y$). The reduction of BD with an application of biochar-treated soil might be due to the highest porosity and water retention capacity of biochar, resulting in the formation of good aggregate soil. This result is supported by Yadav et al. [26], who reported that a porous material, when added to the soil, increases its porosity and thus reduces bulk density. Similar results were reported by Hseu et al. [27], Kätterer et al. [28], and Ndor et al. [29], indicating that the change in porosity of biochar-treated soils was a result of the formation of macrospores and rearrangement of soil particles.

The soil analysis results revealed that the concentration of soil organic carbon content significantly ($p < 0.001$) varied with the control treatments (Table 4). In the 2020 and 2021 field research seasons, the highest value of OC was observed in soil amended with 4 CPB, followed by 7 CPC_CPB and 10 CPC, while the lowest OC was observed in the control treatment (Table 4). There was also a significant difference ($p < 0.05$) observed in the first- and second-year application of amendments. The observed values indicated that the soil OC increased in the second-year season in comparison with the first-year season. However, there was no significant difference observed in the interactive effect between treatment and years ($T \times Y$). In this study, the highest soil OC recorded in the application of 4 CPB might be due to the highest dosage of CPB stimulated to increase soil OC. The report of Phares et al. [30], Zhao et al. [31], and Hartley et al. [32] indicated that the highest application rate of biochar improved the soil porosity and OC of treated plots. The results of Trupiano et al. [33] and Frimpong et al. [34] also indicated that individual application of biochar in combination with compost increased soil OC content more than that in the control soils.

In both years, the application of the organic amendments had a significant effect ($P < 0.001$) on the soil total nitrogen (TN) concentration (Table 4). In 2020, TN contents ranged from 0.45 ± 0.07 to 1.20 ± 0.02%. The highest amount of TN (1.20 ± 0.02%) was detected in 4 CPB, followed by (1.16 ± 0.09%) in 7 CPC_CPB and (1.02 ± 0.07%) in 10 CPC, while the lowest value (0.45 ± 0.07%) was observed in the control treatment. In 2021, the total nitrogen (TN) contents ranged from 0.36 ± 0.11 to 1.38 ± 0.11%. The result of the individual factor and years showed a significant effect ($p < 0.001$) for soil TN. The result showed the mean TN value was higher in 2021 compared to the 2020 growing season (Table 4). A significant difference was not observed in the interactive effect between treatment and years ($T \times Y$). The result indicated that the highest application rate of biochar (4 CPB) might be due to the ability to increase the accumulation of total nitrogen in treated soil. The finding agrees with the report of Cui et al. [35], which indicated that the addition of the highest application rate of biochar significantly improved the contents of total nitrogen. Vaccari et al. [36] reported that the application of biochar retains NH_4+, leading to improved N nutrition in soils. A similar result reported by Abbasi and Anwar [4] indicated that single or combined application of biochar increased the total N of treated plots.

The available phosphorus content of soils was significantly influenced by organic amendments ($p < 0.001$), year ($p < 0.001$), as well as their interaction ($p < 0.05$), both during the 2020 and 2021 growing seasons (Table 4). In both years, the highest soil available P content was observed in 4 CPB, followed by 7 CPC_CPB and 10 CPC, and the least was observed in the control treatments. The result showed that

Table 4: Effects of organic amendments on soil pH, BD, OC, TN, and available P.

Years	Treatment	pH	BD (g cm^{-3})	OC (%)	TN (%)	Avail. P (mg/kg)
2020	Control	6.25 ± 0.03^{i}	1.49 ± 0.10^{a}	1.36 ± 0.02^{i}	0.45 ± 0.07^{i}	0.86 ± 0.03^{g}
	5CPC	6.35 ± 0.03^{h}	1.42 ± 0.02^{b}	3.43 ± 0.13^{g}	0.67 ± 0.12^{i}	1.24 ± 0.03^{e}
	7.5 CPC	6.41 ± 0.06^{fg}	1.32 ± 0.01^{c}	4.31 ± 0.06^{ef}	0.87 ± 0.04^{g}	1.34 ± 0.04^{d}
	10 CPC	6.63 ± 0.02^{e}	1.23 ± 0.02^{cd}	5.60 ± 0.15^{d}	1.02 ± 0.07^{e}	1.61 ± 0.06^{b}
	2 CPB	6.44 ± 0.03^{fg}	1.30 ± 0.01^{c}	4.63 ± 0.22^{de}	0.77 ± 0.09^{h}	1.36 ± 0.04^{d}
	3 CPB	6.55 ± 0.03^{f}	1.19 ± 0.02^{d}	5.13 ± 0.23^{d}	1.00 ± 0.11^{e}	1.58 ± 0.07^{bc}
	4 CPB	6.73 ± 0.02^{d}	1.13 ± 0.01^{d}	6.40 ± 0.07^{b}	1.20 ± 0.02^{b}	1.74 ± 0.03^{ab}
	3.5 CPC_CPB	6.41 ± 0.02^{fg}	1.28 ± 0.05^{c}	3.76 ± 0.34^{g}	0.74 ± 0.08^{h}	1.12 ± 0.06^{f}
	5.25 CPC_CPB	6.53 ± 0.05^{f}	1.21 ± 0.01^{cd}	4.89 ± 0.08^{de}	0.94 ± 0.08^{f}	1.34 ± 0.10^{d}
	7 CPC_CPB	6.69 ± 0.02^{d}	1.16 ± 0.01^{d}	5.96 ± 0.08^{c}	1.16 ± 0.09^{c}	1.70 ± 0.08^{b}
2021	Control	6.18 ± 0.07^{i}	1.51 ± 0.01^{a}	1.25 ± 0.02^{i}	0.36 ± 0.11^{j}	0.82 ± 0.03^{g}
	5 CPC	6.45 ± 0.02^{fg}	1.31 ± 0.04^{c}	3.53 ± 0.15^{gh}	0.74 ± 0.09^{h}	1.32 ± 0.07^{d}
	7.5 CPC	6.56 ± 0.07^{f}	1.22 ± 0.06^{cd}	4.44 ± 0.07^{ef}	1.09 ± 0.11^{d}	1.41 ± 0.04^{c}
	10 CPC	6.79 ± 0.03^{c}	1.11 ± 0.02^{e}	5.93 ± 0.16^{c}	1.24 ± 0.10^{b}	1.79 ± 0.02^{ab}
	2 CPB	6.52 ± 0.02^{f}	1.22 ± 0.03^{cd}	4.81 ± 0.27^{de}	0.86 ± 0.13^{g}	1.47 ± 0.04^{c}
	3 CPB	6.54 ± 0.02^{d}	1.13 ± 0.02^{e}	5.34 ± 0.11^{d}	1.06 ± 0.11^{d}	1.61 ± 0.04^{b}
	4 CPB	6.89 ± 0.04^{a}	1.04 ± 0.03^{f}	6.80 ± 0.07^{a}	1.38 ± 0.11^{a}	2.06 ± 0.10^{a}
	3.5 CPC_CPB	6.48 ± 0.05^{fg}	1.25 ± 0.01^{cd}	3.86 ± 0.32^{g}	0.86 ± 0.09^{g}	1.22 ± 0.05^{e}
	5.25 CPC_CPB	6.52 ± 0.07^{de}	1.19 ± 0.01^{d}	4.99 ± 0.11^{de}	1.07 ± 0.10^{d}	1.46 ± 0.13^{c}
	7 CPC_CPB	6.84 ± 0.01^{b}	1.12 ± 0.04^{e}	6.50 ± 0.29^{b}	1.35 ± 0.08^{a}	1.83 ± 0.07^{b}
	Year (Y)	***	***	***	***	***
	Treatment (T)	***	***	*	***	***
	$Y \times T$	*	*	NS	NS	*

CPC = coffee pulp compost, CPB = coffee pulp biochar, and CPC_CPB = coffee pulp compost and coffee pulp biochar. BD: bulk density, OC: organic carbon, TN: total nitrogen, and Avail. P: available phosphorus. Values followed by similar letters under the same column are not significantly different, $^{***}p < 0.001$. $^{**}p < 0.01$. $^{*}p < 0.05$.

the mean available P value was higher in 2021 compared to the 2020 growing season. The increase in the soil available P in all treatments except the control might be due to the increase in soil pH (6.1–6.73) and exchangeable base/cation in the soil treated with 4 CPB. The findings of Agegnehu et al. [37] and Nigussie et al. [23] confirmed that biochar-amended soils have greater soil available P contents compared to soils without treatment. A similar result reported by Ding et al. [8] and Hussain et al. [9] etindicated that field soil amended with biochar has high available phosphorus than amended soil.

The content of available potassium (Table 5) of soils measured in the 2020 and 2020 growing seasons resulted in statistically different values among the amendments ($p < 0.001$), year ($p < 0.001$), and interaction effect ($P < 0.01$). A significantly higher available K content (0.96 ± 0.03 and 1.12 ± 0.03) was observed in soil treated with 4 CPB. Values of available K content of (0.91 ± 0.05 and 1.08 ± 0.03) and (0.90 ± 0.05 and 1.07 ± 0.03) were registered in 7 CPC_CPB and 10 CPC, respectively. The lowest value (0.51 ± 0.04 and 0.49 ± 0.06) was recorded in control treatments in both growing seasons.

Table 5 shows the effects of organic amendments on available potassium, exchangeable Ca^{2+} and Mg^{2+}, and CEC in the 2020 and 2021 growing seasons. The highest application rates of CPB, CPB_CPC, and CPC increased exchangeable Ca^{2+} and Mg^{2+} contents in both years compared to the control treatment. In the 2020 and 2021 growing seasons, the highest Ca^{2+} and Mg^{2+} contents were observed in soils treated with 4 CPB, followed by 7 CPC_CPB and 10 CPC. The result of individual factors in the year showed a significant effect ($p < 0.001$) for soil Ca^{2+} and Mg^{2+}. The result showed that the mean Ca^{2+} and Mg^{2+} values were higher in 2021 compared to the 2020 growing season. There was also a significant ($P < 0.05$) difference observed in the interactive effect between treatment and years ($T \times Y$). The reason might be that the highest application rates of biochar produced increased the highest levels of pH, N, K, OC, Mg^{2+}, Na, and CEC [38]. The finding of Olakayode et al. [39] also indicated that the presence of ash in biochar-treated soil increased soil exchangeable Ca^{2+} and Mg^{2+}, available K, and CEC.

Table 5 shows the individual factor (year) has a significant ($p < 0.001$) effect on soil CEC. In the 2020 and 2021 experiment periods, the highest CEC was recorded in soil treated with 4 CPB, followed by 7 CPC_CPB and 10 CPC. The least CEC was observed in the control treatment. The result showed that the mean CEC value was higher in 2021 when compared to the 2020 growing season. There was also a significant ($P < 0.05$) difference observed in the interactive effect between treatment and years ($T \times Y$). This might be due to the pH and exchangeable cation concentration differences of organic amendments. Generally, individual or combined application of biochar and compost significantly increased the CEC of treated soils. Olakayode et al. [39] reported that the application of biochar can potentially increase the soil CEC due to its highly porous nature and higher surface area. Chang et al. [40] also reported that the application of biochar in agricultural soils could increase CEC over time due to the surface oxidation of biochar and more negatively charged surface functional groups.

Table 5: Effects of organic amendments on soil available K, Ca, Mg, and CEC.

Years	Treatment	Avail. K (mg/kg)	Ca (meq/kg)	Mg (meq/kg)	CEC (meq/kg)
2020	Control	0.51 ± 0.04^{i}	12.43 ± 0.68^{h}	1.55 ± 0.09^{i}	12.42 ± 0.63^{f}
	5 CPC	0.62 ± 0.04^{h}	14.72 ± 0.14^{fg}	2.51 ± 0.02^{h}	13.25 ± 0.29^{e}
	7.5 CPC	0.75 ± 0.03^{f}	15.46 ± 0.16^{f}	3.85 ± 0.62^{g}	13.75 ± 0.13^{e}
	10 CPC	0.90 ± 0.05^{d}	17.65 ± 0.03^{d}	4.53 ± 0.06^{de}	15.82 ± 0.13^{d}
	2 CPB	0.69 ± 0.04^{g}	15.09 ± 0.09^{fg}	3.87 ± 0.09^{g}	13.71 ± 0.83^{e}
	3 CPB	0.81 ± 0.02^{e}	16.57 ± 0.21^{e}	4.08 ± 0.08^{ef}	14.87 ± 0.10^{d}
	4 CPB	0.96 ± 0.03^{c}	18.41 ± 0.21^{c}	4.75 ± 0.02^{d}	17.33 ± 0.09^{c}
	3.5 CPC_CPB	0.72 ± 0.01^{g}	15.85 ± 0.03^{f}	4.24 ± 0.07^{e}	15.73 ± 0.66^{d}
	5.25 CPC_CPB	0.84 ± 0.02^{e}	17.17 ± 0.05^{de}	4.33 ± 0.12^{e}	16.84 ± 0.12^{c}
	7 CPC_CPB	0.91 ± 0.05^{d}	18.04 ± 0.13^{cd}	4.60 ± 0.03^{de}	16.79 ± 0.39^{c}
2021	Control	0.49 ± 0.06^{i}	10.23 ± 0.11^{g}	1.53 ± 0.11^{i}	12.33 ± 0.91^{f}
	5 CPC	0.64 ± 0.02^{h}	16.40 ± 0.79^{e}	2.54 ± 0.11^{h}	13.56 ± 0.14^{e}
	7.5 CPC	0.77 ± 0.01^{f}	17.22 ± 0.19^{de}	4.06 ± 0.11^{f}	15.41 ± 0.08^{d}
	10 CPC	1.07 ± 0.03^{b}	18.76 ± 0.18^{c}	4.96 ± 0.03^{c}	18.18 ± 0.30^{b}
	2 CPB	0.71 ± 0.02^{g}	17.22 ± 0.11^{de}	4.11 ± 0.16^{ef}	15.44 ± 0.24^{d}
	3 CPB	0.82 ± 0.01^{e}	17.86 ± 0.11^{d}	4.28 ± 0.12^{e}	15.93 ± 0.26^{d}
	4 CPB	1.12 ± 0.03^{a}	20.91 ± 0.51^{a}	5.35 ± 0.11^{a}	19.40 ± 1.03^{a}
	3.5 CPC_CPB	0.75 ± 0.03^{f}	17.70 ± 0.26^{d}	4.27 ± 0.09^{e}	16.74 ± 0.11^{c}
	5.25 CPC_CPB	0.85 ± 0.01^{e}	17.93 ± 0.10^{d}	4.62 ± 0.10^{d}	16.98 ± 0.12^{c}
	7 CPC_CPB	1.08 ± 0.03^{b}	19.59 ± 0.41^{b}	5.15 ± 0.07^{b}	19.09 ± 0.80^{a}
	Year (Y)	***	***	***	***
	Treatment (T)	***	***	***	***
	$Y \times T$	**	*	*	*

CPC = coffee pulp compost, CPB = coffee pulp biochar, and CPC_CPB = coffee pulp compost biochar. Avail K: available potassium, Ca: calcium, Mg: magnesium, and CEC: cation exchange capacity. Values followed by similar letters under the same column are not significantly different, *** $p < 0.001$. ** $p < 0.01$. * $p < 0.05$.

3.4. *Effects of Organic Amendments on Growth and Yield of Hot Pepper*

3.4.1. Plant Height. The main factor (treatment) effect on hot pepper plant height showed a significant difference ($P < 0.001$) in the 2020 and 2021 growing seasons (Table 6). In the first year, the application of 4 CPB, 7 CPC_CPB, and 10 CPC increased plant height by 55.87%, 52.91%, and 48.66% when compared to the control. The mean plant height of treatments in the second year was also highest in 4CPB (56.50 ± 1.92), followed by 7 CPC_CPB (52.60 ± 3.34) and 10 CPC (47.83 ± 2.24), while the least value was observed in the control (22.98 ± 2.47) treatment. The result of the individual factor, the year, showed a significant effect ($p < 0.05$) on plant height. Moreover, the mean plant height in 2021, as compared to the 2020 growing season, increased by 4.50%, 3.9%, and 3.03% in 4 CPB, 7 CPC_CPB, and 7 CPC, respectively.

This might be because the availability of nutrients, good porosity, and moisture retention capacity in the 4 $t{\cdot}ha^{-1}$ CPB application rate of biochar contributed to an increase in the plant height of hot pepper as compared to other treatments. The result agreed with the findings of Bhattarai et al. [41] and Maru et al. [42] the highest application rate of biochar increased plant height than the control treatment. A similar finding was also reported by Abbasi and Anwar [4], confirming that individual application of biochar increases plant growth and biomass production of maize crops. Likewise, Mensah and Frimpong [43] assured that the application of biochar improved plant height and the number of plant leaves of both local and improved varieties. Similar findings reported by Maru et al. [42], Sikder and Joardar [44], Bhattarai et al. [41], and Tariku et al. [45] indicated that the soil treated with biochar improved soil nutrient content and increased plant height compared to the control treatment.

3.4.2. Number of Leaves per Plant. The number of leaves per plant in treated plots showed a statistical ($P < 0.001$) difference in the 2020 and 2021 growing seasons (Table 6). Application of CPB, CPC, and CPC_CPB improved leave numbers when compared with the control. The maximum value leaf number was observed in the 4 CPB, 7 CPC_CPB, and 10 CPC than other treatments in both growing seasons (Table 6). The result indicated that leaf numbers significantly increased as the levels of CPB, CPC, and CPC_CPB increased. In the second year (2021), leaf number significantly improved when compared with the first year (2020). The interaction $Y \times T$ was not significant for leave numbers. The highest number of leaf numbers registered in 4 CPB might be due to the availability of nutrients and growth hormones which were helpful to improve leaf number. This finding agrees with Trupiano et al. [33], who reported that biochar application increases the leaf numbers of lettuce. A similar result was also reported by Prasad et al. [46], who depicted that the application of biochar increases the number of leaves. This could be because of the availability of organic matter in biochar and their capacity to easily uptake nutrients and maintain soil moisture, eventually increasing the number of leaves per plant.

3.4.3. Total Fresh Biomass Weight (g). Significant differences ($P < 0.001$) in total fresh biomass were recorded among

Table 6: Effect of organic amendments on growth parameter of hot pepper in 2020 and 2021.

Years	Treatment	Plant height (cm)	Leaf number	Total fresh biomass weight (g)	Yield (quintal/ha)
2020	Control	23.81 ± 2.35^{h}	93.67 ± 4.16^{g}	95.67 ± 4.16^{i}	0.60 ± 0.04^{g}
	5 CPC	30.97 ± 3.02^{g}	110.67 ± 5.03^{f}	121.67 ± 5.03^{h}	2.69 ± 0.16^{f}
	7.5 CPC	43.31 ± 3.45^{d}	122.67 ± 3.06^{e}	136.67 ± 3.06^{efg}	3.65 ± 0.10^{e}
	10 CPC	46.38 ± 1.93^{c}	146.67 ± 7.02^{c}	152.67 ± 7.02^{c}	5.47 ± 0.53^{c}
	2 CPB	33.95 ± 1.06^{f}	124.33 ± 5.69^{e}	131.33 ± 5.69^{gh}	3.38 ± 0.59^{e}
	3 CPB	38.64 ± 1.83^{e}	135.33 ± 7.09^{d}	140.33 ± 7.09^{ef}	4.48 ± 0.20^{d}
	4 CPB	53.96 ± 1.74^{a}	165.00 ± 9.17^{a}	168.00 ± 9.17^{a}	7.45 ± 0.48^{ab}
	3.5 CPC_CPB	34.62 ± 0.74^{f}	125.17 ± 6.66^{e}	126.67 ± 6.66^{h}	3.48 ± 0.04^{e}
	5.25 CPC_CPB	42.56 ± 2.03^{d}	136.00 ± 7.21^{d}	138.00 ± 7.21^{efg}	4.42 ± 0.27^{d}
	7 CPC_CPB	50.56 ± 2.28^{b}	155.00 ± 9.17^{b}	160.00 ± 9.17^{b}	6.99 ± 0.41^{b}
2021	Control	22.98 ± 2.47^{g}	92.67 ± 4.51^{g}	92.67 ± 4.5^{i}	0.59 ± 0.04^{g}
	5 CPC	32.72 ± 2.61^{f}	116.33 ± 5.13^{f}	126.33 ± 5.13^{h}	2.80 ± 2.43^{f}
	7.5 CPC	40.36 ± 3.66^{d}	126.33 ± 3.06^{e}	146.33 ± 3.06^{def}	3.80 ± 0.15^{e}
	10 CPC	47.83 ± 2.24^{c}	148.33 ± 5.69^{c}	160.33 ± 5.69^{b}	5.56 ± 0.52^{c}
	2 CPB	35.53 ± 1.51^{e}	126.00 ± 6.56^{e}	138.00 ± 6.56^{fg}	3.52 ± 0.59^{e}
	3 CPB	39.56 ± 1.71^{d}	137.00 ± 7.00^{d}	150.00 ± 7.00^{cd}	4.61 ± 0.15^{d}
	4 CPB	56.50 ± 1.92^{a}	170.00 ± 8.19^{a}	170.00 ± 8.19^{a}	7.81 ± 0.17^{a}
	3.5 CPC_CPB	36.66 ± 0.78^{de}	128.67 ± 3.06^{e}	131.67 ± 3.06^{gh}	3.64 ± 0.09^{e}
	5.25 CPC_CPB	38.99 ± 2.64^{d}	139.00 ± 5.57^{d}	142.00 ± 5.57^{efg}	4.65 ± 0.21^{d}
	7 CPC_CPB	52.60 ± 3.34^{b}	159.33 ± 9.24^{b}	169.33 ± 11.24^{a}	7.10 ± 0.29^{b}
	Year (Y)	*	*	**	*
	Treatment (T)	***	***	***	***
	$Y \times T$	NS	NS	NS	NS

CPC = coffee pulp compost, CPB = coffee pulp biochar, and CPC_CPB = coffee pulp compost and coffee pulp biochar. Values followed by similar letters under the same column are not significantly different, $^{***}p < 0.001$. $^{**}p < 0.01$. $^{*}p < 0.05$.

treatments (Table 6). In each growing season, the total fresh biomass was increased with the maximum application rate of CPB, CPC_CPB, and CPC as compared to the control. In the 2020 growing season, the highest total fresh biomass (168.00 ± 9.17 g) was observed in 4 CPB, followed by (160.00 ± 9.17 g) 7 CPC_CPB and (152.67 ± 7.02 g) 10 t·ha^{-1} CPC, while the lowest (95.67 ± 4.16 g) was recorded in the control treatment. There was also a significant difference ($p < 0.01$) observed in total fresh biomass weight in the 2020 and 2021 growing seasons. Interestingly, in the 2021 growing season, the total fresh biomass weight in 4 CPB, 7 CPC_CPB, and 10 CPC was higher by 45.5%, 45.3%, and 42.2%, respectively, than the control treatment (Table 6). The interaction $Y \times T$ was not significant for total fresh biomass weight. The highest total fresh biomass weight recorded in 4 CPB might be due to the rate of application of biochar influenced to increased total fresh biomass weight of hot pepper. This result agrees with Viger et al. [47], who reported that the addition of wood chips biochar increased lettuce and Arabidopsis plant biomass by 111% more than other treatments. Similar findings were reported by Liu et al. [48], Khaitovet et al. [49], and Adhikari et al. [50], indicating that the rate of application of biochar improved the total plant fresh biomass weight of crops.

3.4.4. Yield per Hectare. The application of organic amendments significantly ($P < 0.001$) increased the yield of hot pepper when compared to the control (Table 6). In both years, the yield of hot pepper was increased with the highest doses of CPB, CPC_CPB, and CPC. There was also a significant difference ($p < 0.05$) observed in yield between the first and second years. Compared to 2020, there was an increase in hot pepper yield by 4.61, 1.62, and 1.55% for 4 CPB, 10 CPC, and 7CPC_CPB, respectively, and a reduction of 1.67% for the control. The highest yield per hectare observed in 4 CPB might be due to the highest availability of nutrients, porosity, and water-holding capacity, which are more helpful to increase the growth parameters and yield of hot pepper than other treatments. This finding agrees with the result of Adekiya et al. [51], Katterer et al. [28], Tariku et al. [45], and Agbede et al [52], who confirmed that the highest application rate of biochar increased the yield of vegetables and cereal crops.

4. Conclusion

The study showed that the highest individual biochar application rate significantly increased soil pH, soil organic carbon, total nitrogen, available phosphorus, exchangeable Ca and Mg, CEC, and reduced bulk density in both experimental growing seasons. In addition, the highest dose of biochar increased the growth response (plant height, leaf number, and total fresh biomass weight) and yield of hot peppers. The combined application of biochar and compost also significantly affected selected soil properties such as pH, OC, TN, P, K, Ca^{2+}, Mg^{2+}, and the growth of hot pepper.

Data Availability

All data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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