

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

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 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.

Key word: Biochar, Humic acid, cropping system, characterization, extraction and yield

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 ($> 9.6 \text{ t ha}^{-1}$) 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} (Anon., 2014).

Climate change and global warming has worldwide adverse consequences. Biochar production and its use in agriculture can play a vital role in climate change mitigation and help improved quality and management of waste materials coming from agriculture and forestry. Biochar is a carbonaceous material obtained from thermal decomposition of residual biomass at relatively varying temperatures and under oxygen limited conditions (Pyrolysis). Biochar is currently a subject of active research worldwide because it can constitute a viable option for sustainable agriculture due to its potential as a long term sink for carbon in soil and benefits for crops (Alburquerque *et al.*, 2013).

Varied technological methods of pyrolysis can convert 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 700 °C), 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 400 °C) 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 (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 enable it to adsorb or retain nutrients and retain water and also provide a habitat for beneficial microorganisms to flourish (Glaser *et al.* 2002, Lehmann *et al.* 2006 and Warnock *et al.*, 2007). 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. The role of biochar in soil biological processes therefore represents a frontier in soil science research with many unexplained phenomena awaiting exploration. In this connection, it is proposed to study the role of biochar in improving soil properties and crop production when applied individually and in combination with humic acid, FYM and inorganic NPK.

Humic substances are major components of organic matter, have both direct and indirect effects on plant growth (Sangeetha *et al.*, 2006). 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.

MATERIAL 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 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: P₂O₅: K₂O kg ha⁻¹. The nitrogen was given in three equal splits viz., 1/3rd as basal, 1/3rd at knee high stage (30 DAS) and the remaining 1/3rd 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.

Initial composite soil sample from 0-15 cm depth was collected from the experimental plot and analysed for physical and chemical properties and the results are presented in Table 2.

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 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 (Schnitzer and Skinner, 1968) 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.

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 (1981). The fractions were further purified by treating with HCl - HF mixture (5 ml of each HCl 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.

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 HNO₃ and keeping it overnight. Diacid mixture (10 ml) in

9:4 proportion (HNO₃:HClO₄) 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 .2

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 (1984). 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 been interpreted and discussed based on the pooled data of two years (2019 and 2020).

RESULTS AND DISCUSSION

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

Characterization of biochar

Representative biochar sample collected from Mundaragi taluk, Gadag district was analysed for different parameters (Table 3).

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 0.021 ppm, respectively.

The powdered biochar was characterized for different physical (BD and WHC) and chemical properties. The data showed (Table 4) 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, (2015), Wan *et al.* (2014) and Rondon *et al.* (2007) 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 (Lehman *et al.*, 2009). 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.* (2013) and Lua and Yang, (2004).

Characterization of humic acid

The data on the characteristics of humic acid extracted from vermicompost are presented in Table 4.

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 (2011) 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 (Jindo *et al.*, 2012). Atiyeh *et al.* (2002) and muter *et al.* (2015). Paola *et al.* (2006) 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.* (2011) 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.

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 5.

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 (T₁₃) as compared to other treatments. However, it was on par with T₁₂ which received 100 % NPK + biochar @ 2.5 t ha⁻¹ + HA @ 10 kg ha⁻¹ (79.85 q ha⁻¹) followed by T₃ 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 T₁₃ 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 T₁₂ supplied with 100 % 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.* (2009), Chen *et al.* (2010) and Ogawa and Okimori (2010) and Madhavi (2014) 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.

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 6.

The perusal of pooled data indicated that, the residual effect of 100 % NPK + biochar @ 5.0 t ha⁻¹ + HA @ 10 kg ha⁻¹ (T₁₃) 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 (T₁₂) 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.* (2015) reported that addition of biochar to soybean increased the number of seeds per plant. Mirl *et al.* (2013) 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.* (2014) and Bandara *et al.* (2015) 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. However, in present study residual biochar and humic acid applied in combination recorded

higher yield and yield attributing parameters in the treatment T₁₃ (100 % NPK + biochar @ 5 t ha⁻¹ 8 t ha⁻¹ + HA @ 10 kg ha⁻¹).

CONCLUSION

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.

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Table 1. Initial physico-chemical properties of soil of the experimental site

Sl. No.	Particulars	values
I. Physical properties		
1.	Textural class	Clay
2.	Bulk density (Mg m^{-3})	1.43
3.	Maximum water holding capacity (%)	49.67
II. Chemical properties		
1.	Soil pH (1:2.5)	8.01
2.	Electrical conductivity (1:2.5), (dSm^{-1})	0.29
3.	Carbon pools	
3.	Organic carbon (g kg^{-1})	4.80
4.	Available N (kg ha^{-1})	230.50
5.	Available P_2O_5 (kg ha^{-1})	31.60
6.	Available K_2O (kg ha^{-1})	385.63
7	Exchangeable calcium [$\text{C mol (p}^+) \text{ kg}^{-1}$]	15.78
8	Exchangeable magnesium [$\text{C mol (p}^+) \text{ kg}^{-1}$]	9.65
9	Available S (kg ha^{-1})	18.50
10	DTPA extractable Zn (mg kg^{-1})	0.27
11	DTPA extractable Fe (mg kg^{-1})	2.39
12	DTPA extractable Mn (mg kg^{-1})	3.04
13	DTPA extractable Cu (mg kg^{-1})	1.20

Table. 2: Methods followed for analysis of biochar and humic acid

A. Biochar			
Sl. No.	Parameter	Method	Reference
1	pH	Potentiometry	Jackson (1973)
2	EC(dS m ⁻¹)	Conductometry	Jackson (1973)
3	MWHC (%)	Keen's cup method	Piper (1966)
4	Bulk density	Core method	Barnyard and Henry, (1921)
5	Particle density	International pipette method	Piper (1966)
6	Porosity		
7	Total carbon (%)	Dry combustion method	Page <i>et al.</i> (1982)
8	Total nitrogen (%)	Kjeldahl digestion distillation method	Jackson (1973)
9	Total phosphorus (%)	Diacid digestion and vanadomolybdate method	Jackson (1973)
10	Total potassium (%)	Diacid digestion and flame photometer method	Jackson (1973)
11	Total calcium and magnesium (%)	Complexometric titration method	Jackson (1973)
12	Total Sulphur (ppm)	0.15% CaCl ₂ extraction and turbidimetry	Jackson (1973)
13	DTPA extractable micronutrients like Zn, Fe, Cu & Mn (ppm)	Diacid digestion and atomic absorption spectrophotometry	Jackson (1973)
B. Humic acid			
1	pH	Potentiometry	Jackson (1973)
2	Total acidity (me g ⁻¹)	Ba(OH) ₂ method	Schnitzer and Gupta (1965)
3	Elemental analysis: carbon, hydrogen, nitrogen and sulphur	dry combustion method using CHNS analyser	Orlov <i>et al.</i> (1992)
4	Total Fe, Mn, Zn and Cu (ppm)	Diacid digestion and Atomic Absorption	Jackson (1973)

		Spectrophotometry	
5	HA Concentration (%)	Stevenson method	Stevenson (1994)
6	Ash content (%)	Hesse method	Hesse (1994)

Table 3. 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

Table 4. 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

Table 5: 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
T₁ : Absolute control	32.75	30.12	31.44	40.83	37.34	39.09
T₂ : 100 % NPK + FYM @ 7.5 t ha ⁻¹	55.49	58.75	57.12	60.49	67.27	63.88
T₃ : T ₂ + HA @ 10.0 kg ha ⁻¹	77.35	81.61	79.48	96.14	102.51	99.33
T₄ : 75 % NPK + Biochar @ 2.5 t ha ⁻¹	49.31	52.21	50.76	57.35	62.12	59.74
T₅ : 75 % NPK + Biochar @ 5.0 t ha ⁻¹	51.65	54.84	53.25	59.70	64.50	62.10
T₆ : 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
T₇ : 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
T₈ : 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
T₉ : 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
T₁₀ : 100 % NPK + Biochar @ 2.5 t ha ⁻¹	54.17	57.45	55.81	66.19	72.20	69.20
T₁₁ : 100 % NPK + Biochar @ 5.0 t ha ⁻¹	57.57	60.91	59.24	69.55	75.70	72.63
T₁₂ : 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
T₁₃ : 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
T₁₄ : 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
T₁₅ : 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 : Farmyard manure

Table 6: 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
T₁ : Absolute control	7.24	6.91	7.08	10.75	10.01	10.38
T₂ : 100 % NPK + FYM @ 7.5 t ha ⁻¹	10.16	11.29	10.73	12.45	13.65	13.05
T₃ : T ₂ + HA @ 10.0 kg ha ⁻¹	12.58	14.57	13.58	16.45	18.17	17.31
T₄ : 75 % NPK + Biochar @ 2.5 t ha ⁻¹	9.44	10.34	9.89	11.41	12.19	11.80
T₅ : 75 % NPK + Biochar @ 5.0 t ha ⁻¹	9.97	10.66	10.32	11.86	12.67	12.27
T₆ : 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
T₇ : 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
T₈ : 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
T₉ : 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
T₁₀ : 100 % NPK + Biochar @ 2.5 t ha ⁻¹	9.61	10.54	10.08	12.29	13.15	12.72
T₁₁ : 100 % NPK + Biochar @ 5.0 t ha ⁻¹	10.05	11.14	10.60	12.74	14.22	13.48
T₁₂ : 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
T₁₃ : 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
T₁₄ : 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
T₁₅ : 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 : Farmyard manure