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B Gowthami
MSc. (Ag.), Department of Soil Science & Agricultural Chemistry, Agricultural College, Bapatla, Guntur, Andhra Pradesh, India

P Gurumurthy
Associate Professor and Head, Soil Science & Agricultural Chemistry, Agricultural College, Naira, Srikakulam, Andhra Pradesh, India

CH Sujani Rao
Professor, Soil Science & Agricultural Chemistry, Agricultural College, Bapatla, Guntur, Andhra Pradesh, India

Corresponding Author:
B Gowthami
MSc. (Ag.), Department of Soil Science & Agricultural Chemistry, Agricultural College, Bapatla, Guntur, Andhra Pradesh, India

Effect of biochar on soil physico-chemical and chemical properties in relation to groundnut growth in red sandy loam soils of North Coastal Andhra Pradesh

B Gowthami, P Gurumurthy and CH Sujani Rao

Abstract
A field experiment was conducted in red sandy loam soils of North Coastal Andhra Pradesh to study the effect of biochar on soil physico-chemical and chemical properties in relation to growth of groundnut crop (variety K-6) during *rabi*, 2018-19. Biochar application to soil had significant influence on soil pH, CEC, organic carbon, available nitrogen, available phosphorus and available potassium where as non significant influence on electrical conductivity, available sulphur and micronutrients metal cations *viz*., Zn, Fe, Mn, Cu was noticed. Soil pH significantly increased when biochar applied @ 6 t ha^{-1}. At harvest stage of groundnut highest soil organic carbon (0.53%) was observed in T_8 (75% RDF + biochar @ 6 t ha^{-1}) and lowest (0.32%) in T_1 (control). The highest available nitrogen, phosphorus and potassium were observed in T_5 (100% RDF + biochar @ 6 t ha^{-1}) @ 191.10, 36.04, 331.77 kg ha^{-1}, respectively and lowest corresponding values were observed in control @ 131.63, 15.48, 207.68 kg ha^{-1} at peg penetration stage of groundnut. A slight increase in EC and available sulphur and slight decrease in micronutrients was noticed which was non- significant. At pod development stage highest leaf area index (3.16) was recorded in T_5 treatment (100% RDF + biochar @ 6 t ha^{-1}) which was significantly higher than T_1 (control) @ 2.40. In general the dry matter accumulation increased from peg penetration to pod development stage of groundnut. Highest dry matter accumulation of 2950.90 kg ha^{-1} and 6427.54 kg ha^{-1}, respectively at peg penetration and pod development stage was observed in T_5 (100% RDF + biochar @ 6 t ha^{-1}) which was on par with T_3 (100% RDF + biochar @ 2 t ha^{-1}), T_4 (100% RDF + biochar @ 4 tha^{-1}), T_8 (75% RDF + biochar @ 6 t ha^{-1}) treatments.

Keywords: Biochar, sandy loams, soil fertility properties, groundnut

Introduction

Biochar is a fine grained, carbon rich, porous product obtained when biomass is subjected to thermo chemical conversion process (pyrolysis) at temperature of 300-350°C in an environment with little or no oxygen. Biochar is not a pure carbon, but rather mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. It can be prepared by several methods like Pit method, Drum method, Heap method *etc.* According to Ministry of New and Renewable Energy (MNRE, 2014) [17], Government of India, about 502 million tonnes of crop residue is generated annually in the country and had surplus waste of 141 million tonnes per annum, of which about 93 million tonnes of crop residues are burnt in each year (IARI, 2012) [9]. In Andhra Pradesh 43.89 million tonnes of crop residue is generated annually and surplus waste of 7.0 million tonnes per annum, of which 2.73 million tonnes is burnt each year (IARI, 2012) [9]. Residue burning traditionally provides a fast way to clear the agricultural crop residue but it leads to loss of nutrients (N and S), organic matter, microbial activity and also leads to environmental pollution. Hence, conversion of organic waste to produce biochar using the pyrolysis process is one viable option that can enhance natural rates of carbon sequestration in the soil, safe recycling of farm waste and improve the soil quality.

In recent years there has been increased use of biochar as an addition to agricultural soils, since it is seen as potentially improving both crop productivity and soil quality (Vaccari *et al*., 2011; Baronti *et al*., 2014) [23, 2]. It is an alternative that may be potentially integrated into sustainable agricultural systems.

However an accurate evaluation of the biochar effects on physico chemical and chemical properties of the soil is needed, since the effects of excessively high inputs are difficult to remedy.

Material and Methods

The present study was carried out during *rabi*, 2018-19. The experimental plot was geographically situated at an altitude of 12 m above mean sea level, 83^0 56.602^l E longitude and 18^0 22.752^l N latitude in the Agricultural College Farm, North Coastal Andhra Pradesh. The experimental soil was sandy loam in texture, neutral in reaction, low in organic carbon. Biochar was prepared under the low oxygen conditions by pyrolysis process with dried Mesta sticks with 29.4 per cent recovery. Initial soil properties of experimental site and properties of biochar were presented in table 1 and 2, respectively. The field experiment was laid in RBD with eight treatments using groundnut (Variety - Kadiri 6) as a test crop.

T_1 - Control
T_2 - 100% RDF (30-40-50: N, P_2O_5 and K_2O, respectively) only
T_3 - 100% RDF + biochar @ 2 t ha^{-1}
T_4 - 100% RDF + biochar @ 4 t ha^{-1}
T_5 - 100% RDF + biochar @ 6 t ha^{-1}
T_6 - 75% RDF + biochar @ 2 t ha^{-1}
T_7 - 75% RDF + biochar @ 4 t ha^{-1}
T_8 - 75% RDF + biochar @ 6 t ha^{-1}

Table 1: Initial fertility properties of the experimental soil

S. No.	Soil Properties	Value
1	Soil reaction (pH in 1: 2.5 soil water suspension).	6.7
2	Electrical conductivity (EC 1 : 2.5) (dS m^{-1})	0.38
3	Soil organic carbon (%)	0.32
4	CEC (cmol (p^+) kg^{-1})	14.02
5	Available nitrogen (kg ha^{-1})	130.5
6	Available phosphorus (P_2O_5) (kg ha^{-1})	15.67
7	Available potassium (K_2O) (kg ha^{-1})	195.4
8	Available sulphur (mg kg^{-1})	16.87
9	Zinc	0.62
10	Iron	17.28
11	Manganese	13.68
12	Copper	1.74

Table 2: Characteristics of biochar used in the experiment.

S. No.	Characteristics of biochar	Values
1	Soil reaction (pH in 1:10 char water suspension)	8.38
2	Electrical conductivity (1:10 char water extract in dS m^{-1})	2.39
3	Organic carbon (%)	35.04
4	CEC (cmol (p^+) kg^{-1})	54.56
5	Nitrogen (%)	0.09
6	Phosphorus (%)	0.16
7	Potassium (%)	0.33
8	Sulphur (%)	0.10
9	Zinc (ppm)	26.12
10	Iron (ppm)	28.55
11	Manganese (ppm)	7.98
12	Copper (ppm)	4.39

Soil physico-chemical properties: Soil reaction was determined in 1:2.5 soil water suspensions using combined glass electrode (Jackson, 1973) [10]. The soluble salt content of soil samples was determined in supernatant of 1: 2.5 soil water suspensions using electrical conductivity bridge (Jackson, 1973) [10]. For estimation of CEC, 4 g soil sample was saturated with 1 N sodium acetate (pH 8.3), excess sodium acetate was leached out by washing out with 95% ethanol. Then the adsorbed sodium was displaced with neutral normal ammonium acetate. The concentration of sodium in the leachate was estimated flame photometrically. The CEC was calculated and expressed as cmol (p^+) kg^{-1} soil (Bower *et al*, 1952) [4]. Organic carbon was estimated by adopting wet digestion method of Walkley and Black's (1934) [24] and the results expressed in percentage.

Soil chemical properties: Available nitrogen content in the soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [22] and results expressed in kg ha^{-1}. Available phosphorus in the soil samples was extracted with 0.5 M $NaHCO_3$ of pH 8.5 and the phosphorus in the extract was estimated using spectrophotometer at 660 nm (Watanabe and Olsen, 1954) [25] and the results expressed in kg ha^{-1}. Available potassium in soil was extracted with NN ammonium acetate and potassium in the extract was determined flame photometrically (Muhr *et al.*, 1965) [18] and the results expressed in kg ha^{-1}. Available sulphur in soil was extracted with 0.15% calcium chloride dehydrate and sulphur in the extract was determined by turbidimetric method using spectrophotometer at 420 nm (Chesnin and Yein, 1951) [6] and the results expressed in mg kg^{-1} soil. Available zinc, copper, manganese and iron in the soils were determined in DTPA extract, using atomic absorption spectrophotometer (Lindsay and Norvell, 1978) [14] and the results expressed in ppm.

Plant growth parameters: Plant height (cm) was measured from the base of the plant to the top of the main shoot of the five labeled plants in each plot. Leaf area was measured by using leaf area meter and was expressed as leaf area index (LAI) using the formula suggested by Watson (1952). Plant samples for dry matter study were collected at peg penetration, pod development and harvest stages. At each sampling, five plants were uprooted at random in each treatment. These samples were shade dried followed by oven dried at 65ºC till a constant weight was recorded. The dry weight of these samples was recorded. Later dry matter production was computed on per hectare basis and expressed in kg ha^{-1}.

Results and Discussion

Effect of biochar on soil physico-chemical properties

Soil reaction (pH): The data in the table 3 reveals that there was increasing trend in pH with increased application rates of biochar from 2 t ha^{-1} to 6 t ha^{-1} compared to control treatment. Due to alkaline nature of biochar, up on its addition to soil caused increase in soil pH. Further soil pH slightly increased from peg penetration to harvest stage of groundnut. At harvest stage higher soil pH of 7.33 and 7.28 was recorded in the T_5 (100% RDF + biochar @ 6 t ha^{-1}) and T_8 (75% RDF + biochar @ 6 t ha^{-1}), respectively, both the treatments were significantly superior to T_1 (control) and T_2 (100% RDF). Gautam *et al*., 2017 [8] opined that alkaline nature of biochar which upon addition to soil could have contributed towards reducing the acidity (increasing soil pH). Yuan and Xu (2011) [27] also observed a significant increase in soil pH due to biochar addition which might be due to the release of basic cations in soil.

Electrical conductivity (EC): There was no significant but a slight increase in soil EC with the biochar addition was observed. From peg penetration to harvest stage EC showed a decreasing trend which might be due to percolation of salts along with irrigation water. At peg penetration stage highest EC (0.42 dS m^{-1}) was observed in the T_5 treatment (100% RDF + biochar @ 6 t ha^{-1}) was applied followed by 0.41 dS m^{-1} in T_4 treatment (100% RDF + biochar @ 4 t ha^{-1}) and lowest in control (0.36 dS m^{-1}). The increase in EC with the application of biochar might be due to ash residues in biochar dominated by carbonates of alkali and alkaline earth metals (Nigussie *et al*., 2012) [19].

Soil organic carbon: The soil organic carbon content was showed significant increase when biochar applied @ 4 t ha^{-1} and 6 t ha^{-1} (T_4, T_5, T_7 & T_8) than non biochar added treatments (T_1 and T_2). Slight increase of organic carbon was noticed from peg penetration to harvest stage could be due to leaf fall from groundnut crop. At harvest stage, the highest organic carbon (0.54%) was observed in T_8 (75% RDF + biochar @ 6t ha^{-1}) treatment which was on par with T_5 (100% RDF + biochar @ 6 t ha^{-1}) treatment (0.53%) and both the treatments were significantly higher to T_1 (control) and T_2 (100% RDF). Lowest value of organic carbon was noticed at control @ 0.32%. Biochar itself is a matrix of organic complex and its application to soil system increases soil organic carbon (Elangovan *et al*., 2014 and Abrishemkesh *et al*., 2015) [7, 1].

Cation exchange capacity (CEC): There was significant increase in soil CEC at higher application rates of biochar. Higher CEC of 18.37 cmol (p^+) kg^{-1} and 17.59 cmol (p^+) kg^{-1} was observed in T_5 (100% RDF + biochar @ 6 t ha^{-1}) and T_8 (75% RDF + biochar @ 6 t ha^{-1}) treatments, respectively at peg penetration stage which were significantly superior to T_1 (control) and T_2 (100% RDF). Among the biochar applied treatments significant difference in CEC of found between 2 t ha^{-1} treatments (T_3 and T_6) and 6 t ha^{-1} treatments (T_5 and T_8). The soil CEC in general slightly increased towards harvest stage of groundnut crop. Significant increase in CEC with addition of biochar was also supported by Masulili *et al*., 2010 [16], which revealed the presence of high carboxylic and phenolic functional groups in biochar results in high surface negative charge which caused greater ability to exchange cations. Biochar has a greater ability than other soil organic materials to adsorb cations due to its high surface area, high negative charge and high charge density (Elangovan *et al*., 2014) [7].

Effect of biochar on soil chemical properties

Available Nitrogen: Addition of biochar to soil impacted available soil nitrogen content (table 4). There was a significant difference in soil available N content between control and biochar + RDF applied treatments. The available nitrogen at peg penetration, pod development and harvest stages was highest (191.10, 175.90, 159.96 kg ha^{-1} respectively) in T_5 treatment (100% RDF + biochar @ 6 t ha^{-1}) and lowest corresponding values in control (T_1) were 131.63, 112.40, 102.44 kg ha^{-1} in all the three stages respectively. The difference in soil available nitrogen in 100% RDF applied treatments (T_2, T_3, T_4 & T_5) was significantly higher compared to 75% RDF applied treatments (T_6, T_7 & T_8) and control (T_1) in all the stages of crop growth. Among various stages of crop growth the soil available nitrogen was high at peg penetration stage. Slight increase in available nitrogen was noticed with increased rates of biochar application from 2 t ha^{-1} to 6 t ha^{-1}. Although biochar itself is not a direct source of nitrogen but it act as micro habitat for added N fertiliser (added fertilizer which enters inside the biochar pores) and making it available at later stages of crop. Shen *et al*. (2016) reported that biochar application enhanced soil nitrogen availability to the plant, since its believed action as soil conditioner, altering the soil chemical and microbial properties favourably, protecting nitrogen from losses and resulting in an increased availability.

Soil Available Phosphorus: There was significant increase in soil available phosphorus in 100% RDF alone applied (T_2) and RDF (100% or 75%) in combination of biochar applied treatments (T_3, T_4, T_5, T_6, T_7 & T_8) when compared to control (T_1). Significantly high phosphorous was also noticed in when biochar applied @ 6 t ha^{-1} to that of 2 t ha^{-1}. At peg penetration stage the highest available phosphorus (36.04 kg ha^{-1}) was observed in the T_5 (100% RDF + biochar @ 6 t ha^{-1}) which was on par with T_4 (33.32 kg ha^{-1}) and T_3 (31.74 kg ha^{-1}) and lowest available phosphorus (15.48 kg ha^{-1}) was noticed in T_1 (control). The gradual decrease in available phosphorus was observed from peg penetration to harvest stage. The enhancement of available phosphorous due to application of biochar is attributed to the ability of biochar to retain anions the synergistic effect of biochar and fertilizer was observed which improved available phosphorus by combined application. Opal *et al*. (2012) [20] also supported these results of significant increase in available phosphorus with the addition of biochar by improved microbial activity and microbially mediated mineralization of soil phosphorus to available phosphorus form.

Soil available potassium: Significant difference in soil available potassium was observed between the treatments of biochar + inorganic fertilizers (T_3, T_4, T_5, T_6, T_7 & T_8) and control (T_1). The available potassium at peg penetration, pod development and harvest stages was highest (331.77, 314.12, 308.12 kg ha^{-1}, respectively) in T_5 treatment (100% RDF +

biochar @ 6 t ha^{-1}) which was on par with T_4 treatment (100% RDF + biochar @ 4 t ha^{-1}) and T_3 treatment (100% RDF + biochar @ 2 t ha^{-1}) and lowest corresponding values in control (T_1) were 207.68, 192.63, 183.96 kg ha^{-1}, respectively at peg penetration, pod development and harvest stages. Bindu *et al.* (2016) [3] also noticed that high cation exchange capacity of biochar represents its ability to electrostatically sorb or attract cations like K^+ could be the reason for increased availability of potassium in soil and the carbonate and carboxylate functional groups of biochar are responsible for retention of potassium along with other nutrients.

Soil available sulphur: Biochar application to soil did not influence significantly in soil available sulphur but slight increase in the soil available sulphur could be noticed with biochar addition compared to control. Cheah *et al.*, 2014 [5] reported that scanning electron microscope images of the energy dispersive X-ray spectroscopy (SEM-EDS) of corn stover biochar showed distribution of sulphur throughout organic matrix which on its application to the soil increases available sulphur after mineralisation. Non- significant difference in available sulphur due to imposition of treatments is attributed to direct supply of mineral sulphur through application gypsum @ 500 kg ha^{-1} as general crop management practice to all the experiment plots.

Soil available micronutrients: The results obtained on effect of biochar on soil available micronutrients are presented in the table 5 which indicated that there was no significant influence of biochar on available Zn, Fe, Mn and Cu at all the three stages of crop growth. There was marginal decrease of soil available Zn with increased rates of biochar application was found. This slight reduction in soil available zinc was attributed to sorption of zinc to the biochar which form stable complex because of recalcitrant nature of biochar (Jun and Xu, 2013) [11]. Marginal reduction of available iron with increased rates of biochar application was found. The decrease in the available iron content on biochar addition at all three stages of crop growth might be due to immobilization of iron (Masulili *et al*., 2010) [16]. In all the three crop stages, slight decrease in available manganese was noticed in biochar applied plots, which could be due to the surface adsorption of manganese by biochar (Masto *et al*., 2013) [15]. With increasing rates of biochar application (2 t ha^{-1} to 6 t ha^{-1}) slight but non- significant reduction in soil available copper was observed at all the three growth stages.

Crop growth: Biochar application to soil caused slight increase in plant height but was not significant (Table 6). At harvest stage T_5 treatment (100% RDF + biochar @ 6 t ha^{-1}) recorded higher plant height @ 50.13 cm than other treatments and lower plant height of 44 cm was recorded in T_1 (control). The leaf area index increased from peg penetration to pod development. At pod development stage highest LAI (3.16) was recorded in T_5 treatment (100% RDF + biochar @ 6 t ha^{-1}) which was significantly higher than T_1 (control), T_2 (100% RDF) and T_6 (75% RDF + biochar @ 2 t ha^{-1}). In general the dry matter accumulation increased from peg penetration to pod development (Table 6). Highest dry matter accumulation of 2950.90 kg ha^{-1} and 6427.54 kg ha^{-1}, respectively at peg penetration and pod development stage was observed in T_5 (100% RDF + biochar @6 t ha^{-1}) which was on par with T_3 (100% RDF + biochar @ 2 t ha^{-1}), T_4 (100% RDF + biochar @ 4 t ha^{-1}), T_8 (75% RDF + biochar @ 6 t ha^{-1}) treatments, however, T_5 was significantly superior to treatments T_6 (75% RDF + biochar @ 2 t ha^{-1}), T_7 (75% RDF + biochar @ 4 t ha^{-1}), T_2 (100% RDF) and T_1 (control). Application of biochar resulted in better soil physical environment and also increased availability of nutrients by improving biological activity which resulted in higher plant growth and biomass production. (Laxman Rao *et al*., 2017) [12]. Lehmann *et al*. (2003) [13] suggested that biochar not only improve the availability of nutrients but also promote vegetative growth by improving the photosynthetic pigment production and hence increases dry matter production.

Table 3: Effect of biochar on soil physico-chemical properties (pH, EC, OC and CEC)

Treatments	Ph			EC (dS m^{-1})			Organic carbon (%)			CEC (cmol (p^+) kg^{-1})		
	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest
T_1	6.75	6.74	6.77	0.36	0.32	0.31	0.30	0.30	0.32	14.42	14.73	14.39
T_2	6.77	6.79	6.87	0.38	0.34	0.32	0.32	0.34	0.34	14.19	14.89	14.52
T_3	6.88	6.92	6.99	0.40	0.35	0.32	0.39	0.41	0.43	15.30	16.92	16.09
T_4	6.93	7.06	7.17	0.41	0.37	0.34	0.45	0.46	0.48	16.66	17.87	17.21
T_5	7.18	7.25	7.33	0.42	0.40	0.36	0.51	0.52	0.53	18.37	19.26	18.59
T_6	6.76	6.84	6.98	0.37	0.33	0.31	0.40	0.41	0.44	14.76	15.10	14.84
T_7	6.89	6.95	7.11	0.39	0.36	0.33	0.45	0.47	0.48	16.85	15.84	16.17
T_8	7.12	7.19	7.28	0.40	0.37	0.34	0.52	0.51	0.54	17.59	18.18	17.78
S.Em±	0.09	0.09	0.10	0.03	0.04	0.03	0.03	0.04	0.04	0.93	0.96	0.87
CD @ 0.05	0.29	0.27	0.32	NS	NS	NS	0.09	0.12	0.13	2.65	2.93	2.66
CV (%)	2.42	2.27	2.62	8.16	6.64	7.30	10.82	10.22	11.36	10.16	10.09	9.37

Table 4: Effect of biochar on soil available macro nutrients (N, P_2O_5, K_2O and S)

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})			Sulphur (mg kg^{-1})		
	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest
T_1	131.63	112.40	102.44	15.48	13.48	12.81	207.68	192.63	183.96	17.07	16.17	13.40
T_2	179.23	152.98	145.81	28.27	21.94	18.60	290.77	273.10	265.75	18.67	17.67	14.88
T_3	183.73	166.06	150.40	31.74	24.75	21.42	311.19	295.53	288.87	19.33	17.33	14.67
T_4	186.87	160.95	154.69	33.32	25.66	23.99	322.37	303.37	296.70	20.46	18.76	14.10
T_5	191.10	175.90	159.96	36.04	28.38	25.38	331.77	314.12	308.12	20.98	19.59	15.69
T_6	160.33	144.44	130.33	19.68	16.35	15.10	255.46	239.81	223.15	18.66	16.66	13.66
T_7	176.93	149.65	141.69	24.75	20.75	19.42	274.91	258.58	231.91	19.05	18.05	14.12
T_8	180.80	156.46	152.71	27.82	22.16	20.30	285.33	262.00	238.66	19.52	19.18	14.52

S.Em±	7.16	6.75	6.87	1.53	1.10	1.22	12.03	12.86	10.58	1.72	1.63	1.13
CD @ 0.05	21.57	20.50	20.88	4.64	3.34	3.71	36.50	39.02	32.09	NS	NS	NS
CV (%)	8.72	8.81	9.58	9.78	8.80	10.81	7.31	8.33	7.19	15.23	15.98	13.79

Table 5: Effect of biochar on soil available micronutrients (zinc, iron, manganese and copper)

Treatmtents	Zinc (ppm)			Iron (ppm)			Manganese (ppm)			Copper (ppm)		
	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest
T_1	0.62	0.60	0.58	17.36	15.36	14.70	14.28	13.85	13.28	1.47	1.31	1.11
T_2	0.65	0.64	0.60	17.52	16.85	15.52	16.31	14.74	13.77	1.48	1.32	1.19
T_3	0.64	0.63	0.57	17.08	15.71	14.38	15.10	14.67	13.07	1.42	1.29	1.15
T_4	0.62	0.61	0.58	16.49	15.82	13.03	14.44	13.12	12.44	1.39	1.20	1.12
T_5	0.60	0.54	0.55	15.46	14.33	12.95	13.96	13.10	12.07	1.33	1.17	1.10
T_6	0.64	0.61	0.57	17.28	16.28	14.28	16.30	14.66	12.96	1.40	1.27	1.14
T_7	0.63	0.59	0.56	16.53	14.87	13.53	15.41	13.41	12.89	1.35	1.18	1.10
T_8	0.58	0.56	0.56	15.80	14.80	13.16	14.25	13.11	12.45	1.30	1.15	1.09
S.Em±	0.03	0.03	0.03	1.29	1.32	0.96	1.30	1.18	1.09	0.10	0.05	0.06
CD @ 0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.58	11.55	10.73	13.39	14.98	12.15	15.13	14.91	14.96	13.62	7.63	9.57

Table 6: Effect of biochar on growth parameters and dry matter accumulation of groundnut

Treatments	Plant height (cm)			Leaf area index			Dry matter accumulation (kg ha^{-1})	
	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration stage	Pod development stage
T_1	31.57	43.17	44.00	1.62	2.40	2.33	2134.7	4972.7
T_2	34.17	44.00	47.17	1.85	2.68	2.45	2544.6	5643.3
T_3	34.17	45.17	48.00	2.01	2.85	2.61	2669.1	5857.9
T_4	35.00	46.33	49.18	2.05	2.93	2.69	2834.9	6213.7
T_5	35.67	47.17	50.13	2.19	3.16	2.73	2950.9	6427.5
T_6	31.00	44.00	45.00	1.83	2.61	2.40	2507.4	5473.0
T_7	32.00	44.33	45.67	1.96	2.75	2.42	2732.1	5610.6
T_8	33.33	45.00	45.83	1.98	2.83	2.58	2784.3	5705.8
S.Em±	2.12	2.59	2.66	0.07	0.09	0.07	117.2	244.1
CD @ 0.05	NS	NS	NS	0.21	0.26	0.23	355.5	640.5
CV (%)	11.10	9.89	9.20	6.51	6.63	5.32	7.67	7.36

Conclusion

Favourable improvement of soil physico-chemical and chemical properties *viz*., pH, CEC, organic carbon content, available nitrogen, phosphorus and potassium was noticed with addition of biochar to soil compared to biochar not applied treatments in sandy loam soils. Among biochar applied treatments, marked increment in nutrients availability properties was found from 2 t ha^{-1} to 6 t ha^{-1}. Application of biochar significantly increased groundnut leaf area index, drymatter accumulation.

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