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Effect of cotton stalk Biochar on maize productivity under calcareous clay soil condition

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Abstract
A field experiment was conducted with maize hybrid NK6240 at Tamil Nadu Agricultural University, Coimbatore during rabi 2010-2011 on Inceptisol to evaluate the effect of biochar on yield, nutrient uptake and status of the soil fertility. The experiment was laid out in a Randomized Block Design (RBD) with three replications having 12 treatments. The experimental results revealed that the application of biochar @ 10 t ha^{-1} along with the recommended dose of NPK(250:75:75 kg ha^{-1}) + FYM @ 12.5 t ha^{-1} and Azospirillum @ 2 kg ha^{-1} recorded significantly higher yield and NPK uptake with sustained soil fertility. Further for getting increased productivity of maize and sustained soil fertility, application of biochar coupled with IPNS or recommended doses of NPK fertilizers can be advocated.

Keywords: Biochar, biomass, maize, yield, uptakes and soil fertility

Introduction
Biochar produced from pyrolysis of plant stocks is a fine-grained charcoal, high in organic carbon and largely resistant to decomposition. Biochar creates a recalcitrant soil carbon pool that is carbon-negative, serving as a net withdrawal of atmospheric carbon dioxide stored in highly recalcitrant soil carbon stocks. The inspiration for the supplementation of soil with charcoal is one of the ancient soil management practices (Marris, 2006 and Renner, 2007) [8, 9] and its application to agricultural soils may be both economically viable and beneficial. There is every need to protect soils under an increasingly uncertain climate. The ability of biochar to increase the capacity of soils to absorb and store water makes it all important. The more that adding biochar to soil may be one of the few ways by which the fundamental capacity of soil to store and sequester organic matter could be increased. Biochar-amended soil reduces not only the fertilizer requirements, but also the climate and environmental impact of crop lands (Lehmann, 2007 and Brown 2009) [6, 1]. Also, it improves a host of soil physical properties (Chen *et al.* 2007) [3]. Biochar is a variable charge organic material that has the potential to increase cation exchange capacity and related soil properties (Glaser *et al.* 2002) [4]. Application of biochar with inorganic fertilizers significantly increased the yield of maize, peanut, cowpea (Yamato *et al.* 2006.) [10] and many other crops. In this context the present investigation was undertaken to assess the effect of biochar on the yield of maize and soil fertility.

Materials and Methods
Field experiment was conducted during 2010-2011at Eastern Block of Tamil Nadu Agricultural University Farm, Coimbatore on Inceptisol with maize hybrid NK6240. The farm is located in the Western agro climatic Zone of Tamil Nadu at $11^0$12" North latitude and $77^0$03" East longitude at an altitude of 426.74 m above MSL. The soil of the experimental site belongs to Perianaickenpalayam series (Vertic Ustropept), mixed black, calcareous, clay in texture, moderately alkaline in reaction (pH 8.21) and non-saline (EC 0.64 dS m^{-1}). The initial soil fertility was low in available N (185 kg ha^{-1}) and organic carbon (4.77 g kg^{-1}), medium in available P (21.5 kg ha^{-1}) and high in available K (533 kg ha^{-1}). The experiment consisted of 12 treatments replicated thrice in a Randomized Block Design. The treatments are: T_1-Biochar @ 5 t ha^{-1}; T_2-Biochar @10 t ha^{-1}; T_3-Biochar @15 t ha^{-1}; T_4-NPK alone; T_5-NPK + Biochar @ 5 t ha^{-1}; T_6-NPK + Biochar @ 10 t ha^{-1}; T_7-NPK + Biochar @ 15 t ha^{-1}; T_8-NPK + FYM @12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}; T_9-NPK + FYM @12.5 t ha^{-1} + Biochar @5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}; T_{10}-NPK + FYM @12.5 t ha^{-1} + Biochar @ 10 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}; T_{11}-NPK + FYM @12.5 t ha^{-1} + Biochar @ 15 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}; and T_{12}-Absolute Control.

The biochar used for this experiment was prepared from cotton stalks by pyrolisis. The pyrolised biochar was powdered and incorporated into the surface soil. The organic carbon content of the biochar was 174.6 g kg^{-1} and total N, P and K content was 0.322, 0.0013, and 1.038 per cent respectively.

The biochar and FYM @12.5 t ha^{-1} were applied basally to all Integrated Plant Nutrition System (IPNS) treatments as per the treatment schedule and fertilizer N, P_2O_5 and K_2O @ 250:75:75 kg ha^{-1} (blanket recommendation) was applied to all the fertilized treatments. The entire dose of P_2O_5 and K_2O as single super phosphate and muriate of potash respectively were applied basally and N as urea was applied in three splits *viz.*, basal (25% of RDF), at 25 DAS (50% of RDF) and 45 DAS (25% of RDF). Azospirillum @ 2 kg ha^{-1} was applied to the IPNS treatments a week after sowing and fertilizer application.

Results and Discussion

Grain and stover Yield

The grain yield of maize (Table 1) ranged from 1330 kg ha^{-1} in absolute control to 7996 kg ha^{-1} in T_{11} (NPK + FYM @12.5 t ha^{-1} + Biochar @ 15 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}) respectively. However, T_{11} was on par with T_{10} (NPK + FYM @12.5 t ha^{-1} + Biochar @ 10 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}) which has recorded an yield of 7874 kg ha^{-1} with an increase of 15.4% over T_8 (NPK + FYM @12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}) indicating that maize responded to biochar application when applied under IPNS. An increase in grain yield to the tune of 15.4, 25.0 and 29.0 per cent was recorded by the same treatment over NPK + FYM @12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}, NPK + Biochar @ 10 t ha^{-1} and NPK alone respectively. The magnitude of response to application of biochar was well pronounced when applied along with FYM and Azospirillum followed by NPK alone. These results corroborate the finding of Yamato *et al*. (2006) [10] and Igarahi (1996)

Among the NPK alone treatments, T_7 was on par with T_6, T_5 and T_4 indicating that different levels of biochar with inorganic fertilizers did not have any significant influence when applied without organics or biofertilizer. Though T_{12} (absolute control) had recorded significantly lower yield when compared to biochar with NPK alone and IPNS (NPK +FYM+ Azospirillum), it was on par with different levels of biochar alone applied plots (T_1 to T_3). Similar observations were also noticed by Lehmann *et al*. (2003) [7]. With regard to stover yield also similar trend of results were recorded.

Table 1: Effect of biochar application on yield and total NPK uptake by maize

Treatments		Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})
T1	Biochar @5 t ha^{-1}	1352	1922	24.87	5.86	19.34
T2	Biochar @10 t ha^{-1}	1408	2042	28.71	6.29	22.12
T3	Biochar @15 t ha^{-1}	1496	2214	29.73	7.46	23.39
T4	NPK alone	6106	7450	107.59	19.94	76.18
T5	NPK+ Biochar @ 5 t ha^{-1}	6152	7504	120.02	20.61	78.42
T6	NPK+ Biochar @10 t ha^{-1}	6300	7812	123.08	21.96	82.2
T7	NPK+ Biochar@ 15 t ha^{-1}	6324	7906	130.09	22.08	88.7
T8	NPK+FYM @ 12.5 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	6824	8530	134.68	24.8	90.06
T9	NPK+FYM @ 12.5 t ha^{-1} + Biochar @5 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	7336	8878	138.88	26.24	94.18
T10	NPK+FYM @ 12.5 t ha^{-1}+ Biochar @10 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	7874	9170	154.63	33.34	105.18
T11	NPK+FYM@ 12.5 t ha^{-1} + Biochar@15 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	7996	9436	160.28	34.02	109.74
T12	Absolute Control	1330	1910	23.34	4.28	18.88
CD (0.05)		297	359	8.82	2.86	6.61

Nutrient Uptake

The uptake of NPK by maize revealed that, N uptake ranged from 23.34 kg ha^{-1} to 160.28 kg ha^{-1}; P uptake from 4.28 kg ha^{-1} and 34.02 kg ha^{-1} and K uptake ranged between 18.88 kg ha^{-1} and 109.74 kg ha^{-1} (Table 1). It was found that though the highest NPK uptake was recorded in T_{11} treatment, it was on par with T_{10} but significantly higher than T_9. Under NPK alone, though T_7 has recorded higher uptake it was on par with T_6. The lowest total NPK uptake was recoded in the absolute control (T_{12}) which was on par with biochar alone treatments (T_1 to T_3). The research finding reported by Chan *et al*., (2007) [2] was in concurrence with the results obtained in the present investigation.

Effect of biochar on the fertility status of the post-harvest soil

Available Nutrient Status

The statistical scrutiny of the available nutrient status of the post-harvest soil (Table 2.) revealed that, among all the treatments T_{11}(NPK + FYM @12.5 t ha^{-1} + Biochar @ 15 t ha^{-1} + Azospirillum @ 2 kg ha^{-1}) had registered numerically higher available N,P and K status which was on par with T_{10}, T_9 and T_8. The lowest available nutrient status was noticed in the absolute control (T_{12}).

It was also observed that on an average increase of 15.7,10.8 and 2.2 per cent of available N; 52.1,32.6 and 4.7 per cent of available P; 18.1,14.3 and 4.3 per cent of available K respectively was recorded for biochar with IPNS, biochar with NPK alone and biochar alone treatments over initial status. The results have clearly proved that the magnitude of increase was higher with IPNS followed by NPK alone and negligible with biochar alone treatments. Yamato *et al*., (2006) [10] and Glaser *et al*. (2002) [4] reported similar trend of results obtained in the present investigation.

Organic Carbon

The results of organic carbon content of the soil had shown that all the treatments were significantly differed from each other but T_6 and T_5 were on par and T_3 and T_2 treatments were also comparable with each other. The organic carbon content

of the soil varied between 3.22 g $kg^{-1}$and 5.91 g kg^{-1}(Table 2). Among the treatments T_{11} recorded the highest organic carbon content and the lowest value was noticed in T_{12} treatment. It was observed that on an average increase of 18.8,10.4 and 2.1 per cent respectively was recorded for biochar with IPNS, biochar with NPK alone and biochar alone treatments over initial status. The results have clearly shown that the magnitude of increase was higher with IPNS followed by NPK alone and biochar alone treatments. The results corroborate with the findings of Chan *et al*. (2007) [2].

Table 2: Effect of biochar application on soil available NPK and organic carbon status

Treatments		Available-N (kg ha^{-1})	Available-P (kg ha^{-1})	Available-K (kg ha^{-1})	Organic Carbon (g kg^{-1})
T1	Biochar @5 t ha^{-1}	185	21.1	543	4.82
T2	Biochar @10 t ha^{-1}	189	22.8	555	4.89
T3	Biochar @15 t ha^{-1}	192	23.6	569	4.91
T4	NPK alone	198	25.5	593	5.12
T5	NPK+ Biochar @ 5 t ha^{-1}	203	26.5	603	5.21
T6	NPK+ Biochar @10 t ha^{-1}	205	29.0	609	5.25
T7	NPK+ Biochar@ 15 t ha^{-1}	207	30.1	615	5.31
T8	NPK+FYM @ 12.5 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	209	31.7	623	5.40
T9	NPK+FYM @ 12.5 t ha^{-1} + Biochar @5 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	210	32.2	626	5.51
T10	NPK+FYM @ 12.5 t ha^{-1}+ Biochar @10 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	215	32.6	629	5.71
T11	NPK+FYM@ 12.5 t ha^{-1} + Biochar@15 t ha^{-1}+ Azospirillum @ 2 kg ha^{-1}	217	33.3	634	5.91
T12	Absolute Control	175	19.7	530	3.22
CD (0.05)		9	1.7	15	0.05

Conclusion

From the present study, it can be concluded that application of biochar @ 10 t ha^{-1} along with the recommended dose of NPK (250:75:75 kg ha^{-1}) + FYM @ 12.5 t ha^{-1} and Azospirillum @ 2 kg ha^{-1} was found to the best treatment for getting significantly higher yield and uptake by maize with sustained soil fertility. Further biochar application should preferably be coupled with IPNS or atleast with recommended doses of NPK fertilizers for getting increased productivity of maize and sustained soil fertility.

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