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Biochar-fertilizers interactions study on soil available micronutrients of summer groundnut under south Saurashtra conditions

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Abstract
The aim of this study was to evaluate the effect of biochar with organic and inorganic fertilizers on soil micronutrient availability in summer groundnut during 2022 and 2023 at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. The biochar was prepared from cotton stalk and procured from Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, JAU, Junagadh. Prior to field application, biochar and FYM was enriched with *Rhizobium spp.* at 2.0 lit., Phosphorus solubilizing bacteria (PSB) at 2.0 lit., Potassium solubilizing bacteria (KSB) at 2.0 lit., *Trichoderma harzanium* at 2.0 kg., *Pseudomonas fluorescence* at 2.0 kg, *Beauveria bassiana* at 2.0 kg per hectare. Ten treatments combinations comprising of cotton stalk biochar at 1.5, 3 and 4.5 t/ha with 100%, 75% and 50% RDF (25:50:50 kg N:P_2O_5:K_2O ha^{-1}) and 5 t/ha FYM. All of these was added as basal application to summer groundnut. 75% RDF with FYM at 5 t ha^{-1} shows its superiority in respect of DTPA-extractable Fe, Mn, Cu, Zn and B at 30, 60, 90 days after sowing and at harvest under medium black calcareous soil. Further, application of cotton stalk biochar at 4.5 t ha^{-1} with 100% RDF and 75% RDF also equally effective in soil available micronutrients.

Keywords: Cotton stalk biochar, DTPA-extractabale, *Trichoderma harzianum*, *Pseudomonas fluorescence* and *Beauveria bassiana*

Introduction

Groundnut (*Arachis hypogaea* L.) in which *Arachis hypogaea* is derived from two greek words "*Arachis*" meaning to legume and "*hypogaea*" meaning below ground, referring to the formation of pods in the soil. It is highly self-pollinated crop belongs to the family *leguminaceae* and sub family *papilionaceae*. Globally, Groundnut is one of the most popular and universal crop cultivated in area of 32.70 million ha with a production of 53.90 million tonnes in more than 120 countries across the world under different agro ecological environments. It is 13th most important food crop and 4th most important oilseed crop of the world.

Crop residue management is a common problem encountered by farmers due to shorter turn around period, lack of requisite machinery for crop residue incorporation in the smaller landholdings and increased combine harvesting leaving behind a large amount of unmanaged crop residue in the field. Crop residue burning is a common practice for managing crop residues. It is an inexpensive and effective method to remove excessive residue to facilitate timely planting and to control pests and weeds. Crop residue burning has high impact on sustainable agriculture. So management of this crop residue is one of the emerging problems in agriculture sector (Chaturvedi *et al.*, 2019) [2]. Utilization of crop residues and converting waste biomass into biochar would transfer significant amount of carbon from active to inactive carbon pool. The use of biochar as soil amendment is proposed as a new approach to improving soil productivity.

Biochar is defined as charcoal obtained when organic materials are burned under low pressure and high temperature condition through pyrolysis process under low or absence of oxygen. It is fine-grained charcoal, high in organic carbon and largely resistant to decomposition. Because of its porous nature, it has a lot of surface area for water and nutrients to hold o and supply to plants as well as keep carbon intact without releasing to the atmosphere. Biochar is a unique material that when applied as soil amendment can effectively improve the physical, chemical and biological properties of soil and thereby solve many of the soil limitations (Yashikaa *et al*., 2020) [18]. It's applications to soil have beneficial effect on crop productivity through increasing nutrient use efficiency, water holding capacity and decreased bulk density.

Materials and Methods

The field trial was conducted during summer season of the year 2022 and 2023 at C-8 and D-5 of Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh.

Table 1: Soil physico-chemical properties of the experimental sites before experiment

Soil depth	Year	Physical composition (International pipette method)			
		Sand%	Silt%	Clay%	Textural class
0-15 cm	2022	27.50	14.75	58.70	Clayey
0-15 cm	2023	24.22	14.97	60.81	Clayey

Soil depth cm	Year	Bulk density g cm^{-3}	Porosity	WHC	pH	EC	OC	Fe	Mn	Zn	Cu	B
			%			dS m^{-1}	g kg^{-1}	mg kg^{-1}				
0-15	2022	1.45	42	40	7.88	0.44	6.51	5.90	9.44	0.59	1.56	0.52
0-15	2023	1.42	45	42	7.79	0.48	6.70	5.29	10.25	0.66	1.52	0.58

The experiment was comprised of ten treatments *viz.,* T_1: absolute control, T_2: FYM at 5 t ha^{-1}, T_3: 100% RDF (25:50:50 kg N-P_2O_5-K_2O ha^{-1}), T_4: 100% RDF + cotton stalk biochar (CSB) at 1.5 t ha^{-1}, T_5: 100% RDF + CSB at 3 t ha^{-1}, T_6: 100% RDF + CSB at 4.5 t ha^{-1}, T_7: 75% RDF + CSB at 1.5 t ha^{-1}, T_8: 75% RDF + CSB at 3 t ha^{-1}, T_9: 75% RDF + CSB at 4.5 t ha^{-1} and T_{10}: 75% RDF + FYM at 5 t ha^{-1} were laid out in randomized block design with three replications. Variety Gujrat Junagadh Groundnut - 31 was used in these experiment. Prior to field application, biochar and FYM was enriched with *Rhizobium spp.* at 2.0 lit., Phosphorus solubilizing bacteria (PSB) at 2.0 lit., Potassium solubilizing bacteria (KSB) at 2.0 lit., *Trichoderma harzanium* at 2.0 kg., *Pseudomonas fluorescence* at 2.0 kg, *Beauveria bassiana* at 2.0 kg per hectare.

Biochar was procured from Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, JAU, Junagadh. Biochar having alkaline pH range of 8.2 to 9.4 and having 60-62% organic carbon, 0.027% total nitrogen, 0.014% total phosphorus and 0.776% total potassium. The nutrient content of farmyard manure was 0.62-0.19-0.40% N:P_2O_5:K_2O.

The groundnut crop was sown on February 26th and 19th during 2022 and 2023, respectively at 30 x 10 cm spacing using seed rate of 120 kg ha^{-1}. The gross and net plot size was 5.0 x 1.8 m and 4.0 x 1.2 m, respectively for both years of experiment. The crop was raised as per the recommended package of practices. The crop was harvested at physiological maturity on June 17th and 9th during 2022 and 2023, respectively.

Soil analysis was carried out for only one representative sample of experiment field at 30, 60, 90 DAS and at harvest of the crop for sample of each plot of experiment field by following standard procedures. Soil sample was collected up to 0-15 cm depth was taken from each net plot. All the soil samples were air dried, oven dried and powdered with a wooden mortar and pestle and passed through a 2 mm sieve.

Estimation of available nitrogen in soil was determined by Alkaline Permanganate method as described by Subbiah and Asija (1956) [17]. Available phosphorus in soil was determined by Olsen's method as suggested by Olsen *et al.* (1954) [14]. Available potash in soil was determined by Flame Photometer method as suggested by Jackson (1974) [7]. Available sulphur in soil was determined by heat soluble method as described by Chaudhary and Cornfield (1966) [3].

Results

Bulk Density, Water Holding Capacity (WHC) and Porosity

Table 2 illustrates the outcomes of an assessment of the data related to bulk density, water holding capacity and porosity of soil after harvest of groundnut which indicated that there was a lack of significant interaction among various treatments in pooled findings. A year parameter was deemed as significant in soil pH of pooled findings might be due to good initial soil properties in 2023 as compared to 2022.

Here, the addition of biochar and FYM added organic matter to soil that favoured the aggregation and made soil more porous which decreased the bulk density and increase water holding capacity. Similar results were found by Shah and Shah (2018) [16] in soils after harvest of maize and Ndor *et al*. (2015) [13] in soils after harvest of sesame.

Soil $pH_{2.5}$ and $EC_{2.5}$

The data regarding soil $pH_{2.5}$ and $EC_{2.5}$ measured at 30, 60, 90 DAS and at harvest of groundnut are furnished in Table 2 and Table 3, respectively. A year found significant in pooled data of soil $pH_{2.5}$ at 30, 60 and 90 DAS might be due to good initial soil properties in 2nd year as compared to 1st year. The concerned data (Table 2 and 3) revealed that different treatments did not show a significant influence on soil $pH_{2.5}$ and $EC_{2.5}$ at 30, 60, 90 DAS and at harvest in pooled data.

Overall lower $pH_{2.5}$ were values noted in the treatment consists of FYM and cotton stalk biochar in comparison to absolute control and RDF which might be due to decomposition of organic matter which released some organic acids that lower the $pH_{2.5}$ of soil and also minimal values of $EC_{2.5}$ found in a combination of FYM along chemical fertilizers might be due to buffering nature of organic matter present in FYM which stabilize salt content added through the leaching of salts reported by Maurya *et al.* (2017) [12] in groundnut.

Soil Organic Carbon (SOC)

The outcomes of the SOC evaluation at 30, 60, 90 DAS and groundnut harvest are outlined in Table 3. A year was found significant in pooled data of SOC at 90 DAS and at groundnut harvest due to difference in initial soil properties of both the years.

Glimpses of data (Table 3) indicated that different treatments did showed a significant influence on SOC in pooled results. In pooled of 2022 and 2023, Application of 100% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_6) recorded significantly the higher SOC at 30, 60, 90 DAS and at harvest (8.737, 8.430, 8.150 and 7.640 g kg^{-1}, respectively) which found statistically on par with 100% RDF + cotton stalk biochar at 3 t ha^{-1} (T_5), 75% RDF + cotton stalk biochar at 3 t ha^{-1} (T_8) and 75% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_9) in at 30, 60, 90 DAS and at harvest and also at par with 100% RDF + cotton stalk biochar at 1.5 t ha^{-1} (T_4) in pooled of at harvest data.

Available Iron (Fe)

The data about soil available Fe in pooled analysis at 30, 60, 90 DAS and at harvest of groundnut are depicted in Table 4.

The data summarized in Table 4 showed that soil available Fe at 30, 60, 90 DAS and at harvest in pooled was influenced significantly by the different treatments. Due to difference in initial properties of 2022 and 2023, year was found significant in soil available Fe at different interval. The FYM at 5 t ha^{-1} (T_2) registered the maximum soil available Fe at 30, 60, 90 DAS and at harvest (6.367, 5.585, 5.979 and 5.632 mg kg^{-1}, respectively) in pooled, but it was statistically equivalent to with 75% RDF + FYM at 5 t ha^{-1} (T_{10}) at 30, 60, 90 DAS and at harvest and with 75% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_9) at 30, 60 DAS and at harvest and with 100% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_6), 75% RDF + cotton stalk biochar at 3 t ha^{-1} (T_8) at 30 and 60 DAS in pooled analysis.

Available Manganese (Mn)

The appraisal of data on soil available Mn at 30, 60, 90 DAS and at harvest of groundnut in combined findings are given in Table 4. A year in pooled data is seen as significant at 90 DAS and at harvest might be due to more favourable weather conditions and good initial soil properties in 2023 as compared to 2022.

The data (Table 4) on the soil available Mn at 30, 90 DAS and at harvest indicated a substantial influence in pooled data. Additional of FYM at 5 t ha^{-1} (T_2) in pooled exhibited considerably increased soil available Mn at 30 DAS *i.e.*, 12.137, 11.119 and 10.872 mg kg^{-1}, respectively, it was found statistically at par with 100% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_6) only at 30 DAS while, 75% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_9) at 90 DAS and at harvest of groundnut and 75% RDF + FYM at 5 t ha^{-1} (T_{10}) only at 30 and 90 DAS of groundnut.

Available Zinc (Zn)

Table 5 presents the assessment of the data on soil available Zn at 30, 60, 90 DAS and at groundnut harvest in combined findings. A year in pooled data was deemed significant because the values of soil available Zn in 2023 were higher than those in 2022 at periodical intervals of groundnut might be due to good initial soil properties in 2023.

During the field experiment, different treatments imposed their notable impact on soil available Zn at 30, 60, 90 DAS and at harvest in pooled (Table 5). In pooled, treatment FYM at 5 t ha^{-1} (T_2) stated significantly maximum values of soil available Zn at 30, 60, 90 DAS and at harvest (0.659, 0.646, 0.630 and 0.607 mg kg^{-1}, respectively). It was found statistically equivalence with 75% RDF + FYM at 5 t ha^{-1} (T_{10}) and with 75% RDF + cotton stalk biochar at 4.5 t ha^{-1} (T_9) only at 30, 60 DAS and at harvest of groundnut.

Available Copper (Cu)

The soil available Cu at 30, 60, 90 DAS and at harvest in pooled data are depicted in Table 5. A year was found significant in pooled data due to differences in climate or initial properties of soil in both the years.

A cursory look at the data (Table 5) highlighted that in pooled soil available Cu at various interval had a lack of significant effect of various applications but, the application of FYM at 5 t ha^{-1} (T_2) in pooled data (1.558, 1.519, 1.500 and 1.464 mg kg^{-1}, respectively) recorded numerically greater values of soil available Cu at 30, 60, 90 DAS and at harvest.

Available Boron (B)

The data provided in Table 6 illustrated that pooled data of soil available B at 30, 60, 90 DAS and at harvest. In pooled data, it was determined that the year was significant might be due good initial soil properties in 2023 as compared to 2022 at various interval of groundnut.

There was absence of significance in data of soil available B at 30, 60, 90 DAS and at harvest in pooled data (Table 6). Addition of FYM at 5 t ha^{-1} (T_2) in pooled data found with numerically highest soil available B at 30, 60, 90 DAS and at harvest with values of 0.545, 0.533, 0.501 and 0.461 mg kg^{-1}, respectively.

Almost the availability of all micronutrients like Fe, Mn, Zn, Cu and B significantly influenced by various fertilizers treatments at different growth stages and at harvest. However, soil available copper and boron were remained unaffected during pooled results of experiment. Overall, FYM at 5 t ha^{-1} proved its superiority followed by all treatments except absolute control in respect of micronutrients availability.

The application of FYM at 5 t ha^{-1} increases soil available micronutrients at various stages of the crop growth period of groundnut. The main role of FYM is as a chelating agent which draws ions from water solutions into soluble complexes. FYM enhances soil structure and microbial activity, which in turn promotes the breakdown of organic matter and facilitates the release of micronutrients bound within organic compounds. Additionally, the organic matter in FYM helps to improve cation exchange capacity (CEC), which enhances the soil's ability to retain and exchange micronutrients with plant roots. Combining FYM with inorganic fertilizers, it can ensure a more comprehensive and balanced nutrient supply, promoting healthy plant growth and enhanced soil fertility over time. This approach also reduces the risk of micronutrient deficiencies, leading to more sustainable agricultural practices. These findings are suggested by Kamalakannan and Elayaraja (2020) [8] in groundnut. However, in biochar along with inorganic fertilizers increased soil available micronutrients. Biochar, a porous carbonaceous material provides a habitat for many of the microorganisms and holds many of cations like Fe^{+2}, Fe^{+3}, Mn^{+2}, Zn^{+2} and increases the availability of micronutrients in the soil. These findings are supported by Devika *et al.* (2018) [4] in maize, Calistus *et al*. (2023) [1] and Pandey *et al*. (2023) [15] in sorghum.

Table 2: Effect of different treatments on soil physico-chemical properties at different growth stages and at harvest (pooled)

Treatments	Bulk density (g cm^3)	Water holding capacity (%)	Porosity (%)	Soil pH$_{2.5}$ at 30 DAS	Soil pH$_{2.5}$ at 60 DAS	Soil pH$_{2.5}$ at 90 DAS	Soil pH$_{2.5}$ at harvest
T_1	1.422	39.05	43.55	7.811	7.837	7.934	8.083
T_2	1.377	42.50	46.93	7.671	7.607	7.571	7.511
T_3	1.405	39.65	43.79	7.861	7.879	7.947	8.095
T_4	1.393	40.85	44.75	7.799	7.827	7.915	8.050
T_5	1.381	41.74	46.02	7.796	7.830	7.907	7.945
T_6	1.368	43.17	47.34	7.728	7.768	7.862	7.844
T_7	1.395	40.33	45.15	7.759	7.816	7.893	7.929
T_8	1.386	41.10	45.19	7.732	7.795	7.865	7.849
T_9	1.380	41.72	46.35	7.706	7.694	7.677	7.628
T_{10}	1.366	43.32	47.48	7.697	7.636	7.611	7.553
S.Em.±	0.022	1.00	1.10	0.147	0.158	0.172	0.155
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.V.%	3.82	5.95	5.88	4.65	4.97	5.40	4.83
Year							
S.Em.±	0.010	0.47	0.52	0.069	0.074	0.081	0.073
C.D. at 5%	NS	NS	1.57	0.211	0.226	0.247	NS
Y × T							
S.Em.±	0.031	1.42	1.55	0.208	0.223	0.244	0.219
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

(Where T_1: absolute control, T_2: FYM at 5 t ha^{-1}, T_3: 100% RDF (25:50:50 kg N-P_2O_5-K_2O ha^{-1}), T_4: 100% RDF + cotton stalk biochar (CSB) at 1.5 t ha^{-1}, T_5: 100% RDF + CSB at 3 t ha^{-1}, T_6: 100% RDF + CSB at 4.5 t ha^{-1}, T_7: 75% RDF + CSB at 1.5 t ha^{-1}, T_8: 75% RDF + CSB 3 t ha^{-1}, T_9: 75% RDF + CSB at 4.5 t ha^{-1} and T_{10}: 75% RDF + FYM at 5 t ha^{-1})

Table 3: Effect of different treatments on soil EC$_{2.5}$ and soil organic carbon (SOC) at different growth stages and at harvest (pooled)

Treatments	Soil EC$_{2.5}$ at 30 DAS	Soil EC$_{2.5}$ at 60 DAS	Soil EC$_{2.5}$ at 90 DAS	Soil EC$_{2.5}$ at harvest	SOC at 30 DAS	SOC at 60 DAS	SOC at 90 DAS	SOC at harvest
T_1	0.504	0.517	0.564	0.554	6.669	6.616	6.312	6.159
T_2	0.473	0.499	0.519	0.526	7.632	7.418	7.226	6.874
T_3	0.503	0.512	0.556	0.551	7.179	6.902	6.656	6.567
T_4	0.499	0.510	0.555	0.550	7.585	7.320	7.478	7.179
T_5	0.480	0.505	0.537	0.541	8.225	7.905	7.862	7.595
T_6	0.459	0.488	0.504	0.516	8.657	8.430	8.150	7.640
T_7	0.492	0.507	0.550	0.550	7.637	7.131	6.877	7.023
T_8	0.479	0.500	0.531	0.539	8.260	7.933	7.703	7.538
T_9	0.463	0.491	0.515	0.520	8.612	8.192	7.980	7.631
T_{10}	0.458	0.486	0.503	0.513	7.939	7.548	7.443	7.021
S.Em.±	0.012	0.009	0.016	0.012	0.247	0.241	0.223	0.197
C.D. at 5%	NS	NS	NS	NS	0.709	0.692	0.639	0.565
C.V.%	6.20	4.43	7.38	5.34	7.73	7.84	7.40	6.78
Year								
S.Em.±	0.006	0.004	0.008	0.006	0.117	0.114	0.105	0.093
C.D. at 5%	0.017	0.013	0.023	0.017	NS	NS	0.320	0.283
Y × T								
S.Em.±	0.017	0.013	0.023	0.017	0.350	0.341	0.315	0.279
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

(Where T_1: absolute control, T_2: FYM at 5 t ha^{-1}, T_3: 100% RDF (25:50:50 kg N-P_2O_5-K_2O ha^{-1}), T_4: 100% RDF + cotton stalk biochar (CSB) at 1.5 t ha^{-1}, T_5: 100% RDF + CSB at 3 t ha^{-1}, T_6: 100% RDF + CSB at 4.5 t ha^{-1}, T_7: 75% RDF + CSB at 1.5 t ha^{-1}, T_8: 75% RDF + CSB 3 t ha^{-1}, T_9: 75% RDF + CSB at 4.5 t ha^{-1} and T_{10}: 75% RDF + FYM at 5 t ha^{-1})

Table 4: Effect of different treatments on soil available Fe and Mn (mg kg^{-1}) at different growth stages and at harvest (pooled)

Treatments	Soil Available Fe at 30 DAS	Soil Available Fe at 60 DAS	Soil Available Fe at 90 DAS	Soil Available at harvest	Soil Available Mn at 30 DAS	Soil Available Mn at 60 DAS	Soil Available Mn at 90 DAS	Soil Available Mn at harvest
T_1	5.474	4.679	4.863	4.777	10.276	10.370	10.185	9.750
T_2	6.367	5.585	5.979	5.632	12.137	11.331	11.119	10.872
T_3	5.280	4.553	4.816	4.659	10.239	10.287	10.069	9.597
T_4	5.630	4.802	4.944	4.907	10.461	10.606	10.268	9.773
T_5	5.667	4.913	5.308	5.059	11.047	10.696	10.399	9.899
T_6	5.971	5.140	5.413	5.147	11.550	10.777	10.539	10.166
T_7	5.643	4.859	5.257	4.909	10.528	10.661	10.288	9.808

T_8	5.923	5.138	5.336	5.089	11.081	10.720	10.459	9.966
T_9	6.108	5.333	5.419	5.283	11.258	10.966	10.892	10.532
T_{10}	6.133	5.511	5.641	5.415	11.868	11.241	10.957	10.716
S.Em.±	0.156	0.165	0.167	0.138	0.276	0.257	0.198	0.220
C.D. at 5%	0.448	0.472	0.478	0.395	0.791	NS	0.567	0.630
C.V.%	6.57	7.98	7.71	6.64	6.12	5.84	4.60	5.33
Year								
S.Em.±	0.074	0.078	0.079	0.065	0.130	0.121	0.093	0.104
C.D. at 5%	0.224	0.236	0.239	0.198	NS	NS	0.284	0.315
Y × T								
S.Em.±	0.221	0.233	0.236	0.195	0.390	0.363	0.280	0.311
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

(Where T_1: absolute control, T_2: FYM at 5 t ha^{-1}, T_3: 100% RDF (25:50:50 kg N-P_2O_5-K_2O ha^{-1}), T_4: 100% RDF + cotton stalk biochar (CSB) at 1.5 t ha^{-1}, T_5: 100% RDF + CSB at 3 t ha^{-1}, T_6: 100% RDF + CSB at 4.5 t ha^{-1}, T_7: 75% RDF + CSB at 1.5 t ha^{-1}, T_8: 75% RDF + CSB 3 t ha^{-1}, T_9: 75% RDF + CSB at 4.5 t ha^{-1} and T_{10}: 75% RDF + FYM at 5 t ha^{-1})

Table 5: Effect of different treatments on soil available Zn and Cu (mg kg^{-1}) at different growth stages and at harvest (pooled)

Treatments	Soil Available Zn at 30 DAS	Soil Available Zn at 60 DAS	Soil Available Zn at 90 DAS	Soil Available Zn at harvest	Soil Available Cu at 30 DAS	Soil Available Cu at 60 DAS	Soil Available Cu at 90 DAS	Soil Available Cu at harvest
T_1	0.584	0.560	0.543	0.530	10.276	10.370	10.185	9.750
T_2	0.659	0.646	0.630	0.607	12.137	11.331	11.119	10.872
T_3	0.572	0.559	0.520	0.515	10.239	10.287	10.069	9.597
T_4	0.602	0.577	0.559	0.542	10.461	10.606	10.268	9.773
T_5	0.614	0.596	0.569	0.561	11.047	10.696	10.399	9.899
T_6	0.623	0.608	0.580	0.572	11.550	10.777	10.539	10.166
T_7	0.606	0.580	0.561	0.549	10.528	10.661	10.288	9.808
T_8	0.619	0.598	0.581	0.567	11.081	10.720	10.459	9.966
T_9	0.631	0.617	0.584	0.576	11.258	10.966	10.892	10.532
T_{10}	0.650	0.629	0.602	0.581	11.868	11.241	10.957	10.716
S.Em.±	0.012	0.012	0.013	0.012	0.276	0.257	0.198	0.220
C.D. at 5%	0.034	0.034	0.036	0.034	0.791	NS	0.567	0.630
C.V.%	4.76	4.87	5.44	5.25	6.12	5.84	4.60	5.33
Year								
S.Em.±	0.006	0.006	0.006	0.006	0.130	0.121	0.093	0.104
C.D. at 5%	0.017	0.017	0.018	0.017	NS	NS	0.284	0.315
Y × T								
S.Em.±	0.221	0.233	0.236	0.195	0.390	0.363	0.280	0.311
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

(Where T_1: absolute control, T_2: FYM at 5 t ha^{-1}, T_3: 100% RDF (25:50:50 kg N-P_2O_5-K_2O ha^{-1}), T_4: 100% RDF + cotton stalk biochar (CSB) at 1.5 t ha^{-1}, T_5: 100% RDF + CSB at 3 t ha^{-1}, T_6: 100% RDF + CSB at 4.5 t ha^{-1}, T_7: 75% RDF + CSB at 1.5 t ha^{-1}, T_8: 75% RDF + CSB 3 t ha^{-1}, T_9: 75% RDF + CSB at 4.5 t ha^{-1} and T_{10}: 75% RDF + FYM at 5 t ha^{-1})

Table 6: Effect of different treatments on soil available B (mg kg^{-1}) at different growth stages and at harvest (pooled)

Treatments		Soil available B (mg kg^{-1})			
		At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1:	Absolute control	0.495	0.535	0.515	0.468
T_2:	FYM at 5 t ha^{-1}	0.535	0.554	0.545	0.515
T_3:	100% RDF (25:50:50 kg N:P_2O_5:K_2O ha^{-1})	0.485	0.533	0.509	0.464
T_4:	100% RDF + Cotton stalk biochar at 1.5 t ha^{-1}	0.505	0.537	0.521	0.476
T_5:	100% RDF + Cotton stalk biochar at 3 t ha^{-1}	0.522	0.540	0.531	0.489
T_6:	100% RDF + Cotton stalk biochar at 4.5 t ha^{-1}	0.532	0.547	0.539	0.499
T_7:	75% RDF + Cotton stalk biochar at 1.5 t ha^{-1}	0.517	0.536	0.527	0.481
T_8:	75% RDF + Cotton stalk biochar at 3 t ha^{-1}	0.528	0.547	0.538	0.491
T_9:	75% RDF + Cotton stalk biochar at 4.5 t ha^{-1}	0.531	0.548	0.540	0.503
T_{10}:	75% RDF + FYM at 5 t ha^{-1}	0.537	0.550	0.543	0.509
	S.Em.±	0.018	0.016	0.012	0.016
	C.D. at 5%	NS	NS	NS	NS
	C.V.%	5.99	5.13	5.56	5.68
Year					
	S.Em.±	0.006	0.006	0.006	0.005
	C.D. at 5%	0.017	0.019	0.018	0.014
Y × T					
	S.Em.±	0.017	0.018	0.017	0.014

	C.D. at 5%	NS	NS	NS	NS

Conclusion

On the basis of the results obtained from the present two-years field experimentation, the bulk density, water holding capacity and porosity after harvest of soil were did not differ significantly under influence of various treatments used in experiment also the soil $pH_{2.5}$ and $EC_{2.5}$ at various crop growth stages remained unaffected. The soil organic carbon at 30, 60, 90 DAS and harvest was found significantly increased in addition of 100% RDF + cotton stalk biochar at 4.5 t ha^{-1}, followed by 100% RDF + cotton stalk biochar at 3 t ha^{-1}, 75% RDF + cotton stalk biochar at 3 t ha^{-1} and 75% RDF + cotton stalk biochar at 4.5 t ha^{-1}. The soil available Fe, Mn and Zn at 30, 60, 90 DAS and harvest were obtained significantly higher in application of FYM at 5 t ha^{-1}. Different applications did not impart their significant influence on soil available copper and boron by various applications at periodical stages up to harvest.

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