



Original article

Contrasting effects of maize residue, coal gas residue and their biochars on nutrient mineralization, enzyme activities and CO₂ emissions in sandy loess soil



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ABSTRACT

Mismanagement of crop straw and coal gas residue threatens the atmosphere and the economy. Nevertheless, thermal-pyrolysis is an option for management that turns bio-waste into biochar; its viability and adoption by the public as soil amendments is dependent on the agronomic and environmental values compared between biochar and the raw materials. We undertook a 60-day short-term analysis to assess the impact of various wastes and biochars, as well as inorganic nutrients (N), on carbon dioxide (CO₂) fluxes, soil enzyme activities, soil fertility status, and microbial activities. There were eight treatments of soil amendments: without an amendment (CK), Nutrients (N), straw + nutrients (S+N), straw biochar + nutrients (SB+N), coal gas residue + nutrients (C+N), coal gas residue biochar + nutrients (CB+N), straw + straw biochar + nutrients (S+SB+N) and coal gas residue waste + coal gas residue biochar + nutrients (C+CB+N). The results indicated that soil EC, pH, nitrate N (NO₃-N), SOC, TN and available K were significantly ($p < 0.05$) increased coal gas residue biochar and combined with coal fly ash as compared to maize straw biochar and combined with maize straw and N treatments. The higher concentrations of soil MBC and MBN activities were increased in the maize straw application, while higher soil enzyme activity such as, invertase, urease and catalase were enhanced in the coal fly ash derived biochar treatments. The higher cumulative CO₂ emissions were recorded in the combined applications of maize straw and its biochar as well as coal gas residue and its biochar treatment. Our study concludes, that maize straw and coal fly ash wastes were converted into biochar product could be a feasible substitute way of discarding, since land amendment and decreased CO₂ fluxes and positive changes in soil microbial, and chemical properties, and can be confirmed under long-term conditions for reduction of economical and environment issues.

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1. Introduction

Much of the world's agricultural systems relied heavily on exogenous organic materials to maintain soil structure and provide

nutrients for crop development. (Pittelkow et al., 2015). However, improper usage of organic resources may have detrimental consequences for soil quality and productivity. (Coleman et al., 2002; Poirier et al., 2014). Previous published literature (Wu et al., 2013; Awasthi et al., 2016; Zhang et al., 2017) had investigated on various types of agricultural crop residue for soil nutrients, greenhouse gas emissions (GHGs) and carbon sequestration (Lehmann et al., 2003; Lan et al., 2017) activities of microorganisms (Wang et al., 2015), agricultural production (Khan et al., 2019; Rafique et al., 2020), mitigating climate change (Korai et al. 2018). The main reason of CO₂ emission is affected by high doses or imbalance of chemical fertilizer in the soil and no application of organic amendments (Zhang et al., 2017a; Sial et al., 2019a).

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Agro based crops waste consider a substitute source of soil and plant nutrition (Khan et al., 2019), organic matter, and improve crops yield and soil health. Wu et al. (2013) assessed that soil organic matter (SOM) considered a vital factor for sustaining soil fertility (Lehmann et al., 2003), energy source of soil microorganisms (Wang et al., 2015) plays an ecofriendly role in agricultural soils and positive effects on soil properties. A lot of previous literature (Sadaf et al., 2017; Ghani et al., 2019; Sial et al., 2019d) documented that co-application of organic and inorganic amendments had enhanced soil organic carbon (SOC) and increased nutrients availability over alone chemical fertilizers.

According to the National Bureau of Statistic, 2015 (NBS) of China assessed that total crop yield and sown area in China around 11,3340.50 thousand hectares, and increasing trend in crop production and at the same time crop straw biomass has been generated in huge quantity (Zhang et al., 2015). Since past few decades farmers have been burned crop residue which a traditional practice (Wuest et al., 2005) and caused environment issues. Shi et al. (2014) evaluated that total annual crop straw 2.3×10^8 from maize and 1.3×10^8 from wheat is alternative source of organic matter and soil essential nutrients (Khan et al., 2019). According to Sun et al. (2012) documented that China is the highest consumer of chemical fertilizer, and approximately 35% of the world total consumptions. China has 25% of the world population and largest country according to population in the world (Peng et al., 2017). To maintain the food demand for future generations is major task for China and all over the world. That's why application of higher doses of chemical fertilizers for maximum crop yield, pressure on water and soil resource (Khan et al., 2019). The continuously sole application of chemical fertilizers could be cause economic and environment issues as well as negative impact on soil carbon stocks (Laghari et al., 2015; Pan et al., 2018; Sial et al., 2019d). Previous literature addressed that incorporation of crop straw into soil and improved organic matter contents (Zhang et al., 2017b) improved crop production and soil fertility (Sadaf et al., 2017; Akhtar et al., 2018). Similar, Kirkby et al. (2014) established the straw amendment had positive effects on soil organic matter (SOM) contents and alternative source of microorganisms.

During coal mining the raw coal gangue is byproduct and consists of organic and inorganic components, which has been generated around 100 Mt every year and cause economic and environment task for Chinese Government (Li et al., 2018). Some numerous studies (Zhou et al., 2012; Peng et al., 2018) established that beneficial usage of coal gangue but only 15% utilized in different ways such as power generation, zeolite activated carbon, cement production and as well as fertilizers products. However, the low quantity used of disposal and inappropriate storage of coal gangue, while accumulation and disposal of this huge waste occupied the huge land, negative impact on environment (Wu et al., 2013), contaminate the soil and water (Yang et al., 2017) as well as serious issue for human health (Wang et al., 2018). Biochar is rich source of C which generated under different pyrolysis temperatures (Lehmann and Joseph, 2009) with negligible O_2 atmosphere (Mukherjee et al., 2011), and has different ranges of characteristic, physical and chemical properties (Gul and Whalen, 2016; Lam et al., 2018).

To date most of laboratory studies assessed that various that application of biochar decreased CO_2 emission from soil (Li et al., 2016; Lan et al., 2017), increase soil water holding capacity (WHC) (Tammeorg et al., 2014), soil pH (Sial et al., 2019a), decreased bulk density (Demisie et al., 2014), it is a much more strong than carbon (Lehmann et al., 2003) and also improved soil fertility by addition of biochar as well as change in available nutrients respite from predation for biochemical properties (Paz-Ferreiro et al., 2012; Jeffery et al., 2017). Wang et al. (2015) established that microbial activity is indicator of soil enzymes

activities and soil nutrients availabilities and transfer energy during different biochemical reactions in soils. While, some researchers evaluated that biochar has no significant effect or even increased emissions (Ameloot et al., 2013). Since last few decades couple of studies have done works on different organic waste included maize straw (Zhang et al., 2017; Korai et al., 2018), fruit waste (Sial et al., 2019a,c), sewage sludge and manures (Awasti et al., 2016) and observed positive effects on GHGs, soil fertility and crop yield. To date, limited evaluations on comparison of coal and straw wastes and their biochars on carbon sequestration, enzyme activities and soil nutrients status in sandy loess soil.

We hypothesized that combining maize residue and coal gas residue with these nutrients will improve nutrient mineralization thus decreasing CO_2 efflux more than straw alone. The ongoing study's primary goals, (1) to investigate the effects of maize straw, coal gas residue wastes, and their biochar's on carbon sequestration and soil enzyme activities and (2) to find out the effect of wastes and their biochars on chemical properties of sandy loess soil.

2. Materials and methods

2.1. Collection of straw and coal wastes and soil

Industrial coal gas residue waste (C) was collected from Yuyang District, Yuling County, and maize straw (S) was collected from the experimental area of san yuan station, Shaanxi province China. Maize residues were cut into tiny pieces, and all feedstocks were air-dried at room temperature for a few days before being ground and filtered (2-mm sieve). In a muffle furnace under an N_2 atmosphere, all wastes were pyrolyzed for an hour at 300 °C. The basic properties of S and C, as well as their biochars, are discussed (Table 1).

The bulk soil sample was collected from an experimental field station, at Yulin Academy of Agricultural Sciences, Yu yang District, and the soil had a sandy loam texture. Soil samples were air-dried under room temperature, grounded, and passed through (2-mm sieve) and before basic analysis of soil. The specific properties of soil that were used in the present incubation experiment are seen in (Table 1).

2.2. Experiment design

The incubation experiment has consisted of 60 days carried out by 4 factors (maize straw and industrial coal gas residue and their derived biochar's) \times 2 levels (0, and 1%) in complete randomized design. Eight treatments were designed, T1 (Control) without any amendment, T2 Nutrients means Nitrogen, Phosphors, and Potassium(N), T3 (1% straw+ N), T4 (1% straw biochar + N), T5 (1% coal gas residue waste + N), T6 (1% coal gas residue waste biochar + N), T7 (1% straw + straw biochar + N) and (1% coal gas residue waste + 1% coal gas residue waste biochar + N), and all amendments were mixed well, on a dry weight basis. The dosages of maize straw, coal gas residue, and their derived biochar were applied to equivalent field (20 tons' ha^{-1}) at 0–20 cm surface layer of soil. 300 grams of air-dried soil and all amendments were thoroughly combined before being shipped in plastic jars. Throughout the experiment, the soil moisture level was balanced and held at (60 %) of its water keeping soil moisture. Both amendments were mixed into the soil and incubated in an incubator at (25 °C) for 60 days. Following the completion of the 60-day incubation cycle, some fresh soil samples were held in refrigerators (4 °C) for determination of soil microbial and enzyme activities, while the remaining soils were air-dried at room temperature for necessary parameter determination

Table 1

Initial physio-chemical characteristics of soil, maize straw, coal gas residue waste and their biochars were used in present study.

Parameters	Soil	Maize straw	Straw biochar	Coal gas residue	Coal ash biochar
Clay (22%)					
Silt (8%)					
Sand (70%)					
Textural class (Sandy Loam)				7.79 ± 0.6	10.22
pH (1:2.5)	8.2 ± 0.04	6.70 0.03 (1:20)	9.88 ± 0.8 (1:20)	(1:20)	(1:20)
EC (1:2.5) (dS m ⁻¹)	181 ± 4.3	1225 ± 8	2052 ± 12	365 ± 9	2230 ± 14
Organic carbon (g.kg ⁻¹)	7.89 ± 0.7	42.33 ± 3	55.41 ± 3	49.55 ± 3	58.55 ± 4
Total N (%)	1.01 ± 0.0	1.36 ± 0.02	1.90 ± 0.03	1.45 ± 0.2	1.95 ± 0.1
C:N	9.57 ± 0.7	31 ± 2	29.36 ± 1.5	34.17 ± 4	30.02 ± 4
Total P (g.kg ⁻¹)	1.54 0.05	0.68% ± 0.01	1.26% ± 0.04	0.95 ± 0.06	1.56 ± 0.2
Total K (g.kg ⁻¹)	34.65 ± 2	0.16% ± 0.0	0.42% ± 0.01	0.36 ± 0.05	0.52 ± 0.04
Olsen P (mg.kg ⁻¹)	21.95 ± 1	–	–	–	–
K exchangeable (mg.kg ⁻¹)	165.56 ± 3	–	–	–	–

2.3. Soil analysis

Soil electrical conductivity (EC) and pH were measured in soil-water extract (1:2.5 (w/v)), and straw, fly coal ash, and biochars were measured with a glass electrode and (1:20 (w/v)). The Master-sizer 2000E (Malvern, UK) laser diffractometer was used to assess soil structure or particle size (Sochan et al., 2012). Wet digestion with (H₂SO₄- K₂CrO₇) was used to calculate the amounts of soil organic carbon (SOC), and Elemental Analyzer was used to determine total nitrogen (TN), TOC, and C: N. (Vario Max, Elementar, Germany). Total phosphorus (TP) and total potassium (TK) concentrations in soil were calculated by digestion with (H₂SO₄+ HClO₄) are briefly identified by (Parkinson and Allen, 1975). Soil ammonium (NH₄⁺) and nitrate (NO₃⁻) concentrations were extracted using 2 M KCl (1:10) and shaking for 1 hour, by continuous flow analyzer (Bran and Luebbe AA3, Norderstedt, Germany). The AP concentrations were determined using the Murphy and Riley (1962), protocol after being removed with 0.5 M NaHCO₃ (pH 8.5). After extraction in 1 N (NH₄OAc), the concentrations of available K (AK) were determined using emission spectroscopy. Knudsen et al. (1982). The specific protocol described by (Vance et al., 1987) for measuring soil microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) using chloroform fumigation and direct extraction was followed. MBC was estimated with a conversion factor of (0.45), and MBN was calculated with a conversion factor of (0.45). (0.54) (Jenkinson and Ladd 1981) define formalized.

2.4. Measurement of soil CO₂ effluxes

The soil CO₂ emitted by the soil samples was captured in plastic vials (20 mL) containing 1.0 mol L⁻¹ NaOH and put inside the plastic jars. As previously stated, four blank jars containing only NaOH were also set up. On days 2, 3, 5, 7, 10, 13, 18, 23, 28, 42, and 60 of incubation, the plastic vials containing (NaOH) were replaced with fresh plastic vials. The trapped (CO₂) emissions were precipitated with (1.0 mol L⁻¹ BaCl₂), and then titrated with standard (0.1 mol L⁻¹ HCl) for enumerating and released CO₂ emissions.

2.5. Soil enzymes assays

The colorimetric approach was used to calculate the activities of soil enzymes (urease, catalase, and invertase). Soil urease activity was determined by the determination of NH₄⁺ released from a solution (10%) of urea, and (pH 7.6) citrate buffer solution at 37±1 °C for 5 hours, detailed by (Tabatabai 1994). Catalase and catalase enzymes activities were determined using a standard protocol; five grams of air-dried soil were incubated for 24 h at (37 °C) with

(15 ml of 8% sucrose), 5 ml phosphate buffer at (pH 5.5 and 0.1 toluene).

2.6. Statistical analysis

All incubation data were checked carefully in (Microsoft Excel 2010) and analyzed by using (SPSS 22) while, for figures generation used (Origin Pro. 9.0.). The current study's findings were provided with four replications (means SE). The results of straw and coal gas residue wastes, as well as their biochar amendments, were evaluated using a two-way study of variation (ANOVA). LSD (Least Significant Differences) p<0.05 was used for mean contrast checking.

3. Result and discussion

3.1. Effects of soil amendments on soil electrical conductivity (EC), pH, NO₃⁻-N and NH₄⁺-N

The applications of straw and coal gas residue wastes and derived biochars combined with chemical fertilizers (N) were increased soil electrical conductivity (EC) and pH over the CK. The EC values were ranged from 208 μ S cm⁻¹ to 475 μ S cm⁻¹ among all treatments, and higher EC was noted in the CB + N (475 μ S cm⁻¹) and lower in the CK treatment. The comparison between wastes, biochars and chemical fertilizer applications, the soil EC values were different from each other, while biochars increased the EC values over the wastes and sole application of N fertilizers treatments. However, co-application of waste and biochar was decreased soil EC value as compared to sole biochar application, while sole application of waste decreased soil EC over the sole biochar and combined with waste applications. Over all the coal gas residue waste and its biochar applications were increased soil EC values as compared to the maize straw waste and its biochar application. In case of soil pH, the sole application of chemical fertilizers and combined with maize straw, maize straw biochar was decreased soil pH over the CK treatment. The opposite pattern was observed in the application of coal gas residue waste and its biochar treatments, soil pH was enhanced over other treatments. The higher pH was recorded in the CB + N (9.5) in the order of CW + N (9.3) > CW + N + CB (9.0) > SB + N (8.7) > CK (8.6) > N (8.5) > S + N + SB (8.4) and S + N (8.3), respectively. In case of soil NH₄⁺-N and NO₃⁻-N contents were statistically (p > 0.05) effected by wastes and biochars treatments (Fig. 2, C-D). The higher NO₃⁻-N concentrations were recorded in the (35.5 mg kg⁻¹) CW + N + C B, and minimum in the (2.8 mg.kg⁻¹) CK treatments. However, soil NH₄⁺-N was different from NO₃⁻-N, sole application of N fertilizer was enhanced NH₄⁺-N concentration as compared to the wastes, biochars and CK treatments. The greater NH₄⁺-N concentrations were observed in the (3.4 mg.kg⁻¹) and lower in the (0.2 mg.

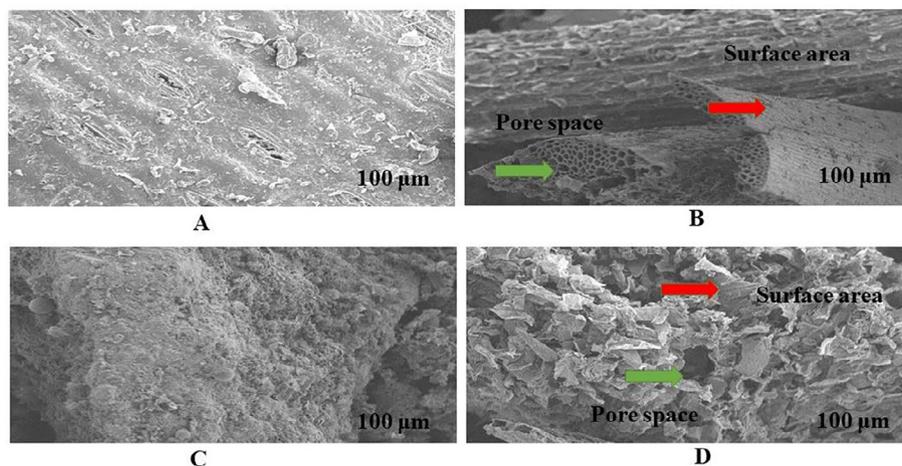


Fig. 1. Electron scanning micrographs of maize straw (A), straw biochar (B) at a temperature of 300 °C, coal gas residue, and biochar coal gas residue at a temperature of 300 °C. The strong red arrows are showing the surface and the soft green arrows represent biochar pores.

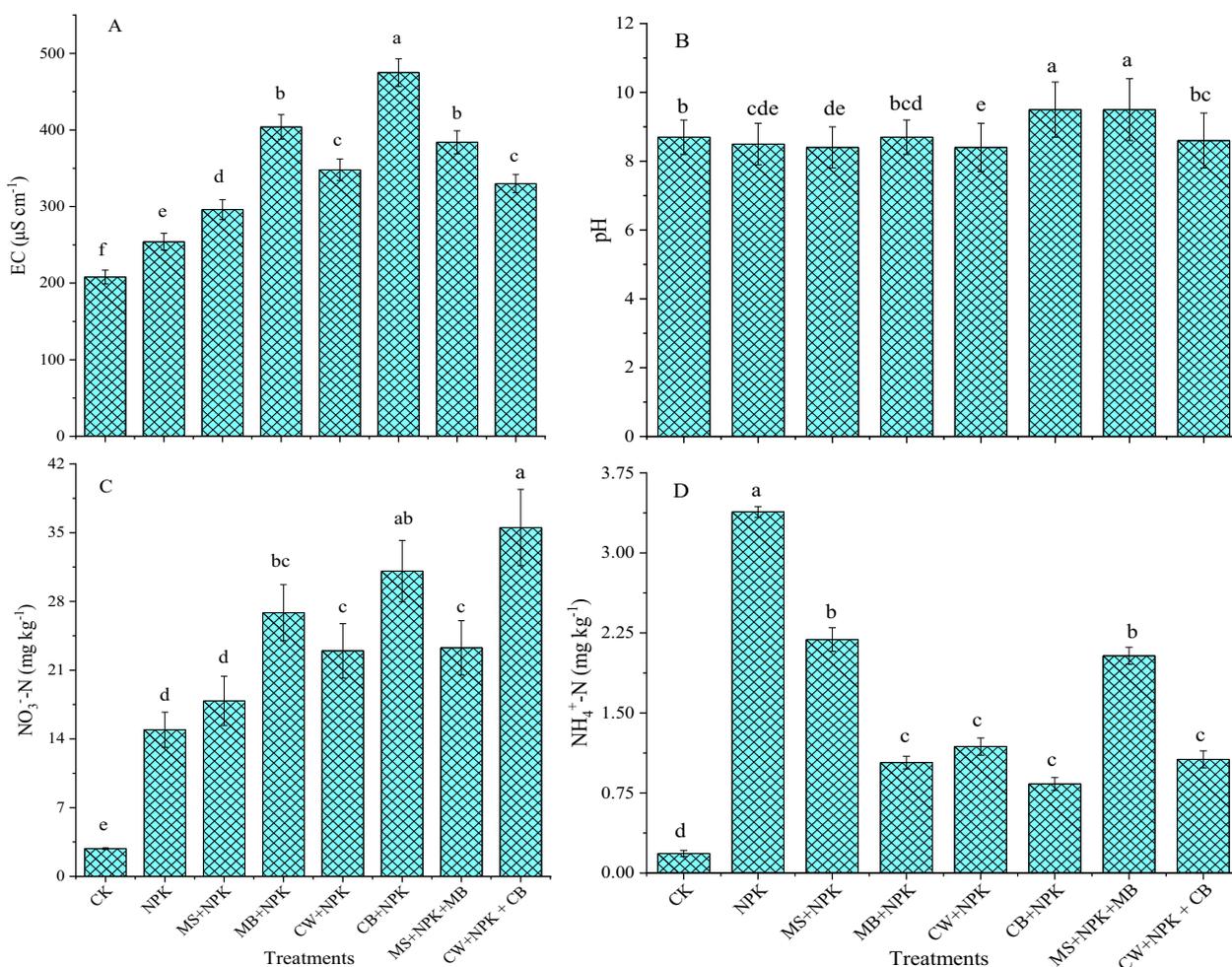


Fig. 2. The effects of maize straw, coal gas residue wastes, and their biochars on soil EC, pH, NO₃-N and NH₄⁺-N (A-E) at 25 ± 1°C for 60 days incubation period. Error bars are the default mean-variance (n = 4). There were major variations (p<0.05) in the means, as shown by different letters. Means of comparisons between treatments.

kg⁻¹) CK. While, biochar sole and combined with waste application was increased soil NH₄⁺-N over CK, but lower than sole application of N. This could be due to soil EC and pH variations after straw, coal fly ash and their biochar applications. Similar, fluctuations were documented by incubation and pot experiment studies

(El- Mahrouky et al., 2015; Zhu et al., 2017; Sadaf et al., 2017; Sial et al., 2019a; Khan et al., 2019) they investigated that organic waste release of acidic decomposable compounds and decreased soil EC and pH. Whereas, biochar application increase soil EC and pH due its liming effects on soil environment (Sial et al., 2019b;

Sikdar et al., 2020). Biochar applications increased soil EC and pH (Khan et al., 2019), liming effects (Randolph et al., 2017) and alkalinity is a major aspect contributed liming potential (Zhu et al., 2017), and caused increasing in soil EC and pH (Sial et al., 2019d). After pyrolysis biochar contained high ash content (Ahmed et al., 2016) and surface functional groups includes phenolic, hydroxyle and carboxyl released from the biochar and to bind H^+ ions when reacted with soil and water (Salam et al., 2019), and cause increase soil EC and pH (Niazi et al., 2018). In current study, soil EC and pH were negatively correlation with NH_4^+-N but soil pH was positively correlation with $NO_3^- -N$. Similar, dynamics were evaluated by Wang et al. (2015) and Sial et al. (2019a,c) under incubation studies. Biochar application improved soil $NO_3^- -N$ concentrations due to ash contents and positive correlation with pH and EC (Haider et al., 2017), these findings are supports to our results because sole and combined with waste application of biochar increased $NO_3^- -N$ concentrations as compared to sole application of waste treatments. Foster et al. (2016) conducted field experiment with applications of cow manure and pine wood biochar (30 tons ha^{-1}), observed that the soil NH_4^+-N concentrations enhanced in the farm yard manure plot, but $NO_3^- -N$ concentrations decreased over biochar and without an amended plots, while, biochar amendment was increased $NO_3^- -N$ concentrations over the manure application.

3.2. Influence of soil amendments on SOC, TN and available K

The SOC contents were significantly ($p < 0.05$) improved under straw, coal gas residue waste, and their biochar's compared with the sole N and CK treatments (Fig. 3). The higher SOC concentration was determined in the CB+N (21.5 $mg.kg^{-1}$), followed by the SB+N (18.8 $mg.kg^{-1}$), C+N + CB (17.3 $mg.kg^{-1}$), S+N+SB (13.1 $mg.kg^{-1}$), C+N (9.7 $mg.kg^{-1}$), S+N (9.5 $mg.kg^{-1}$), N (7.5 $mg.kg^{-1}$) and CK (6.6 $mg.kg^{-1}$), respectively. However, biochars application were significantly increased SOC concentration as compared to the wastes and sole application of N treatments. A similar, picture was observed for soil TN concentration after 60 days incubation period. The applications of maize straw and coal gas residue wastes and their derived biochars combined with nutrients were statistically ($p > 0.05$) improved soil TN over the sole application of N and CK treatments (Fig. 2). Soil TN concentrations range from 0.25 to

1.01 $g.kg^{-1}$ among all treatments, and maximum concentration was recorded in the C+N+CB and lowest in the CK. Soil available potassium (AK) concentrations were improved with the applications of wastes and biochars as well as sole application of N over the CK (Fig. 2). However, the AK concentrations were different the greater percentage increase in the CB+N (87.1%), followed by the SB+N (85.0%), C+N+CB (83.9%), S+N+SB (80.4%), C+N (77.7%), S+N (72.8%) and N (64.3%), respectively, over the CK. The application of organic amendments with chemical fertilizer enhanced soil nutrients concentration (Sial et al., 2019b), but it depends on the soil properties and organic amendments (Sadaf et al., 2017). Some published literatures (Sadaf et al., 2017; Sial et al., 2019d) documented that biochar application improved soil nutrient (SOC, TN and AK) over the its feedstocks, due its high surface area (Sial et al., 2019a) and pore space. Similar pattern was observed by our results because sole biochar application enhanced soil nutrients over the maize, coal gas residue and combined with biochar applications, it may be due to biochar has more surface area and pore space over wastes (Fig. 1).

3.3. Soil amendments' impact on microbial biomass carbon (MBC) and nitrogen (MBN)

The biochars, straw, and coal gas residue wastes, as well as a single application of chemical fertilizer, showed substantial ($p < 0.05$) variations in soil MBC and MBN (Fig. 4). The MBC and MBN were decreased in the sole application of biochars as compared to wastes and combined with waste and biochar treatments, while higher than the sole application of chemical fertilizer and control treatments. The greater MBC was recorded in the S+N (323 $mg.kg^{-1}$), in order to S+N+SB (289 $mg.kg^{-1}$), SB+N (279 $mg.kg^{-1}$), C+N + CB (265 $mg.kg^{-1}$), C+N (244 $mg.kg^{-1}$), CB+N (155 $mg.kg^{-1}$), N (115 $mg.kg^{-1}$) and CK (74 $mg.kg^{-1}$), respectively. A similar pattern was observed in the MBN which was higher in the S+N (83.3 $mg.kg^{-1}$) and lower in the CK (23.5 $mg.kg^{-1}$) treatments. Our results are agreed with published literatures (Korai et al., 2018; Sial et al., 2019a). Zhu et al. (2017) established that feedstocks have created suitable environment for microbial activities due to labile C, which resultant of the raw organic feedstocks (Zhang et al., 2017; Sial et al., 2019b). This could be due to the maize straw and coal gas residue wastes released higher contents

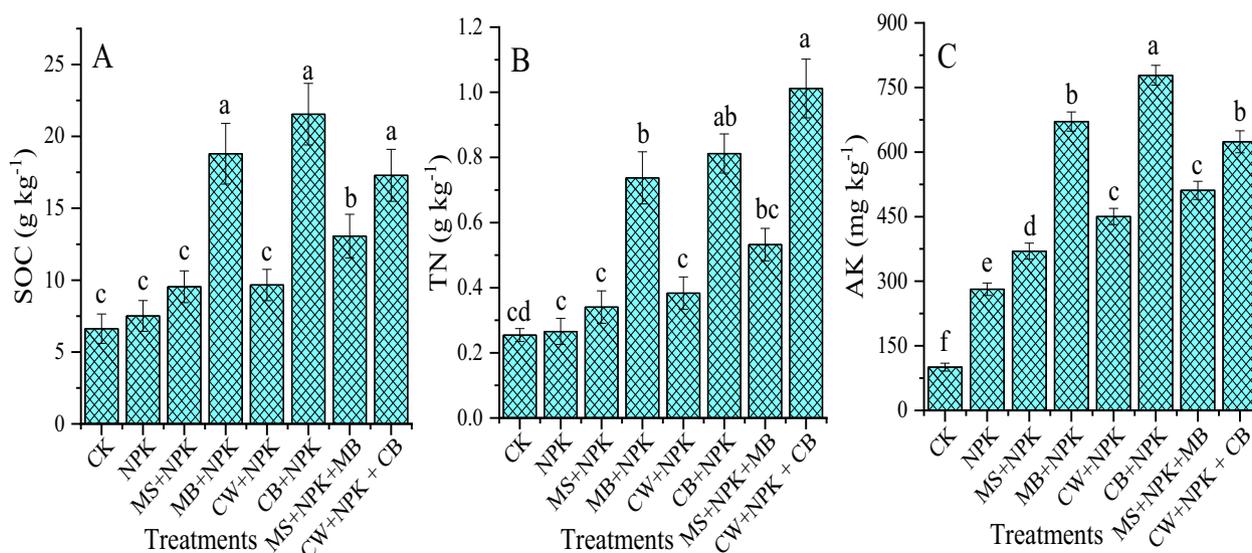


Fig. 3. The effects of maize straw, coal gas residue wastes, and their biochars on SOC, TN, and AK (A–C) incubation time at 25 °C for 60 days. Error bars are the default mean-variance ($n = 4$). There were major variations ($p < 0.05$) in the means, as shown by different letters. Means of comparisons between treatments.

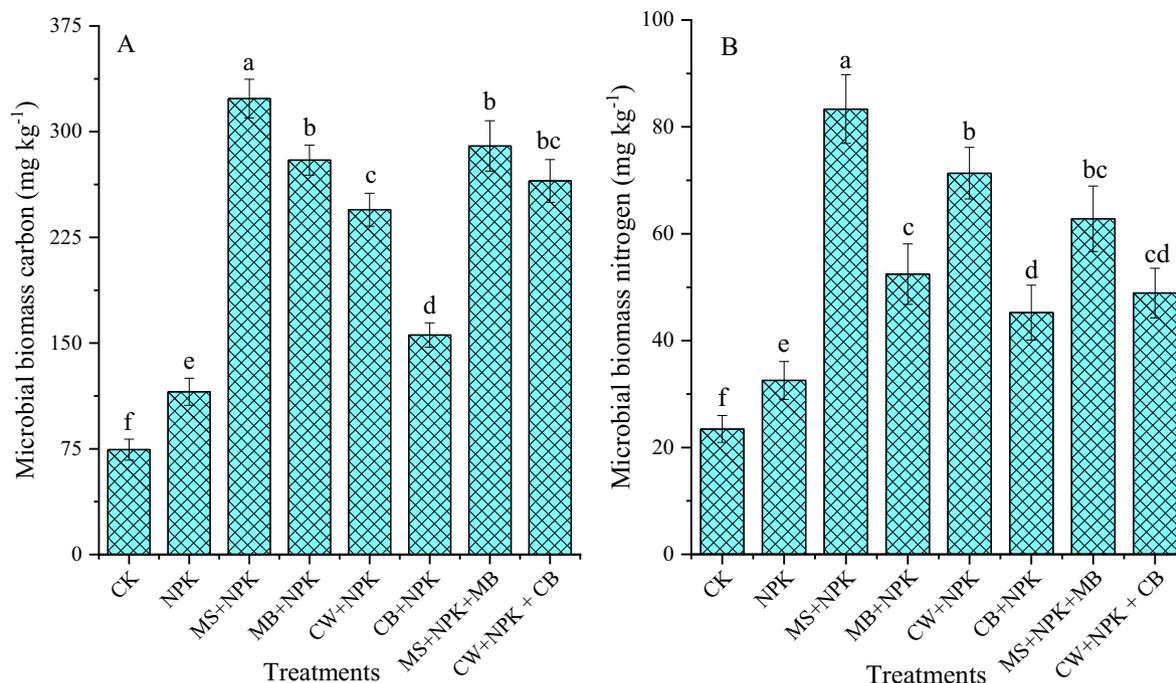


Fig. 4. At 25 °C for 60 days, the impact of maize straw, coal waste, and their biochars on soil microbial biomass carbon and nitrogen (A-B). The standard deviation of the mean (n = 4) is described by the error bars. There were major variations ($p < 0.05$) in the Means Comparisons between the treatments, as shown by different letters.

of labile carbon and cause increase MBC and MBN as compared to biochars and chemical fertilizer treatments. Lehmann and Joseph (2009) documented that soil or amendment pH also affected on microbial activities and increasing pattern in pH could be decreased MBC and MBN (Sial et al., 2019c). Similar picture was evaluated in the present study, that soil pH negatively correlation with MBC and MBN.

3.4. The impact of straw and coal gas residue wastes and their biochars on soil enzymes activities

The soil enzyme activities have depended on properties of amendments and soil characteristics and behavior of enzymes. The soil enzymes activity was enhanced with application of maize straw, coal gas residue and biochar treatments over the CK treatment (Fig. 5 A-C). The greater soil urease activity was determined in the S+N+SB (174 mg urea-N kg⁻¹ soil h⁻¹) and lowest in the CK (68 mg urea-N kg⁻¹ soil h⁻¹). The urease activity was increased with the sole and combined with biochar application of waste treatments as compared to sole biochars application and N treatments. However, maize straw, coal gas residue wastes and their biochar sole as well as combined applications were increased urease activities over the CK treatment. A similar pattern was documented in the previous literatures (Wu et al., 2013; Foster et al., 2016; Zhu et al., 2017; Akhtar et al., 2018; Khan et al., 2019). As compared to CK, wastes and their biochars applications were enhanced invertase and catalase activities (Fig. 5 B&C). The greater invertase activity was determined in the S + N + SB (343 mg glucose kg⁻¹ soil h⁻¹) and minimum in the CK (206 mg glucose kg⁻¹ soil h⁻¹) treatments. The N sole application was not significantly increased invertase activity over the CK treatment. While, catalase activity was increased in the sole application of N over the CK treatment. The greater percentage was recorded in the CB + N (59.3%), followed by C + N + CB (56.2%), SB + N (54.9%), S + N + S B (54.5%), CW + N (51.1%), S + N (45.2%) and N (20.7%), respectively. Similar pictures were investigated under incubation and pot exper-

iment studies (Wang et al., 2015; Lan et al., 2017; Khan et al., 2019; Sial et al., 2019a,b). The hydrolysis of organic compounds accelerated the soil enzymes activities (Wang et al., 2015), and energetic sources for soil microbes (Sial et al., 2019b), implying different C hydrolyzing activities (Zhu et al., 2017) and considered as an indicator of changes in C related soil enzymes (Pathan et al., 2017). Another study conducted by Bera et al. (2016) reported C related enzymes activities decreased in comparison to the feedstock of biochar. These evidences are supported to the current study because biochar treatments were decreased C related enzymes activities over the waste's treatment.

3.5. The effects of straw and coal gas residue wastes and their biochars on carbon dioxide emissions

3.5.1. Carbon dioxide (CO₂)

The influences of soil amendments organic (crop residue or straw, farmyard manure, fruit waste and mining waste) and biochar applications, and inorganic or chemical fertilizers on the carbon sequestration have been evaluated under laboratory and field conditions. However, negative as well as positive effects have been investigated after sole and combined both amendments to soils under both conditions/ incubation and field (Wu et al., 2013; Lan et al., 2017; Korai et al., 2018; Sial et al., 2019a). In the present study, we were used maize straw, coal gas residue, and their biochar's applied with nutrients. The application of soil treatments were effects on carbon dioxide (CO₂) emissions as compared to the CK (Fig. 6). The single application of N raised CO₂ emissions over the CK, while biochar treatments reduced CO₂ emissions over the waste and biochar + waste treatments. From day 1 to day 10, CO₂ emissions were higher with all therapies except CK, and as time passed, emissions steadily decreased but remained higher than CK until day 30. Overall, both biochars applications were decreased CO₂ emissions as compared to the maize straw, coal gas residue, and combined with biochar treatment. The higher cumulative CO₂ emissions were recorded in the S+N+SB, to

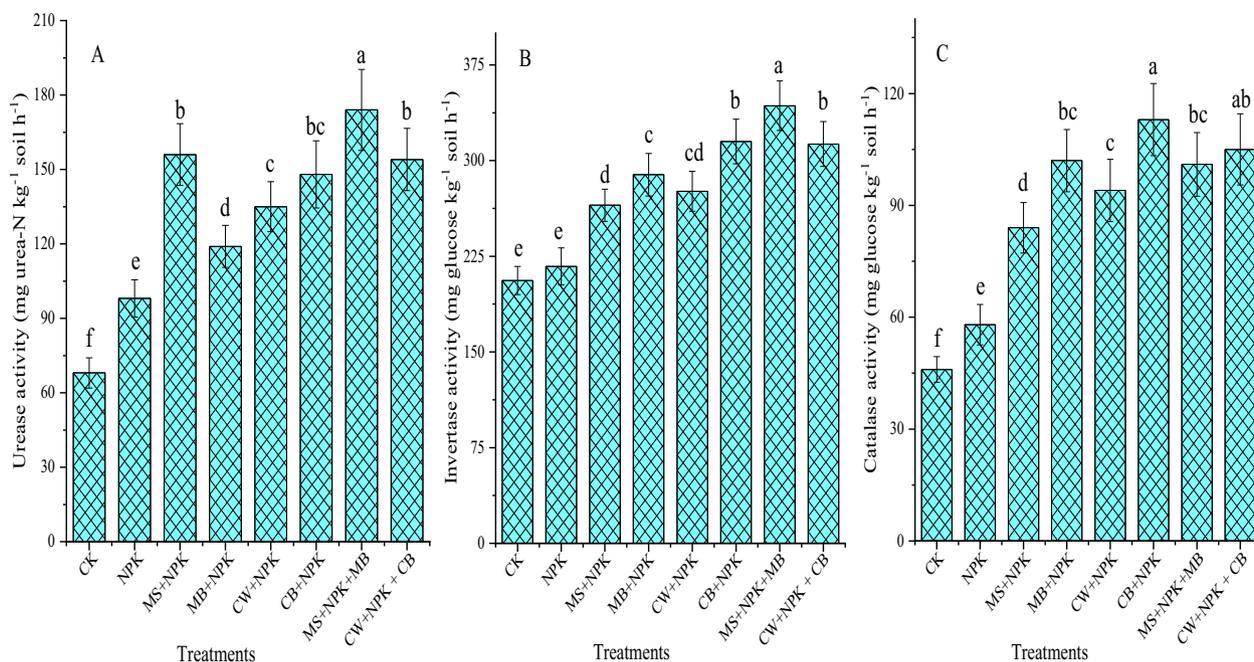


Fig. 5. After a 60-day incubation cycle, the results of maize straw, coal gas residue waste, and their biochar combined with nutrients (N) on soil enzyme activities (urease, invertase, and catalase) (A-C). The standard deviation of the mean (n = 4) is described by the error bars. There were major variations (p<0.05) in the Means Comparisons between the tr, as shown by different letters.

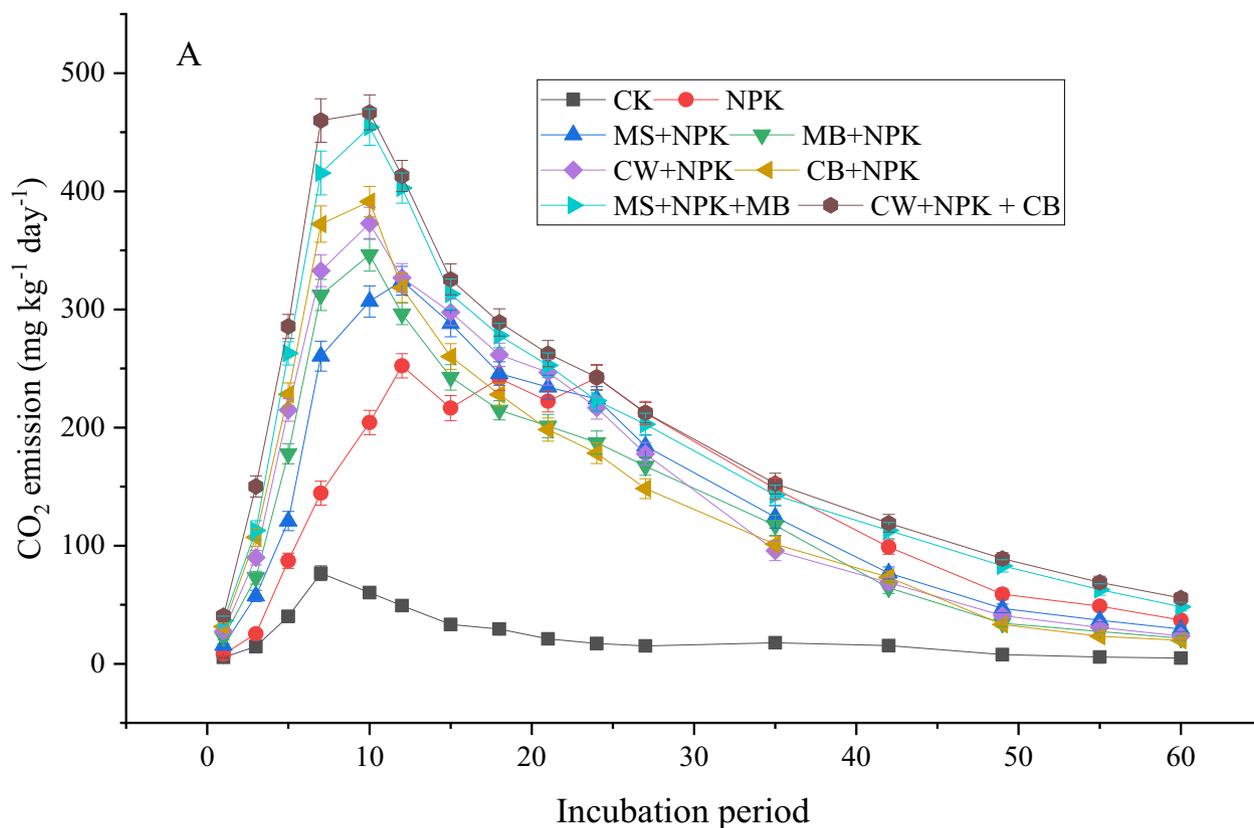


Fig. 6. The effect of maize straw, coal gas residue, and their biochars on CO₂-C emissions over a 60-day incubation. The standard deviation of the mean (n = 4) is described by the error bars. There were major variations (p<0.05) in the means, as shown by different letters. Means of comparisons between treatments.

C+N+CB, S+N, C+N, SB+N, CB+N, and N, respectively (Fig. 7). These findings are agreed with (Zhu et al., 2017; Hawthorne et al., 2017; Sial et al., 2019a). The application of maize straw, coal gas residue

and combined with their biochar displayed higher CO₂ emissions throughout the incubation period. Wu et al. (2013) established that biochar is major source of C for soil and lead abundant amount of C

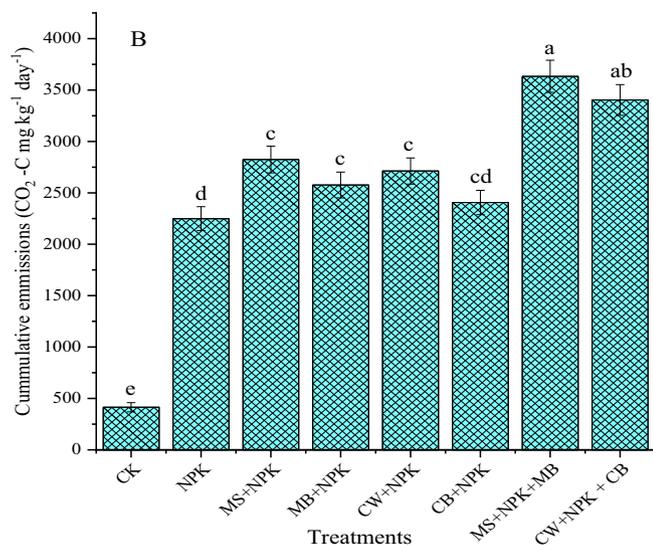


Fig. 7. After a 60-day incubation cycle, the effect of maize straw, coal gas residue, and their biochars on accumulated emissions (CO₂-C) at 25 °C. The standard deviation of the mean (n = 4) is described by the error bars. There were major variations (p < 0.05) in the means, as shown by different letters. Means of comparisons between treatments.

sequestration over the its raw materials. This may be due waste and biochar + waste treatments were displayed higher CO₂ emissions among all treatments. Similar pattern was established by Gascó et al. (2016) who evaluated that biochar application was decreased CO₂ emissions in comparison of its raw material pig manure in a 219-day incubation or controlled conditions. Zhang et al. (2017) recognized that cumulative CO₂ fluxes were lower in the wheat straw derived biochar amended plots and greater CO₂ fluxes measured in the wheat amended plot under field conditions. A 90 day incubation experiment conducted by Sial et al. (2019c) documented that soil microbial biomass carbon (MBC) and nitrogen (MBN) activities also indicator for CO₂ emissions fluctuations. These results are support to our findings because maize straw and coal gas residue wastes displayed maximum CO₂ emissions, MBC and MBN as compared to their biochars.

4. Conclusion

This incubation study demonstrated how maize straw, coal gas residue, and their biochars could be offer soil nutrients, enzyme activities, and CO₂ emissions. Overall, SOC, TN, AK, soil enzyme activities, and MBC and MBN were increased in all treatments over the CK. However, maximum CO₂ emissions were decreased in the biochar treatments as compared to wastes and combined with biochar treatments. In this study concluded that maize straw and coal fly ash wastes converted into to biochar product, and it could be a feasible an alternative option for land amendments, and resulted in decreased CO₂ emissions, and positive changes in soil quality. Therefore, future studies should focus on different organic waste biochars amendments would be tested under long-term experiments and decline the economic and environmental issues in arid soils.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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