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Characterization, Extraction of Biochar and Humic Acid on Yield Parameters of Maize in Maize-Chickpea Cropping System and Its Residual Effect on Chickpea under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Kharif* 2019 and 2020 in a at ICAR-Krishi Vigyana Kendra, Kalaburagi-II (Raddewadagi), Jewargi taluk, Kalaburagi district, to study the characterization, extraction of biochar and humic acid on yield parameters of maize in maize-chickpea cropping system and its residual effect on chickpea under rainfed condition .The results showed that, the biochar was highly alkaline in nature (pH of 8.91), medium in salt content with an electrical conductivity of 1.89 dS m^{-1}. The total carbon content (78.20 g kg^{-1}), nitrogen, phosphorus and potassium (0.64, 0.29 and 1.02 %, respectively). It also showed good amount of secondary and micronutrients. Biochar had also lower the bulk density (0.54 Mg m^{-3}) and good water holding capacity (67.50 %). Whereas, the humic acid showed acidic in reaction (pH 4.20) and higher the nitrogen content (1.38 %). The maize was the test crop to study the direct effect and chickpea was raised to study the residual effect. The experiment were laid out in Randomized Complete Block

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Design with fifteen treatments and replicated thrice. The pooled analysis revealed that significantly higher significantly higher yield and yield parameters of maize and succeeding chickpea crops were recorded with application of 100 % NPK + biochar @ 5 t ha^{-1} + HA @ 10 kg ha^{-1} and it was on par with the treatment receiving 100 % NPK + biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1} compare to other treatments.

Keywords: Biochar; humic acid; cropping system; characterization; extraction and yield.

1. INTRODUCTION

Globally, maize is known as queen of cereal because of the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries under diverse soil, climate, biodiversity and management practices contributing 36 per cent (782 m t) of the global grain production. The United States of America (USA) is the largest producer of maize and contributes nearly 35 per cent of the total production in the world with the highest productivity (> 9.6 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}). Whereas, in India maize is grown over an area of 9.50 million hectares with a production of 23.29 million tonnes and an average productivity of 2.45 t ha^{-1} which is much lower than most of the maize growing countries of the world. “In India, maize is grown in Karnataka, Rajasthan, Madhya Pradesh and Maharashtra. In Karnataka, it occupies an area of 1.38 million hectares with production of 3.98 million tonnes with an average productivity of 2.88 t ha^{-1}” [1].

Maintaining soil organic matter is a prerequisite to ensure soil health and crop productivity in rainfed farming. India ranks first among the countries that practice rainfed agriculture. Out of the estimated 141 Mha net cultivated land in India, about 75 Mha is rainfed, spread over 177 districts of the country and produces about 40% of the total food grain in India. Efficient use of crop residue based amendment in soil is an important strategy to improve the soil fertility and productivity in rainfed areas. Annually 500 Mt crop residues are generated in India, out of which 141 Mt is surplus. Among different crops, oilseeds (29 Mt), pulses (13 Mt) and cotton (53 Mt) generate maximum residues in India, which are advertently niche crops for rainfed areas. The surplus crop residues of castor, cotton and pigeonpea stalk are estimated to be 18.0, 11.8 and 9.0 Mt, respectively. These residues are either partially utilized or un-utilized due to various constraints. Surplus and unused crop residues when left unattended, often disrupt land preparation, crop establishment and early crop growth, and therefore are typically burnt on farm which causes environmental problems and substantial nutrient losses. For more effective management and disposal of the crop residues, their conversion into biochar through thermo-chemical process (slow pyrolysis) is gaining importance as a novel and economically alternative way of managing unusable and excess crop residues. Much of the stimulus for this interest has come from research on the soils of the Amazon basin, known as Terra Preta de Indio, that contain variable quantities of organic black carbon considered to be of anthrogenic origin. Conversion of crop and on-site agroforestry residues to biochar and its soil application as an amendment can turn the hitherto excess residues available in India into a useful materiel for enhancing soil health and crop productivity.

Varied technological methods of pyrolysis can covert feed stocks like grasses, nutshells, forestry products and animal manures to produce biochar. Pyrolysis is the heating of biomass in an oxygen limited atmosphere, causing release of volatile C structures, hydrogen (H), methane (CH_4) and carbon monoxide (CO). The volatile C structures (alcohols, oils, tars, acids, etc.) can be re-condensed as bio-oil. The biochar that remains consists mainly of C, and contains O, H, N, and ash (calcium and potassium). Biochars with large amounts of carbon in poly-condensed aromatic structures are obtained by pyrolyzing organic feed stocks at high temperatures (400 to 700ºC), which has fewer ion exchange functional groups due to dehydration and decarboxylation, potentially limiting its usefulness in retaining soil nutrients. On the other hand, biochar produced at lower temperatures (250 to 400ºC) have higher yield recoveries and contain more C=O and CH functional groups that can serve as nutrient exchange sites after oxidation. Moreover, biochar produced at these 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. Feedstock 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 decay [2]. 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 enable it to adsorb or retain nutrients and retain water and also provide a habitat for beneficial microorganisms to flourish [2,3,4]. However, since biochar possesses recalcitrant carbon, it places a doubt that biochar application may pose risk for soil microbes. Moreover, the pH of majority of biochar is alkaline in nature which may alter the microbially mediated nutrient transformations. The possible connections between biochar properties and the soil biota and their implications for soil processes have not yet been systematically described; hence the driving processes are still poorly identified.

“Biochar provides a suitable habitat for a large and diverse group of soil microorganisms. A higher retention of microorganisms in biochar amended soils may be responsible for greater activity and diversity due to a high surface area as well as surface hydrophobicity of both the microorganisms and biochar. A strong affinity of microbes to biochar can be expected since the adhesion of microorganisms to solids increases with higher hydrophobicity of the surfaces. Biochar is an effective to activate living things and improve natural environment. Carbonized biomass such as rice husk charcoal or wood ash have been valuable material as soil amendment. The optimal biochar combining fertilizer and carbon storage function in soils would activate the microbial community leading to nutrient release and fertilization and would add to the decadal soil carbon pool” [5]. “Biochar’s inherent physical quality contributes to the improvement in the soil porosity” [6].

“Humic substances are major components of organic matter, have both direct and indirect effects on plant growth” [7]. Humic acid (HA) improves the physical chemical and biological properties of the soil and influences plant growth. Because of its molecular structure, it provides numerous benefits to crop production.

2. MATERIALS AND METHODS

Field investigations carried out during 2019-20 and 2020-21 to study the characterization, extraction of biochar and humic acid on yield parameters of maize in maize-chickpea cropping system and its residual effect on chickpea under rainfed condition. The soil of the experimental site was clay in texture which was alkaline in nature (pH 8.01), with low salt content (0.29 dSm^{-1}) and low organic carbon content (4.80 g ka^{-1}).The available nitrogen (230.50 kg ha^{-1}) was low, available phosphorus (31.60 kg ha^{-1}) was medium, available potassium content (385.63 kg ha^{-1}) was high. The experiments were laid out in Randomized Complete Block Design (RCBD) with fifteen treatments and replicated thrice. The two experiments were conducted during *kharif* 2019 and 2020 with maize main crop and the residual effect of the said treatments were studied during *rabi* seasons of 2019 and 2020 with chickpea as succeeding crop.

Recommended dose of fertilizer for maize crop is 100: 50: 25 kg N: P_2O_5: K_2O kg ha^{-1}. The nitrogen was given in three equal splits *viz.,* $1/3^{rd}$ as basal, $1/3^{rd}$ at knee high stage (30 DAS) and the remaining $1/3^{rd}$ at tasseling and silking stage (60 DAS). Entire dose of phosphorous and potassium in the form of diammonium phosphate (DAP) and murate of potash (MOP) respectively were applied as basal dose to the crop.

2.1 Production of Biochar

Representative biochar sample was collected from Munadaragi taluk, Gadag district. The biochar was prepared at 600-700 °C and the feedstock used for preparation of biochar was *Prosopis sp.* and it is called as *Prosopis juliflora* biochar. The biochar sample was analysed for different parameter as per the methods given in Table 1.

2.2 Extraction of Humic Substance

Twenty gram of air dried organic sample was weighed in to 250 ml conical flask 200 ml of 0.1 N NaOH was added [8] and shaken for 24 hours. The dark colored supernatant solution was separated by centrifugation and collected. The extraction procedure was repeated thrice using 50 ml of extractant each time for complete extraction of the humic substances.

2.3 Fractionation and Purification of Humic Substances

The precipitated humic acid fraction was separated by centrifugation. Precipitation and centrifugation was repeated to attain partial purification of humic acid fraction as described by Stevenson [9]. The fractions were further purified by treating with HCI - HF mixture (5 ml of each HCI and HF acids were dissolved in 990 ml of double distilled water) for 24 hours and this acid mixture was separated by centrifugation. The residue so obtained was thoroughly washed with distilled water and freeze dried to obtain humic acid.

2.4 Digestion of Humic Acid Sample for Determination of Elements

A known weight of humic acid sample was taken in a 250 ml conical flask and was pre-digested by adding 10 ml of HNO_3 and keeping it overnight. Diacid mixture (10 ml) in 9:4 proportion (HNO_3:$HClO_4$) was added and heated on sand bath until a snow white residue was obtained. The residue was cooled and diluted to a known volume with distilled water, filtered and made up to 100 ml using distilled water it was further used for estimation of elements. The methods adopted are same as outlined in Table 1.

2.5 Statistical Analysis of Data

The experimental data obtained was subjected to statistical analysis using Fisher's method of analysis of variance as out lined by Gomez and Gomez [16]. The level of significance used in 'F' and't' tests was p= 0.05. Critical difference values were calculated, wherever 'F' test was found significant.Results have beeninterpreted and discussed based on the pooled data of two years (2019 and 2020).

Table 1. Methods followed for analysis of biochar and humic acid

	A. Biochar		
Sl.No.	**Parameter**	**Method**	**Reference**
1	pH	Potentiometry	[10]
2	EC(dS m^{-1})	Conductometry	[10]
3	MWHC (%)	Keen's cup method	[11]
4	Bulk density	Core method	Barnyard and Henry (1921)
5	Particle density	International pipette method	[11]
6	Porosity		
7	Total carbon (%)	Dry cumbustion method	[12]
8	Total nitrogen (%)	Kjeldahl digestion distillation method	[10]
9	Total phosphorus (%)	Diacid digestion and vanadomolybdate method	[10]
10	Total potassium (%)	Diacid digestion and flame photometer method	[10]
11	Total calcium and magnesium (%)	Complexometric titration method	[10]
12	Total Sulphur (ppm)	0.15% $CaCl_2$ extraction and turbidimetry	[10]
13	DTPA extractable micronutrients like Zn, Fe, Cu & Mn (ppm)	Diacid digestion and atomic absorption spectrophotometry	[10]
	B. Humic acid		
1	pH	Potentiometry	[10]
2	Total acidity (me g^{-1})	$Ba(OH)_2$method	[38]
3	Elemental analysis: carbon, hydrogen, nitrogen and sulphur	dry combustion method using CHNS analyser	[13]
4	Total Fe, Mn, Zn and Cu (ppm)	Diacid digestion and Atomic Absorption Spectrophotometry	[10])
5	HA Concentration (%)	Stevenson method	[14]
6	Ash content (%)	Hesse method	[15]

3. RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

3.1 Characterization of Biochar

Representative biochar sample collected from Mundaragi taluk, Gadag district was analysed for different parameters (Table 2).

Table 2. Characterization of *Prosopis* biochar

Sl. No	Parameters	Value
Physical properties		
1.	Bulk density (Mg m^{-3})	0.42
2.	MWHC (%)	67.50
Chemical properties		
3.	pH (1:10)	8.91
4.	EC(dS m^{-1})	1.89
5.	Total carbon (%)	78.20
6.	Total Nitrogen (%)	0.64
7.	Total Phosphorus (%)	0.29
8.	Total Potassium (%)	1.02
9.	Total Sulphur (%)	0.38
10.	Total Calcium (%)	0.090
11.	Total Magnesium (%)	0.061
12.	Total Zn (ppm)	0.033
13.	Total Fe (ppm)	1.08
13.	Total Cu (ppm)	0.021
14.	Total Mn (ppm)	0.043

The data revealed that, the biochar recorded the maximum water holding capacity of 67.50 per cent and bulk density of 0.42. Mg $m^{-3.}$.The chemical composition of biochar was found to be alkaline in nature with a pH of 8.91 and the electrical conductivity of 1.89 dS m^{-1}. The total carbon content of 78.20 g kg^{-1} was recorded; the total nitrogen, phosphorus and potassium were 0.64, 0.29 and 1.02 per cent, respectively. It also showed good amount of total calcium, magnesium and sulphur with consists of 0.090, 0.061 and 0.38 per cent, respectively. Biochar also recorded appreciable quantities of total iron, manganese, zinc and copper to an extent of 1.08, 0.043, 0.033 and 0.021ppm, respectively.

The powdered biochar was characterized for different physical (BD and WHC) and chemical properties. The data showed (Table 2) that, the *Prosopis* biochar had lower bulk density of 0.54 Mg m^{-3}. Similar results were reported by Brewer et al. (2014) who estimated that the bulk density of biochar produced from different feedstock ranged from 0.25 to 0.60 gcm^{-3}. Biochar derived from *Prosopis juliflora* wood recorded high water holding capacity (67.5 %). This might be due to higher total carbon and surface area. The chemical analysis suggested that biochar found to be alkaline in nature with pH 8.91, medium in salt content with an electrical conductivity of 1.89 dS m^{-1}. It might be due to presence of ash residue that is dominated by carbonates of alkali and alkaline earth metals. Similar results were observed by Rumi, [17], Wan et al. [18] and Rondon et al. [19] who reported that wood biochar was found to have higher saline salt content, followed by coir waste biochar. The total carbon, nitrogen, phosphorus and potassium were found to be higher with 78.20, 0.64, 0.29 and 1.02 per cent, respectively. The higher nitrogen and phosphorus content observed in the biochar which might be attributed to the optimum heat maintained during pyrolysis. It also recorded good amount of calcium, magnesium and sulphur and the values were 0.09, 0.06 and 0.38 per cent, respectively [20]. The content of iron, manganese, zinc and copper found to be in appreciable amounts in biochar. Variability in physical and chemical properties of biochar depends on the material used to produce biochar, the oxygen supply and the temperature achieved during pyrolysis. Similar results were reported by Wang et al. [21] and Lua and Yang, [22].

3.2 Characterization of Humic Acid

The data on the characteristics of humic acid extracted from vermicompost are presented in Table 3.

Table 3. Characterization of humic acid extracted from vermicompost

Sl. No	Parameters	Values
1	Humic acid content (%)	4.98
2	Ash content (%)	2.51
3	Total acidity (me g^{-1})	5.17
4	pH (1:2.5)	4.20
5	Total carbon (%)	43.51
6	Total Hydrogen (%)	4.96
7	Total Nitrogen (%)	1.38
8	Total Phosphorus (%)	0.23
9	Total Potassium (%)	0.56
10	Total Sulphur (%)	0.81
11	Total Calcium (%)	0.06
12	Total Magnesium (%)	0.04
13	Total Zn (ppm)	250.5
14	Total Fe (ppm)	3251.5
15	Total Cu (ppm)	108.20
16	Total Mn (ppm)	515.3

The data revealed that the humic acid extracted from vermicompost was acidic in reaction (pH 4.20). The concentration of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur were 1.38, 0.23, 0.56, 0.06, 0.04 and 0.81 per cent, respectively. The average concentration of humic acid content, ash content, iron, manganese, copper and zinc and were 4.98, 2.51, 3251.5, 515.31, 108.20 and 250.5 per cent respectively. It also contained some quantity of elemental composition of total carbon and hydrogen were 43.51 and 4.96 per cent. Similar findings were reported by Sathisha and Devarajan [23] and they reported higher organic carbon in the humic acid extracted from vermicompost which may be due to higher nutrient contents of the test materials in the present study. Similar findings were also observed with respect to nutrient concentration in different organic sources [24]. Atiyeh et al. [25] and Muter et al. [26], Paola et al. [27] stated that humic acid derived from municipal solid waste compost had C, H, N and ash content (52.4, 5, 4.7 and 1.21 % respectively). Similar results were presented by Kasongo et al. [28] who reported that, the nutrient content of coffee pulp acts as an alternative to fertilizer with beneficial effect in improving soil properties and supply of nutrients for adequate growth and development of plants.

3.3 Grain and Stover Yield (q ha^{-1}) of Maize

The data pertaining to grain and straw yield of maize crop as influenced by biochar and humic acid application during both the years as well as pooled data analysis are presented in Table 4.

Significantly higher grain yield (82.91 q ha^{-1}) was recorded with application of 100 % NPK + biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1} (T_{13}) as compared to other treatments. However, it was on par with T_{12} which received100 % NPK + biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1} (79.85 q ha^{-1}) followed by T_3 with application of 100 % NPK + FYM @ 7.5 t ha^{-1} + HA @ 10 kg ha^{-1} (79.48 q ha^{-1}). While, significantly the lowest grain yield of 31.44 q ha^{-1} was recorded in absolute control treatment as compared to other treatments.

Similarly, significantly higher stover yield (105.76 q ha^{-1}) was recorded in T_{13} treatment which received 100 % NPK + biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1} compared to other treatments. However, it was on par with T_{12} supplied with100 % NPK + biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1} (100.33 q ha^{-1}). Whereas, the lowest stover yield of 39.09 q ha^{-1} was recorded in absolute control. Similar trend was observed during individual years and as well as pooled data. Higher grain and stover yield in maize could be attributed to better uptake of essential nutrients and its translocation to economic parts as well as improvement in yield attributing characters like cob weight, cob length and number of grain per corn.

Economic yield is expressed as a function of factor that contributed to yield which is known as yield attributes. Increase in yield might be attributed to improvement in yield components due to better partitioning of carbohydrates from leaf to reproductive parts resulting in increased yield. Addition of more nutrients through biochar, humic acid and inorganic fertilizers resulted in higher grain and stover yield. Many research works have reported that biochar and humic acid enhance the yield of different crops *viz.,* sugarcane, rice and maize tomato, chickpea etc. These results supported by Asai et al. [29], Chen et al. [30] and Ogawa and Okimori [31] and Madhavi [32] reported that “application of recommended dose of NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} were significant in increasing seed yield. Though in the absence of biochar, 75 % NPK put forth significantly lower yield than 100 % NPK. Integration with biochar at the highest level of 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1}, the yields from the two levels of fertilizer (75 and also 100 % NPK) were at a par”.

3.4 Seed and Haulm Yield (q ha^{-1}) of Residual Chickpea Crop

The data showed similar trend with respect to seed and haulm yield. Seed and haulm yields of chickpea were significantly influenced by the residual effect of biochar and humic acid during individual years as well as pooled data are presented in Table 5.

The perusal of pooled data indicated that, the residual effect of 100 % NPK + biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1} (T_{13}) treatment showed significantly higher seed and haulm yield (16.66 and 20.75 q ha^{-1}, respectively) compared to other treatments. However, which was on par with treatment (T_{12}) which received 100 % NPK + biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1} (13.82 and 18.67 q ha^{-1}, respectively). Whereas, significantly lower seed and haulm yields was obtained in absolute control (7.08 and 10.38 q ha^{-1}, respectively). Similar trend was observed during both the years.

The yield data indicated a significant influence of residual biochar and humic acid on chickpea. This could be mainly due to attributed by nutrients present in the soil and in the biochar and humic acid, which were made available to the crop. Balanced supply of nutrients might have enabled chickpea crop to produce higher pod bearing branches and higher number of pods per plant. Yooyen et al. [33] reported that "addition of biochar to soybean increased the number of seeds per plant". Mirl et al. [34] reported that "an increase in seed yield and haulm yield was observed in the biochar treatment as compared to no biochar treatment. Soil treated with biochar and humic acid increased the stover yield of crop. The better performance of chickpea crop might be due to the presence of bacterial activity which helps in increasing the phosphorus availability in soil, thereby improving plant growth and yield". Viruel et al. [35] and Bandara et al. [36] they reported that "the increased the crop growth and yield by combined application of biochar and FYM. The timely availability of nitrogen with the interaction effect of biochar and humic acid mineralization might be responsible for the production of highest seed and stover yield. The superiority of *Prosopis sp.* biochar applied treatments over RDF alone was due to biochars was being protected from further decomposition thereby it could supply longer and steady source of macro and micronutrients [37]. However, in present study residual biochar and humic acid applied in combination recorded higher yield and yield attributing parameters in the treatment T_{13} (100 % NPK + biochar @ 5 t ha^{-1} 8 t ha^{-1} + HA @ 10 kg ha^{-1})".

Table 4. Grain and stover of maize as influenced by application of biochar and humic acid in maize - chickpea cropping system under rainfed condition

Treatments	**Grain yield (q ha^{-1})**			**Stover yield (q ha^{-1})**		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
T_1: Absolute control	32.75	30.12	31.44	40.83	37.34	39.09
T_2: 100 % NPK + FYM @ 7.5 t ha^{-1}	55.49	58.75	57.12	60.49	67.27	63.88
T_3: T_2 + HA @ 10.0 kg ha^{-1}	77.35	81.61	79.48	96.14	102.51	99.33
T_4: 75 % NPK + Biochar @ 2.5 t ha^{-}	49.31	52.21	50.76	57.35	62.12	59.74
T_5: 75 % NPK + Biochar @ 5.0 t ha^{-1}	51.65	54.84	53.25	59.70	64.50	62.10
T_6: 75 % NPK + Biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1}	67.76	71.66	69.71	75.17	81.60	78.39
T_7: 75 % NPK + Biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1}	70.27	74.46	72.37	80.78	88.64	84.71
T_8: 75 % NPK + Biochar @ 2.5 t ha^{-1} + FYM@ 7.5 t ha^{-1}	62.13	66.23	64.18	67.68	72.36	70.02
T_9: 75 % NPK + Biochar @ 5.0 t ha^{-1} + FYM@ 7.5 t ha^{-1}	64.4	68.12	66.26	70.84	77.80	74.32
T_{10}: 100 % NPK + Biochar @ 2.5 t ha^{-1}	54.17	57.45	55.81	66.19	72.20	69.20
T_{11}: 100 % NPK + Biochar @ 5.0 t ha^{-1}	57.57	60.91	59.24	69.55	75.70	72.63
T_{12}: 100 % NPK + Biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1}	77.82	81.87	79.85	97.21	103.45	100.33
T_{13}: 100 % NPK + Biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1}	80.25	85.56	82.91	101.45	110.07	105.76
T_{14}: 100 % NPK + Biochar @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}	73.78	77.49	75.64	86.04	96.02	91.03
T_{15}: 100 % NPK + Biochar @ 5.0 t ha^{-1} + FYM@ 7.5 t ha^{-1}	76.40	80.77	78.59	90.21	101.57	95.89
S. Em.±	0.97	1.22	1.09	1.43	3.01	1.98
C.D. at 5 %	2.84	3.55	3.19	4.14	8.71	5.75

Note: HA :Humic Acid; FYM : Farm Yard Manure

Table 5. Residual effect of biochar and humic acid on grain and haulm yield of chickpea in maize-chickpea cropping system under rainfed condition

Treatments	Seed yield (q ha^{-1})			Haulm yield ((q ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled
T_1: Absolute control	7.24	6.91	7.08	10.75	10.01	10.38
T_2: 100 % NPK + FYM @ 7.5 t ha^{-1}	10.16	11.29	10.73	12.45	13.65	13.05
T_3: T_2 + HA @ 10.0 kg ha^{-1}	12.58	14.57	13.58	16.45	18.17	17.31
T_4: 75 % NPK + Biochar @ 2.5 t ha^{-}	9.44	10.34	9.89	11.41	12.19	11.80
T_5: 75 % NPK + Biochar @ 5.0 t ha^{-1}	9.97	10.66	10.32	11.86	12.67	12.27
T_6: 75 % NPK + Biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1}	11.71	13.12	12.42	14.21	15.62	14.92
T_7: 75 % NPK + Biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1}	12.10	13.34	12.72	14.58	17.18	15.88
T_8: 75 % NPK + Biochar @ 2.5 t ha^{-1} + FYM@ 7.5 t ha^{-1}	10.94	11.79	11.37	13.26	14.74	14.00
T_9: 75 % NPK + Biochar @ 5.0 t ha^{-1} + FYM@ 7.5 t ha^{-1}	11.29	12.42	11.86	13.87	15.44	14.66
T_{10}: 100 % NPK + Biochar @ 2.5 t ha^{-1}	9.61	10.54	10.08	12.29	13.15	12.72
T_{11}: 100 % NPK + Biochar @ 5.0 t ha^{-1}	10.05	11.14	10.60	12.74	14.22	13.48
T_{12}: 100 % NPK + Biochar @ 2.5 t ha^{-1} + HA @ 10 kg ha^{-1}	12.75	14.88	13.82	16.79	20.54	18.67
T_{13}: 100 % NPK + Biochar @ 5.0 t ha^{-1} + HA @ 10 kg ha^{-1}	15.11	18.20	16.66	19.39	22.10	20.75
T_{14}: 100 % NPK + Biochar @ 2.5 t ha^{-1} + FYM @ 7.5 t ha^{-1}	12.18	14.18	13.18	14.78	17.55	16.17
T_{15}: 100 % NPK + Biochar @ 5.0 t ha^{-1} + FYM@ 7.5 t ha^{-1}	12.55	14.45	13.50	16.22	18.01	17.12
S. Em.±	0.77	0.92	0.85	0.84	0.98	0.91
C.D. at 5 %	2.22	2.66	2.41	2.42	2.82	2.56

Note: HA : Humic Acid; FYM : Farm Yard Manure

4. CONCLUSION

Use of biochar in agricultural systems is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality and crop productivity. Further, several studies across the world have established that biochar application increases conventional agricultural productivity and mitigate GHG emissions from agricultural soils.

Prosopis biochar was found to be a rich source of carbon and nutrients with alkaline pH, medium EC, lower density and higher maximum holding capacity. The prosopis biochar and humic acid is a good source of microorganisms and hastens the better mineralization rate and increased the efficiency of biochar in soil. Study indicates the necessity of combined application of biochar, humic acid and fertilizer for higher growth, yield and quality parameters of maize and residual chickpea crop as compared to alone application of biochar, FYM and fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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