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P Madhavi
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Pjtsau, Hyderabad, Telangana, India

V Sailaja
Associate Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Pjtsau, Hyderabad, Telangana, India

T Ram Prakash
Senior Scientist, AICRP on weed control, PJTSAU, Hyderabad, Telangana, Idina

SA Hussain
Professor, Dept. of Agronomy, College farm, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Correspondence
P Madhavi
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Pjtsau, Hyderabad, Telangana, India

Nutrient status of soil after maize harvest and uptake of stover influenced by fertilizers, biochar and humic acid application

P Madhavi, V Sailaja, T Ram Prakash and SA Hussain

Abstract
A field study was carried out at college farm, College of Agriculture, Rajendranagar, Hyderabad, Andhra Pradesh during *Kharif* 2013 to evaluate combined application of biochar with humic acid as a fertility amendment at varied fertiliser levels. The experiment was laid out in a Randomized Block Design and replicated thrice with three factors comprised of factor-I (fertilizers- 100 % RDF and 75 % RDF), Factor-II (biochar levels- 0, 5 and 7.5 t ha^{-1}) and Factor-III (humic acid levels of 0 and 30 kg ha^{-1}). Soil had a pH of 7.72, EC of 0.217 dS m^{-1} with low organic carbon (0.49%) and available nitrogen (138.6 kg ha^{-1}), high available phosphorus (31.28 kg ha^{-1}) and potassium (629 kg ha^{-1}) and sufficient available sulphur (28 ppm). After maize harvest, nutrient status of experiment site was analyzed. Recommended dose of NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} was recorded significantly highest available N (182 kg ha^{-1}) and P (66.5 kg ha-1). In case of potassium, 75% NPK alone recorded highest (533 kg ha^{-1}) followed by 75% NPK with @ 7.5 t ha^{-1} biochar (476 kg ha^{-1}). Recommended dose of NPK and 75% NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} were at par in available sulphur. High nitrogen, phosphorus and sulphur uptake was obtained with application of recommended NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1}, whereas uptake of P was highest with reduced NPK along with biochar @ 5 t ha^{-1} and humic acid at 30 kg ha^{-1}.

Keywords: biochar, humic acid, nutrient status, maize, nutrient uptake.

Introduction
Maize (*Zea mays* L.) is an important food and feed crop which ranks third after wheat and rice in the world. It is a multipurpose crop that provides food for humans, feed for animals (especially poultry and livestock) and raw material for the industries. India is the fifth largest producer of maize in the world contributing 3 per cent of the global production (Arif *et al*. 2012) [1].

Nowadays, global food security combined with the need to develop more sustainable agricultural systems and reduced greenhouse gas emissions necessiate many changes in agricultural management. Central to this tenet is the need for replenished soil organic matter reserves to sustain nutrient cycling; and improved WUE that help to mitigate climate change. Since excessive application of chemical fertilizers may affect soil health and sustainable productivity, it's imperative to search for possible alternate organic source that can sustain soil health and crop production (Jones *et al*., 2012) [4]. The application of biochar to agricultural land is receiving increasing attention as an intervention strategy for the sequestration of carbon and as a means of improving soil quality and nutrient cycling thereby aiming at reduced fertilizer use (Richard et al. 2012) [8].

Biochar production and its use in agriculture can play a key role in climate change mitigation and help improve the quality and management of waste materials coming from agriculture and forestry. Studies suggest that biochar sequesters approximately 50% of the carbon available within the biomass feedstock being pyrolyzed (Kelsi Bracmort, 2010) [5]. Humic substances are major components of organic matter, have both direct and indirect effects on plant growth (Sangeetha *et al*., 2006) [9]. 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.

This present investigation is planned to integrate biochar with humic acid to evaluate its efficacy as a fertility amendment at varied fertiliser levels.

Material and Methods

This experiment was conducted during *kharif*, 2013 at the College Farm, Acharya N.G Ranga Agricultural University, Rajendranagar, Hyderabad. The details of the material used and the methods adopted during the course of the present investigation are described under appropriate headings.

Physical and chemical properties of the experiment site was analysed. Its texture was determined by Bouyoucos hydrometer method (Piper, 1966) [7].The pH and Electrical conductivity of the soil samples were determined in soil: water (1:2) suspension using a glass electrode pH meter and conductivity meter respectively (Jackson, 1973) [3].Organic carbon percentage in soil sample was determined by wet digestion method (Walkley and Black, 1934) [11]. Available nitrogen in soil sample was estimated by alkaline permanganate method (Subbiah and Asija, 1956) [10]. Available phosphorus in soil sample was extracted with $NaHCO_3$ (0.5 M) and the phosphorus in the extract was estimated by colorimetric method using ascorbic acid as the reductant; the intensity of blue colour developed was read in spectrophotometer at 680 nm (Watanabe and Olsen, 1965) [12]. Available potassium in the soils was extracted by employing Ammonium Acetate (NN) and determined by aspirating the extract to the ELICO Flame photometer (Jackson, 1973)[3]. Available sulphur in soil samples was extracted with calcium chloride (0.15%) solution (Williams and Steinbergs, 1961) [13] and sulphur in the extract was estimated by turbidimetric method on UV-Visible spectrophotometer at 410 nm (Chesnin and Yien, 1963) [2].

The nitrogen (N), phosphorus (P) and potassium (K) contents thus obtained were expressed in percentage. The uptake of N, P and K by the crop was computed and expressed in kg ha-1 as follows.

$$\text{Uptake of nutrient (kg /ha)} = \frac{\text{Nutrient content (\%) x Dry matter yield (kg /ha)}}{100}$$

The data on the observations made were analyzed statistically by applying the technique of analysis of variance for randomized block design as suggested by Panse and Sukhatme (1978) [6].

Results and Discussion

Nutrient status of soil

***Nitrogen*.**

Significantly higher and lower available N were respectively present in the treatments receiving recommended NPK in integration with biochar @ 7.5 t ha^{-1} and 75% NPK alone the corresponding values being 178 and 135 kg ha^{-1}. In respect of available N, the treatment receiving 100% NPK alone and 75% NPK with 5 t ha^{-1} of biochar was on par with the value being 148 kg ha^{-1}.

The interaction between biochar and humic acid was found significant. When neither biochar nor humic acid were added, the available N was 129 kg ha^{-1} that increased significantly to 172 kg ha^{-1} with the combined application of biochar at 7.5 t ha^{-1} with humic acid. The treatments receiving humic acid alone and biochar at 5 t ha^{-1} alone were at a par, likewise, humic acid applied with biochar at 5 t ha^{-1} and biochar alone at 7.5 t ha^{-1} were also on par in respect of available N (Table 1).

Table 1: Available N (kg ha^{-1}) at harvest of maize as influenced by fertiliser, biochar and humic acid levels and their interaction

Treatments	BC @ 0 t ha^{-1}			BC @ 5. 0 t ha^{-1}			BC @ 7.5 t ha^{-1}			Fertiliser Mean
Fertiliser levels	**HA$_1$**	**HA$_2$**	**Mean**	**HA^1**	**HA$_2$**	**Mean**	**HA$_1$**	**HA$_2$**	**Mean**	
100% NPK	138	157	148	164	171	168	174	182	178	165
75% NPK	119	150	134	144	151	148	151	162	156	147
Mean	128	153	141	154	161	158	163	172	168	155
CV (%)	4.49									
CD at 5% level	Fert. = 4.84 Biochar =5.93 Humic acid = N.S				Fert. x biochar = 8 Fert. x humic acid = N.S Biochar x humic acid = 8 Fert. x biochar x humic x acid = N.S					

Phosphorous

Available P content significantly increased from 33.93 kg ha^{-1} was obtained with 75% NPK and was not integrated with biochar to 59.68 kg ha^{-1} was obtained with recommended NPK with biochar @ 7.5 t ha^{-1}. At the recommended NPK, biochar could significantly increase the available P content even at the highest level of 7.5 t ha^{-1}, while at 75% NPK, the increase was only upto 5.0 t ha^{-1} levels and there was a decline in the available P content at 7.5 t ha^{-1} level.

Available P showed a significant depletion at harvest than in the early stages of crop growth. The interaction between fertilisers and humic acid was found significant. There was a considerable and significant decline in the available P content when the crop was supplemented with 75% NPK alone the value being 34.59 kg ha^{-1} while 62.86 kg ha^{-1} of available P remained in the soil when recommended NPK was conjunctively applied with humic acid. At both the fertiliser levels, humic acid application could significantly increase the available P content.

Interaction between biochar and humic acid resulted in a significant increase in available P content from 36.90 kg ha^{-1} when both were not applied to 54.84 kg ha^{-1} due to the combined application of 7.5 t ha^{-1} of biochar and 30 kg ha^{-1} of humic acid. When 75% NPK was applied alone, it resulted in a significantly lower in available P content of 31.45 kg ha^{-1} which increased significantly to 43.18 kg ha^{-1} when biochar at 7.5 t ha^{-1} and humic acid were combinedly applied. However, the resultant available P was significantly higher when integration was at recommended level of NPK, the value being 66.50 kg ha^{-1} (Table 2).

Table 2: Available P (kg ha^{-1}) at harvest of maize as influenced by fertiliser, biochar and humic acid levels and their interaction

Treatments	BC @ 0 t ha^{-1}			BC @ 5. 0 t ha^{-1}			BC @ 7.5 t ha^{-1}			Fertiliser Mean
Fertiliser levels	**HA$_1$**	**HA$_2$**	**Mean**	**HA^1**	**HA$_2$**	**Mean**	**HA$_1$**	**HA$_2$**	**Mean**	
100% NPK	42.35	61.67	52.01	47.49	60.41	53.95	52.85	66.5	59.67	55.21
75% NPK	31.45	36.41	33.93	39.64	42.2	40.92	32.67	43.18	37.92	37.59
Mean	36.90	49.04	42.97	43.56	51.30	47.44	42.76	54.84	48.80	46.40
CV (%)	4.06									
CD at 5% level	Fert. = 1.30 Biochar = 1.59 Humic acid = 1.30				Fert. x biochar = 2.25 Fert. x humic acid = 1.84 Biochar x humic acid = 2.25 Fert. x biochar x humic x acid = 3.19					

Potassium

At both the levels of fertiliser application, the available K remained in the soil was low at 5 t ha^{-1} of biochar; the respective values being 285.30 and 266.45 kg ha^{-1}. Significantly higher available K of 444.60 kg ha^{-1} was present in the soil at 75% NPK alone. Available K content was significantly lower i.e., 293.67 kg ha^{-1} when 75% NPK was integrated with humic acid as against 419.03 kg ha^{-1} with 75% NPK alone.

Interaction between biochar and humic acid resulted in a significant decrease in available K content from 495.95 kg ha^{-1} when biochar and humic acid were not applied to 255.80 kg ha^{-1} due to the application of 5 t ha^{-1} of biochar. 75% NPK, when applied alone was significantly gives higher available K content of 533.3 kg ha^{-1}. However lower available K content of 239.7 kg ha^{-1} was observed with treatment receiving 75 percent NPK with biochar @ 7.5 t ha^{-1} and humic acid (Table 3).

Table 3: Available K (kg ha^{-1}) at harvest of maize as influenced by fertiliser, biochar and humic acid levels and their interaction

Treatments	BC @ 0 t ha^{-1}			BC @ 5. 0 t ha^{-1}			BC @ 7.5 t ha^{-1}			Fertiliser Mean
Fertiliser levels	**HA$_1$**	**HA$_2$**	**Mean**	**HA^1**	**HA$_2$**	**Mean**	**HA$_1$**	**HA$_2$**	**Mean**	
100% NPK	458	369	414	264	306	285	342	279	311	336
75% NPK	533	355	444	247	285	266	476	239	358	356
Mean	495	362	429	255	295	275	409	259	334	346
CV (%)	0.91									
CD at 5% level	Fert. = 2.1 Biochar = 2.6 Humic acid = 2.1				Fert. x biochar = 3.7 Fert. x humic acid =3.0 Biochar x humic acid = 3.7 Fert. x biochar x humic x acid = 5.3					

Sulphur

Significantly increased available S content from 24.14 ppm was obtained with recommended NPK and was not integrated with biochar to 27.06 ppm was obtained with 75% NPK with biochar @ 7.5 t ha^{-1}. However these results were on par with treatment received recommended NPK along with biochar @ 5 t ha^{-1}.

Available S significantly was lower when recommended NPK was applied with the value 21.62 ppm, while when combined with humic acid resulted in a significantly higher status of 28.32 ppm. However, this was on par with 75% NPK either alone or in combination with humic acid.

Interaction between biochar and humic acid was significant. Available S content was significantly lower (22.25 ppm) when biochar was applied alone @ 7.5 t ha^{-1} while significantly higher value of 30.68 ppm when the same was integrated with humic acid. However, this was on par with treatment receiving biochar @ 5 t ha^{-1} along with humic acid (Table 4).

Table 4: Available S (ppm ha^{-1}) at harvest of maize as influenced by fertiliser, biochar and humic acid levels and their interaction

Treatments	BC @ 0 t ha^{-1}			BC @ 5. 0 t ha^{-1}			BC @ 7.5 t ha^{-1}			Fertiliser Mean
Fertiliser levels	**HA$_1$**	**HA$_2$**	**Mean**	**HA^1**	**HA$_2$**	**Mean**	**HA$_1$**	**HA$_2$**	**Mean**	
100% NPK	22.26	26.02	24.14	21.66	27.85	24.76	20.94	31.10	26.02	24.97
75% NPK	30.90	22.56	26.73	27.06	27.05	27.06	23.55	30.25	26.90	26.89
Mean	26.58	24.29	25.44	24.36	27.45	25.91	22.24	30.67	26.46	25.93
CV (%)	12.65									
CD at 5% level	Fert. = N.S Biochar = N.S Humic acid = N.S				Fert. x biochar = 3.93 Fert. x humic acid = 3.20 Biochar x humic acid = 3.93 Fert. x biochar x humic x acid = N.S					

Nutrient uptake

Recommended NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} recorded highest N and sulphur uptake (74.39 and 19.7 kg ha^{-1}), followed by 100% NPK along with biochar at 5 t ha^{-1} and humic acid at 30 kg ha^{-1} (67.06 and 15.52 kg ha^{-1}) respectively. High P uptake was recorded with 75% NPK along with biochar at 7.5 t ha^{-1} and humic acid (26.59 kg ha^{-1}) followed by recommended NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} and with humic acid were at par (20.44 and 19.8 kg ha^{-1}) respectively. Potassium uptake was highest with recommended NPK along with biochar at 7.5 t ha^{-1} and humic acid at 30 kg ha^{-1} (221.2 kg ha^{-1}) followed by recommended NPK with biochar at 7.5 t ha^{-1} (183 kg ha^{-1}) respectively (Fig 1-4).

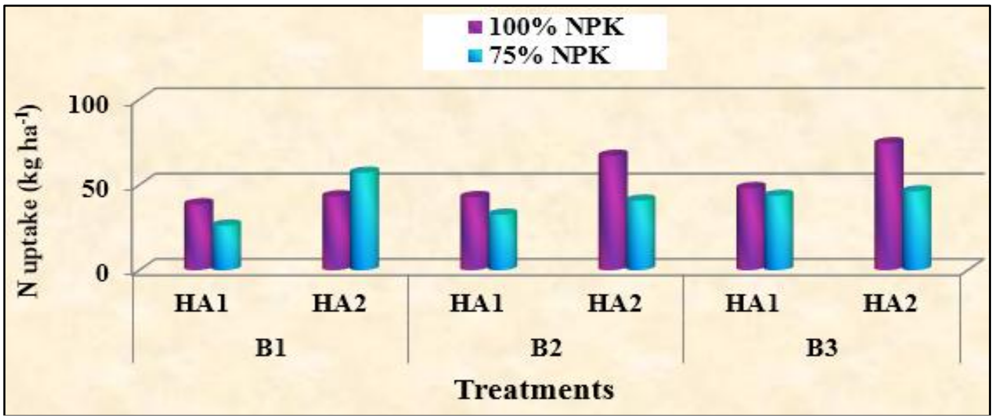

Fig 1: Nitrogen uptake (kg ha^{-1}) at harvest as influenced by fertiliser, biochar and humic acid levels and their interacti on

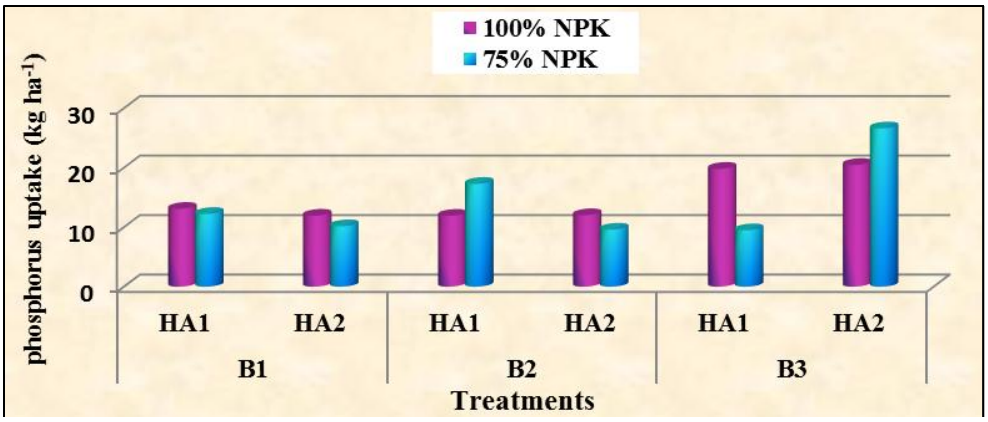

Fig 2: Phosphorus uptake (kg ha^{-1}) at harvest as influenced by fertiliser, biochar and humic acid levels and their interaction

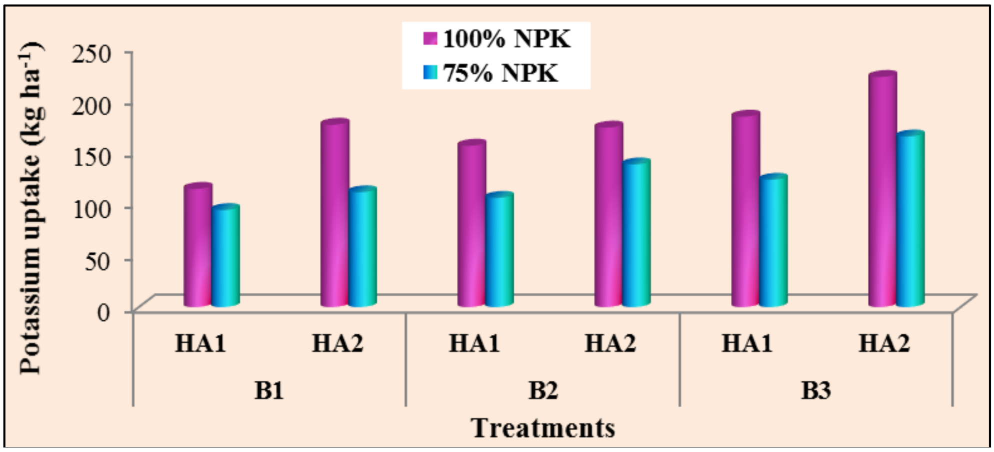

Fig 3: Potassium uptake (kg ha^{-1}) at harvest of maize as influenced by fertiliser, biochar and humic acid levels and their interaction

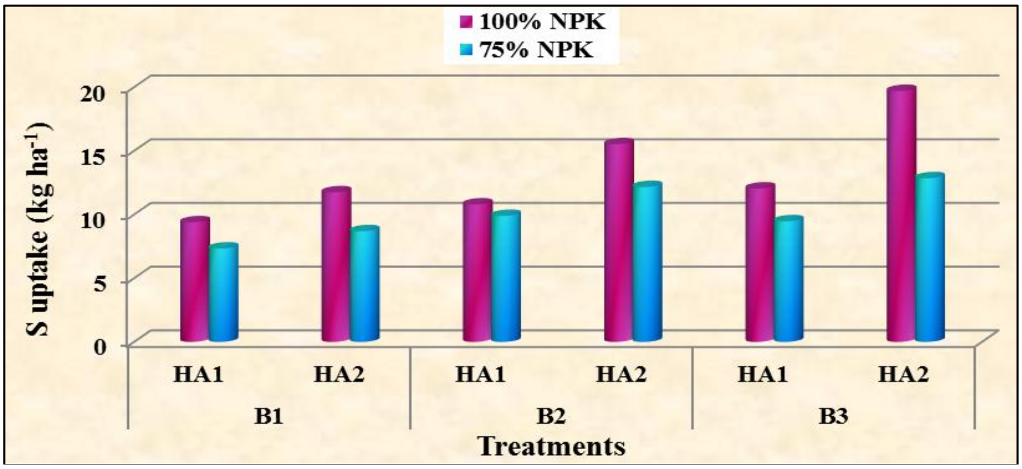

Fig 4: Sulphur uptake (kg ha^{-1}) at harvest as influenced by fertiliser, biochar and humic acid levels and their interaction

Conclusion
Maize is a heavy feeder of nutrients hence it is a very efficient converter of solar energy into dry matter. After harvest of crop, nutrient status of soil was increased compare to initial soil nutrient status might be due to Fertiliser, biochar and humic acid levels exerted significant influence when applied alone or in combinations for maintaining the available NPK and S in soil and also nutrient uptake.

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