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Effect of levels of biochar and FYM on physico-chemical properties, nutrients release and carbon dioxide evolution from the soil

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Abstract

To know the dissolution and release of nutrients from biochar and FYM, an incubation study was conducted during 2018 in College of Agriculture, using sandy loam with acidic pH (5.88) soil collected from Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga. Two kilo gram of soil was filled in separate plastic boxes (2 kg capacity) and treatments imposed as per the treatments details (T_1: Control (without biochar and FYM), T_2: FYM @ 5 t ha^{-1}, T3: FYM @ 10 t ha^{-1}, T_4: Biochar @ 2 t ha^{-1}, T_5: Biochar @ 4 t ha^{-1}, T_6: Biochar @ 6 t ha^{-1}, T_7: Biochar @ 8 t ha^{-1}) and replicated thrice and was laid out in a completely randomized block design (CRBD). results revealed that, application of different levels of biochar increased the pH and EC of soil over control and FYM levels applied treatments, the greater increase of pH (6.20) and EC (0.25 dS m^{-1}) was noticed with the application of CS-biochar @ 8 t ha^{-1} at 120 DAI. Available nitrogen and potassium showed a gradual increase throughout incubation. Significantly, higher available nitrogen (330.26 kg ha^{-1}) and available potassium (229.95 kg ha^{-1}) were registered in the treatment T_7 (CS-biochar @ 8 t ha^{-1}) at 120 DAI. However, available phosphorus content in the soil gradually increased up to 60 days of incubation and slightly decreased afterward. Secondary nutrients gradually increased over an increasing incubation period. Significantly, higher exchangeable Ca (3.64 cmol (p^+) kg^{-1}) and Mg (2.57 cmol (p^+) kg^{-1}) was recorded in the treatment T_7 (CS-biochar @ 8 t ha^{-1}). However, significantly higher available S (12.5 mg kg^{-1}) was registered in the treatment T_3 (FYM @ 10 t ha^{-1}) at 120 DAI. Similarly, DTPA extractable micronutrients significantly, higher Fe (31.69 mg kg^{-1}), Mn (1.24 mg kg^{-1}), Zn (0.58 mg kg^{-1}) and Cu (0.52 mg kg^{-1}) was recorded in the treatment T_7 (CS-biochar @ 8 t ha^{-1}). Application of biochar and FYM levels significantly influenced the CO_2 evolution as compared to control. At 60, 90 and 120 DAI, significantly maximum CO_2 evolution was noticed in the biochar @ 8 t ha^{-1} treatment. In general, the maximum CO_2 evolution increased with the increasing incubation period and levels of biochar.

Keywords: Biochar, FYM, incubation, Co_2, nutrient release

Introduction

In recent years, biochar has emerged as an organic amendment with mineral nutrient elements and hold a promise to improve the soil quality and yield of crops. The biochar is found to have a positive impact on soil fertility, resulting in an increase in crop yield without causing a hazard to soil and water environment.

Biochar produced from varied technological methods of pyrolysis can convert agriculture crop residues like coconut shells, arecanut husks, maize cob, cereal-pulse crop husks, grasses, forestry products, animal and poultry manures to biochar. Pyrolysis is the heating of biomass in a limited oxygen condition or complete in the absence of oxygen, causing the release of volatile carbon structures, hydrogen (H), methane (CH_4) and carbon monoxide (CO). The volatile carbon structures (alcohols, oils, tars, acids, *etc*.) can be re-condensed as bio-oil. The biochar that remains consists mainly C, and contains O, H, N and ash [calcium (Ca), potassium (K), *etc*.,]. Biochars with large amounts of carbon in poly-condensed aromatic structures are obtained by pyrolyzing organic feed stocks at high temperatures (400 to 700 ºC), but also have fewer ion exchange functional groups due to dehydration and decarboxylation, potentially limiting its usefulness in retaining soil nutrients.

On the other hand, biochars produced at lower temperatures (250 to 400 ºC) have higher yield recoveries and contain more C=O and CH functional groups that can serve as nutrient exchange sites after oxidation.

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Moreover, biochars produced at lower pyrolysis temperatures have more diversified organic character, including aliphatic and cellulose type structures. These may be good substrates for mineralization by bacteria and fungi, which have an integral role in nutrient turnover processes and aggregate formation. Biomass selection also has a significant influence on biochar surface properties and its elemental composition. Biochar is a fine grained, highly porous charcoal substance that is distinguished from other charcoals in its intended use as a soil amendment. The particular heat treatment of organic biomass used to produce biochar contributes to its large surface area and its characteristic ability to persist in soils with very little biological decomposition (Lehmann *et al.*, 2006). While raw organic materials supply nutrients to plants and soil microorganisms. Biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar makes it to adsorb or retain nutrients and hold moisture and in addition to this labile fraction of C in biochar provides C and energy to heterotrophic beneficial microorganisms to flourish and the ash fraction may supply some of the mineral nutrient requirements for crops (Glaser *et al.* 2002, and Warnock *et al.* 2007) [18]. Addition of biochar to soils has attracted widespread attention as a method to sequester carbon in the soil. Increased soil carbon sequestration can improve soil quality because of the vital role that carbon plays in chemical, biological and physical soil processes and many interfacial interactions.

Biochar application to soil may thus improve the physical properties of soil because of retardation of native stable organic matter decomposition. It persists for a longer time in soil. Therefore, it is indeed to study the effect of biochar on physico-chemical properties, nutrients release and carbon dioxide evolution from the soil and its potentiality as a nutrient source are very scanty and it deserves detailed investigation.

Materials and methods

To know the dissolution and release of nutrients from biochar and FYM, an incubation study was conducted during 2018 in College of Agriculture, using sandy loam with acidic pH (5.88) soil collected from Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga. Two kilo gram of soil was filled in separate plastic boxes (2 kg capacity) and treatments imposed as per the treatments details (T_1: Control (without biochar and FYM), T_2: FYM @ 5 t ha^{-1}, T3: FYM @ 10 t ha^{-1}, T_4: Biochar @ 2 t ha^{-1}, T_5: Biochar @ 4 t ha^{-1}, T_6: Biochar @ 6 t ha^{-1}, T_7: Biochar @ 8 t ha^{-1}) and replicated thrice and was laid out in a completely randomized block design (CRBD). Moisture content was maintained at field capacity by weighing the boxes periodically and weight loss due to evaporation was made by adding water. With two following basic objectives an incubation study was conducted,

a. To study the effect of different levels of biochar and FYM on chemical properties and nutrient release pattern in soil at different intervals of periods. Destructive sampling of soil was done at 15, 30, 60, 90 and 120 days after incubation and samples were analyzed for pH, EC, primary nutrients (nitrogen, phosphorus and potash), secondary nutrients (calcium, magnesium and sulphur) and micronutrient zinc, iron, manganese and copper by adopting standard procedures.
b. To study the effect of different levels of biochar and FYM on CO_2 evolution as an indicator of microbial activity in soil at different intervals of periods. From three replication, 300 g of 2 mm sieved soil samples were taken in conical flasks and treatments as furnished above were imposed and were incubated at field capacity to monitor CO_2 evolution as influenced by biochar and FYM treatments. During the incubation study, the CO_2 evolution was measured periodically by using the following procedure.

A known volume of standard Na OH was taken in 250 ml capacity centrifuge tube and the tube was put into a conical flask added with soil imposed treatments. Similarly, a blank was maintained without using soil. After sealing the mouth of the flask with wax, it was kept for the required number of days to trap the evolved CO_2. Then the centrifuge tube was taken out and content of the tube was titrated against standard HCl using phenolphthalein indicator after adding the required amount of saturated $BaCl_2$ solution. This was repeated for different periods of sampling *viz.*, 5, 10, 20, 30, 60, 90 and 120 days the incubation study in order to study the rate of CO_2 evolution from imposed treatments. Finally, the amount of CO_2 evolved was calculated using the following formula (Page *et al.*, 1982).

$$\mathrm{CO_2\ evolution\ (mg/100g)} = \frac{(\mathrm{Blank\ TV} - \mathrm{Sample\ TV}) \times \mathrm{N\ HCl} \times 22 \times 100}{300}$$

Results and discussion

Effect of biochar and FYM on soil physico-chemical properties

Results of incubation study on pH and EC of soil due to effect of levels of biochar application is presented in Table 2

The gradual increasing trend of pH was noticed with time of incubation in treatments treated with higher dose of biochar. Even, with respect to EC of soil significant effect of levels of biochar and FYM was seen at all intervals of incubation except 15 DAI. Application of coconut shell biochar at 8 t ha^{-1} (T_7) recorded significantly higher EC 0.20, 0.21, 0.22 and 0.25 dS m^{-1} at 30, 60, 90 and 120 DAI, respectively as compared other treatments and lowest soil EC 0.11, 0.10, 0.13, and 0.12 dS m^{-1} was recorded at 30, 60, 90 and 120 DAI, respectively in control treatment (T_1) where biochar not applied. The EC gradual increasing trend was noticed with time of incubation with increased levels of biochar over FYM applied treatments.

The results of incubation study clearly noticed that, with increase in days of incubation period (15-120 days) and increase in the levels of FYM (5-10 t ha^{-1}) and CS-biochar (2-8 t ha^{-1}). There was increase in pH and EC of soil was recorded due to application of biochar @ 8 t ha^{-1} at 120 DAI compared to FYM application @ 10 t ha^{-1}. Overall, soil pH and EC increased with higher dose of biochar as compared to FYM levels over a period of incubation.

The observed changes in pH of soil incubated with biochar can be ascribed to the release of alkaline compounds, which neutralized the soil acidity and thus increased the soil pH. During pyrolysis, cations (primarily K, Ca, Si and Mg) present in the feedstock formed metal oxides and once applied to soil, these oxides can react with H^+ and monomeric Al species and thus alleviate soil pH. As biochar contain significant quantity of Ca, it can replace the monomeric Al species from soil exchange complex in acidic soil. Accompanying this reaction, there could be increase in soil solution pH caused by the depletion of the readily hydrolysable monomeric Al and the formation of the more neutral $[Al(OH)_3]^0$ species (Novak *et al.*, 2009). The findings of present study are in line with (Laird *et al.*, 2010) [12] who recorded increase in soil pH by applying different kinds of biochar to soil. Application of wood bark biochar at 12 t ha-1 increased the pH by 1.0 to 1.5 units (Yamato *et al*., 2006) [20].

Soil electrical conductivity was increased with increased levels of biochar over a period of incubation. Significant increase in EC with biochar application was often reported in literature (Chintala *et al*., 2014) [4]. Lower EC in some of biochar amended treatments were recorded at different intervals in present investigation compared to control and may be attributed to possible sorption of salts by biochar amended soil. Such low variation in EC of biochar treated soil was also noticed by Thomas *et al*. (2013) [17]. Artiola *et al*. (2012) [1] observed the range of variation in EC from 1.1 to 1.2 dS m-1 in a pot leachate regardless of treatment of pine waste biochar with no temporal trend though it contains 2,200 mg kg-1 of water-soluble salts. The increase in soil EC was likely temporary and small and was not consistently detected in the biochar treated soils as noticed in the present study.

Effect of biochar and FYM on available primary nutrients status

With increase in levels of biochar and FYM and period of incubation there was a increase in the available nitrogen of soil in all treatments at 120 DAI when compared to other intervals of incubation (Table 2). Available nitrogen content of soil as influenced by different levels of biochar was found to be significant at all intervals of incubation except at 15 DAI. Although, there was a significant difference in the available nitrogen content with different levels of coconut shell biochar and FYM application when compared to control, the highest content (330.26 kg ha-1) was recorded with the application of coconut shell biochar @ 8 t ha-1 and lowest (236.35 kg ha-1) was observed in control at 120 DAI, respectively.

Available phosphorus in soil not differed significantly due to levels of coconut shell biochar application at all intervals except at 60 DAI. Further, available phosphorus in soil increased with increased levels of biochar. But, compared to FYM treatments available P status was lower. However, Addition of biochar at all levels decreased the available P2O5 after 60 DAI as compared to 15 DAI (Table 2). Although, there was a difference in the available P2O5 content with different levels of biochar and FYM application when compared to control, the highest content (82.42 kg ha-1) was recorded with the application of coconut shell biochar @ 8 t ha-1 at 60 DAI and lowest (57.58 kg ha-1) in control at 15DAI.

Table 1: Effect of levels of biochar on soil pH and EC at different intervals of incubation

Treatments	pH					EC (dSm^{-1})				
	Days after incubation									
	15	30	60	90	120	15	30	60	90	120
T$_1$: Control (without biochar)	5.60	5.72	5.68	5.58	5.63	0.11	0.11	0.10	0.13	0.12
T$_2$: FYM @ 5 t ha^{-1}	5.84	5.93	6.02	6.07	5.92	0.13	0.13	0.14	0.16	0.16
T$_3$: FYM @ 10 t ha^{-1}	5.83	5.87	5.96	6.10	6.13	0.13	0.14	0.14	0.16	0.15
T$_4$: CS - Biochar @ 2 t ha^{-1}	5.79	5.82	5.91	5.98	6.10	0.14	0.19	0.19	0.21	0.24
T$_5$: CS - Biochar @ 4 t ha^{-1}	5.83	5.90	5.98	6.12	6.17	0.14	0.19	0.20	0.22	0.24
T$_6$: CS - Biochar @ 6 t ha^{-1}	5.83	5.92	6.00	6.14	6.18	0.15	0.19	0.21	0.22	0.24
T$_7$: CS - Biochar @ 8 t ha^{-1}	5.89	5.93	5.99	6.14	6.20	0.16	0.20	0.21	0.22	0.25
S.Em±	0.23	0.24	0.01	0.02	0.01	0.003	0.001	0.001	0.001	0.001
C.D. (*p*=0.05)	NS	NS	0.03	0.06	0.04	NS	0.003	0.004	0.003	0.003

Note: CS: Coconut shell

Table 2: Effect of levels of biochar on available primary nutrients status in soil at different intervals of incubation

Treatments	Available N (kg ha^{-1})					Available P_2O_5 (kg ha^{-1})					Available K_2O (kg ha^{-1})				
	Days after incubation														
	15	30	60	90	120	15	30	60	90	120	15	30	60	90	120
T$_1$: Control (without biochar)	203.46	210.66	228.32	230.36	236.35	57.58	58.47	61.41	62.14	60.50	156.26	148.35	158.22	161.26	152.68
T$_2$: FYM @ 5 t ha^{-1}	225.35	240.63	271.32	29.32	293.22	60.21	65.46	68.22	62.49	68.49	160.39	163.36	167.35	170.55	174.54
T$_3$: FYM @ 10 t ha^{-1}	236.49	273.19	290.58	311.54	321.16	68.38	66.28	69.55	72.45	72.33	162.68	163.53	170.73	180.61	180.61
T$_4$: CS - Biochar @ 2 t ha^{-1}	226.34	236.51	260.28	283.27	309.59	66.36	68.41	71.21	54.18	51.69	157.6	168.46	170.54	185.24	205.14
T$_5$: CS - Biochar @ 4 t ha^{-1}	230.56	256.45	268.21	289.33	223.35	65.30	74.20	75.21	60.46	58.15	156.36	160.45	172.58	183.44	218.21
T$_6$: CS - Biochar @ 6 t ha^{-1}	232.40	230.64	279.54	300.47	328.57	70.48	68.27	78.40	63.21	54.87	158.31	157.05	176.36	196.27	226.38
T$_7$: CS - Biochar @ 8 t ha^{-1}	250.37	263.26	299.91	318.31	330.26	71.47	70.17	82.42	67.54	65.50	160.12	164.57	177.25	198.5	229.95
S.Em±	4.58	1.64	0.92	1.25	1.42	3.21	3.10	1.12	1.23	1.48	1.43	20.29	1.78	1.27	1.50
C.D. (*p*=0.05)	NS	4.98	2.80	3.79	4.32	NS	NS	1.58	NS	NS	NS	NS	5.39	3.87	4.55

Note: CS: Coconut shell

Available K_2O content significantly differed with application of levels of biochar and FYM at all intervals except 15 and 30 DAI in soil (Table 2). However, increase in available K_2O content was observed with incubation time recorded higher at 90 and 120 DAI. Over all other treatment combination, coconut shell biochar @ 8 t ha^{-1} recorded higher available K_2O content of 229.95 kg ha^{-1} at 120 DAI and lower (148.35 kg ha^{-1}) in control treatment at 30 DAI.

Primary nutrients like nitrogen and potassium content in soil increased over a period of incubation with increased levels of biochar (Table 2). After 60 days of incubation primary nutrient (N and K) content was increased remarkably over FYM treatments. But, higher available P_2O_5 content was observed at 15 DAI, 30 DAI and 60 DAI soils. In general, there was decrease in P_2O_5 content over a period of incubation in soil. Such observations were similar Sharpley *et al.* (1983). The combination of adsorption and precipitation of P with Ca^{2+} reduced the available P over a time. Lehmann (2007) [7-18] reported that biochar can adsorb > 3000 mg kg^{-1} of phosphates even at low solution concentration of 40 mg L^{-1}. Such adsorption can greatly contribute to reduction of P content in soil solution. Xu *et al.* (2014) [19] found that among different fractions of P, Ca-P was greatly enhanced with biochar application. Decrease in Ca content at 30 DAI in acidic soil can be linked to precipitation of P as Ca - P in the present study.

The nutrient content of biochars is largely influenced by the type of feedstock and pyrolysis conditions (Singh *et al.*, 2010) [16], whereas the availability of nutrients in biochars is related to the type of bonds associated with the element involved (Yao *et al.*, 2010) [21]. Further, Mukherjee and Lal (2013) [9] in a study observed that, lower temperature fresh biochar (250 °C) released more nutrients than higher temperature biochars (650 °C) and grass biochar released more nutrients than wood biochars. Similarly, in present study higher available primary nutrient content of coconut shell amended soil may be due to higher total nutrient content present in the coconut shell biochar 0.42, 0.17 and 1.26 per cent of N, P and K respectively and produced under 450 ^{o}C.

Effect of biochar and FYM on secondary nutrients status

The results in relation to soil secondary nutrients (Ca, Mg and S) status due to effect of levels of biochar on soil after different intervals of incubation is presented in Table 3.

The exchangeable Ca content in soil differed significantly due to the application of various levels of biochar and FYM at all intervals except 15, 30 and 60 DAI (Table 3). Application of graded levels of biochar and FYM showed a significant effect on exchangeable Ca at 90 and 120 DAI only. A continuous increasing trend of exchangeable Ca content was observed from 15 to 120 DAI, but higher at 120 DAI (3.64 cmol (p^+) kg^{-1}) was recorded in T_7 (CS-biochar @ 8 t ha^{-1}). The exchangeable Ca content varied with the application of different levels of biochar and FYM over an incubation period and lowest exchangeable Ca (2.17 cmol (p+) kg-1) was recorded in control at 120 DAI.

In soil, addition of levels of coconut shell biochar and FYM showed a significant effect on exchangeable Mg at all intervals except 15 and 30 DAI (Table 3). Exchangeable Mg content increased from 15 DAI to 120 DAI in all treatments except in control treatment and higher exchangeable Mg content was observed at 120 DAI and values ranged from 2.07 to 2.67 cmol (p+) kg-1 in FYM and biochar applied treatments. Over a period of incubation, application of FYM @ 10 t ha-1 recorded highest (2.67 cmol (p+) kg-1) exchangeable Mg content and lowest with control (1.15 cmol (p+) kg-1) at 120 DAI, respectively.

Available S in soil influence due to application of different levels of biochar and FYM were found to be significant at 60, 90 and 120 DAI in soil (Table 3). A continuous increasing trend of available sulphur content was recorded from 15 to 120 DAI in all intervals of incubation with increasing levels of biochar and FYM. Of all the treatment, application of FYM @ 10 t ha-1 recorded highest (13.91 cmol (p+) kg-1) and lowest (10.31 cmol (p+) kg-1) of available sulphur recorded in control treatment at 120 DAI respectively.

Increase in exchangeable bases in soil at different incubation intervals can be attributed to release of basic cations from biochar. During pyrolysis, biomass acids are converted into bio- oil and alkalinity is inherited by solid biochar (Laird *et al*., 2010). Most of the Ca, Mg, K, P, and plant micronutrients in feedstock are partitioned into the biochar ash fraction during pyrolysis. Ash in biochar rapidly releases free bases such as Ca, Mg and K to the soil solution thereby not only increases soil pH but also exchangeable bases. Such observations were also noticed by Chan *et al*. (2008) and Arunkumar *et al.* (2017) [2].

Effect of biochar and FYM on DTPA extractable micronutrients status

The results in relation to soil micronutrients (Fe, Mn, Zn and Cu) status due to effect of levels of biochar on soil after different intervals of incubation is presented in Table 4 to 5.

The DTPA extractable Fe content gradually increasing trend was noticed with time of incubation (Table 4). Application of levels biochar and FYM showed significant at 60- and 90-days intervals of incubation period. Application of coconut shell biochar @ 8 t ha-1 (T7), recorded significantly higher DTPA extractable Fe 31.69 mg kg-1 and the lowest DTPA extractable Fe 9.44 mg kg-1 was recorded in control at 120 DAI, respectively as compared other treatments. At 90 DAI, DTPA extractable Fe content

Table 3: Effect of levels of biochar on exchangeable calcium (Ca), exchangeable magnesium (Mg) and available sulphur (S) status in soil at different intervals of incubation

Treatments	**Exch.Ca (cmol (p^+) kg^{-1})**					**Exch. Mg (cmol (p^+) kg^{-1})**					**S (mg kg^{-1})**				
	Days after incubation														
	15	30	60	90	120	15	30	60	90	120	15	30	60	90	120
T_1: Control (without biochar)	2.72	2.97	2.47	2.57	2.17	1.64	1.96	1.41	1.45	1.15	10.78	10.69	10.91	10.93	10.31
T_2: FYM @ 5 t ha^{-1}	2.91	3.07	3.44	3.46	3.40	1.87	2.05	2.33	2.36	2.35	11.63	11.8	12.01	12.23	13.56
T_3: FYM @ 10 t ha^{-1}	2.98	3.14	3.75	3.70	3.66	1.92	2.15	2.66	2.66	2.67	11.42	11.51	12.61	12.8	13.91
T_4: CS - Biochar @ 2 t ha^{-1}	2.76	2.87	2.92	2.99	3.14	1.74	1.85	1.86	1.86	2.08	11.39	11.62	11.8	11.96	12.2
T_5: CS - Biochar @ 4 t ha^{-1}	2.71	2.92	3.05	3.22	3.43	1.67	1.90	1.98	2.12	2.44	11.5	11.58	11.91	12.1	12.31
T_6: CS - Biochar @ 6 t ha^{-1}	2.78	2.99	3.13	3.30	3.47	1.74	1.97	2.06	2.23	2.47	11.6	11.72	11.98	12.25	12.43
T_7: CS - Biochar @ 8 t ha^{-1}	2.77	3.04	3.15	3.35	3.64	1.72	2.03	2.07	2.24	2.57	11.38	11.68	12.06	12.43	12.5
S.Em±	0.07	0.06	0.06	0.12	0.09	0.07	0.07	0.08	0.07	00.7	0.78	0.80	0.21	0.14	0.17
C.D. (p=0.05)	NS	NS	NS	0.38	0.28	NS	NS	0.24	0.20	0.20	NS	NS	0.65	0.42	0.50

Note: CS: Coconut shell

Table 4: Effect of levels of biochar on DTPA extractable iron (Fe) and manganese (Mn) status in soil at different intervals of incubation

Treatments	Fe (mg kg^{-1})					Mn (mg kg^{-1})				
	Days after incubation									
	15	30	60	90	120	15	30	60	90	120
T_1: Control (without biochar)	10.33	10.61	10.8	9.68	9.44	0.43	0.66	0.72	0.56	0.45
T_2: FYM @ 5 t ha^{-1}	13.61	17.1	21.44	23.1	23.86	0.67	0.84	0.98	1.04	0.92
T_3: FYM @ 10 t ha^{-1}	14.82	17.34	23.38	26.92	28.94	0.68	0.92	0.98	1.07	1.1
T_4: CS - Biochar @ 2 t ha^{-1}	14.94	15.7	17.15	28.15	30.9	0.57	0.62	0.78	0.97	1.18
T_5: CS - Biochar @ 4 t ha^{-1}	14.69	15.78	18.25	27.13	30.49	0.61	0.67	0.82	0.97	1.18
T_6: CS - Biochar @ 6 t ha^{-1}	15.45	15.86	18.41	27.41	31.34	0.58	0.7	0.86	1.03	1.21
T_7: CS - Biochar @ 8 t ha^{-1}	14.72	15.94	19.12	28.51	31.69	0.51	0.74	0.86	1.05	1.24
S.Em±	1.50	1.57	0.75	1.44	1.02	0.08	0.07	0.06	0.05	0.07
C.D. (p=0.05)	NS	NS	2.28	4.36	NS	NS	NS	NS	0.16	0.22

Note: CS: Coconut shell

ranged from 9.68 to 28.51 mg kg^{-1}, highest 28.51 mg kg^{-1} and lowest 9.68 mg kg^{-1} DTPA extractable Fe content in CS-biochar @ 8 t ha^{-1} (T_7) and control (T_1), respectively.

The DTPA extractable Mn content gradual increasing trend was noticed with time of incubation. Application of levels biochar and FYM didn't show significant differences at all intervals in incubated soil except 90 and 120 DAI (Table 4). Application of coconut shell biochar @ 8 t ha^{-1} (T_7), recorded significantly higher DTPA extractable Mn 1.24 mg kg^{-1} and the lowest DTPA extractable Mn 0.45 mg kg^{-1} was recorded in control at 120 DAI, respectively as compared other treatments.

Application of levels of biochar and FYM showed significant differences in DTPA extractable Zn content in soil, except 15 and 60 DAI (Table 5). The DTPA extractable Zn content gradual increasing trend was noticed with time of incubation in all levels of biochar and FYM application. Among different intervals significantly higher (0.58 mg kg^{-1}) DTPA extractable Zn content was noticed in T_7 at 120 DAI and lowest DTPA extractable Zn (0.23 mg kg^{-1}) in the treatment, T_1 @ 30 DAI.

Application of levels of biochar and FYM showed significant differences in DTPA extractable Cu content in soil, except 15 and 60 DAI (Table 5). The DTPA extractable Cu content gradual increasing trend was noticed with time of incubation in all levels of biochar and FYM application. Among different intervals significantly highest (0.52 mg kg^{-1}) DTPA extractable Cu content was noticed in T_7 at 120 DAI.

The variation in micronutrient content in soil with the application of different levels biochars can be attributed to their physical and chemical properties. Biochars by virtue of its high surface area, high metal affinity, higher nutrient retention capacity, presence of acidic and basic functional groups and ability to alkalize soil might result in precipitation of micronutrients in soil at early intervals of incubation up to 30 DAI. Such of these mechanisms of metal precipitation due to biochar application were also reported by Park *et al.* (2011) [14]. Although, there was an increase in micronutrients content over a period of incubation, due to mineralization of biochar increased the soluble organic carbon; thereby resulting in the mobilization of micronutrients. Micronutrient is strongly chelated by organic carbon and is less subjected to adsorption process. Beesley and Marmiroli (2011) [3] also reported dependence of micronutrients content on soluble C and pH.

Overall, from present incubation study conclude that, nutrient content in soil increased with increased in levels of biochar and incubation time except available phosphorus. At early days of incubation higher soil nutrient content was noticed in the FYM treatments, it may be due to faster mineralization as compared to biochar which as high C:N ratio. After 30 days of incubation, nutrient content was increased in the treatments received different biochar levels.

Table 5: Effect of levels of biochar on DTPA extractable zinc (Zn) and copper (Cu) status in soil at different intervals of incubation

Treatments	Zn (mg kg^{-1})					Cu (mg kg^{-1})				
	Days after incubation									
	15	30	60	90	120	15	30	60	90	120
T_1: Control (without biochar)	0.26	0.23	0.26	0.29	0.29	0.22	0.27	0.28	0.30	0.31
T_2: FYM @ 5 t ha^{-1}	0.22	0.26	0.29	0.31	0.38	0.12	0.18	0.24	0.23	0.38
T_3: FYM @ 10 t ha^{-1}	0.22	0.27	0.31	0.38	0.46	0.11	0.18	0.26	0.29	0.37
T_4: CS - Biochar @ 2 t ha^{-1}	0.25	0.27	0.30	0.36	0.47	0.19	0.21	0.32	0.43	0.44
T_5: CS - Biochar @ 4 t ha^{-1}	0.24	0.26	0.30	0.38	0.50	0.16	0.23	0.29	0.47	0.48
T_6: CS - Biochar @ 6 t ha^{-1}	0.24	0.26	0.32	0.40	0.52	0.15	0.21	0.30	0.38	0.51
T_7: CS - Biochar @ 8 t ha^{-1}	0.24	0.25	0.31	0.41	0.58	0.16	0.19	0.31	0.46	0.52
S.Em±	0.08	0.004	0.004	0.01	0.01	0.05	0.004	0.03	0.04	0.04
C.D. (p=0.05)	NS	0.012	NS	0.016	0.03	NS	0.012	NS	0.11	0.11

Note: CS: Coconut shell

Effect of levels of biochar and FYM on biological activity (CO_2 evolution) in soil

Microbial respiration in soil is a promising indicator of biological property and mineralization existing in soil. Therefore, in order to assess the biological activity of soil under the application coconut shell biochar and FYM levels, incubation study was conducted.

It was observed that (Table 6), application of biochar and FYM levels significantly influenced the CO_2 evolution as compared to control. Increasing trend of CO_2 evolution was noticed over a period of incubation in all treatments. At 5, 10, 20, 30 and 60 DAI, highest CO_2 evolution was observed in FYM treatments as compared to biochar levels and control treatments, but statistically non-significant. At 60, 90 and 120 DAI, significantly maximum (28.81, 36.68 and 43.81 mg 100 g^{-1} soil, respectively) CO_2 evolution was noticed in the biochar @ 8 t ha^{-1} treatment. In general, the maximum CO_2 evolution increased with the incubation period and levels of biochar.

Periodically the CO_2 evolution was measured (Fig. 1). The carbon content and available nutrients in the biochar are a good source for microorganisms resulting in an increase in degradable composition in biochar treated soil and consequently enhancing the microbial activity (Zimmerman *et al.*, 2011) [22].

Conclusion

Application of different levels of biochar increased the pH and EC of soil over control and FYM levels applied treatments, Available nitrogen, potassium secondary nutrients and DTPA extractable micronutrients showed a gradual increase throughout incubation. However, available phosphorus content in the soil gradually increased up to 60 days of incubation and slightly decreased afterward. Application of biochar and FYM levels significantly influenced the CO_2 evolution as compared to control. An increasing trend of CO_2 evolution was noticed throughout incubation in all treatments including absolute control. However, highest CO_2 evolution was observed in FYM treatments as compared to biochar levels and control treatments, but statistically non-significant. At 60, 90 and 120 DAI, significantly maximum CO_2 evolution was noticed in the biochar @ 8 t ha^{-1} treatment. In general, the maximum CO_2 evolution increased with the increasing incubation period and levels of biochar.

Table 6: Effect of biochar on CO_2 evolution (mg 100 g^{-1} soil) at different intervals of incubation

Treatments	Days after incubation						
	5	10	20	30	60	90	120
T_1: Control (without biochar)	6.38	7.65	7.31	14.16	22.90	24.11	25.57
T_2: FYM @ 5 t ha^{-1}	8.39	11.52	9.96	16.15	23.69	27.01	27.48
T_3: FYM @ 10 t ha^{-1}	8.27	12.46	11.82	16.38	28.19	27.80	28.01
T_4: CS - Biochar @ 2 t ha^{-1}	7.10	3.39	3.92	7.60	18.21	28.43	36.12
T_5: CS - Biochar @ 4 t ha^{-1}	7.07	4.42	4.72	7.29	21.41	30.14	40.15
T_6: CS - Biochar @ 6 t ha^{-1}	7.14	4.24	5.45	7.77	26.77	35.90	43.21
T_7: CS - Biochar @ 8 t ha^{-1}	7.06	4.91	5.34	8.41	28.81	36.68	43.81
S.Em±	1.32	2.65	2.06	0.70	0.87	0.30	0.92
C.D. (*p*=0.05)	NS	NS	NS	2.11	2.63	0.91	2.79

Note: CS: Coconut shell

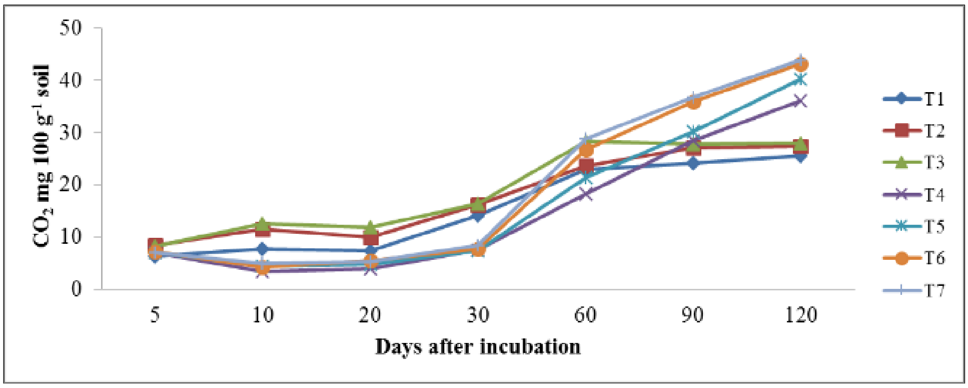

Fig 1: Effect of biochar on CO_2 evolution (mg 100 g^{-1} soil) at different intervals of incubation

T_1: Control (without biochar)	**T_4: CS - Biochar @ 2 t ha^{-1}**	**T_6: CS - Biochar @ 6 t ha^{-1}**
T_2: FYM @ 5 t ha^{-1}	T_5: CS - Biochar @ 4 t ha^{-1}	T_7: CS - Biochar @ 8 t ha^{-1}
T_3: FYM @ 10 t ha^{-1}		

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