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Impact of combined use of biochar, phosphorus and mycorrhiza on baby corn (*Zea mays* L.) yield and soil properties

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ABSTRACT

A greenhouse experiment was conducted during kharif season of 2015to find out the effect of combined use of biochar, phosphorus and mycorrhiza on baby corn yield and soil properties in an Inceptisol of Varanasi, India. The experiment was laid out under factorial completely randomized design with three replications. Treatments comprised of four levels of biochar and two levels of phosphorus in combination with two levels of arbuscular mycorrhiza.Results revealed that application of 30 kg P_2O_5 ha^{-1} produced highest corn (4.11 g pot^{-1}) and straw dry weight (130 g pot^{-1}). Application of lantana biochar proved superior in respect of corn and straw dry weight production over other biochars. Yields of baby corn were also improved with arbuscular mycorrhiza inoculation over no inoculation. All the biochars improved physico-chemical properties and available N, P and K over no biochar (control). Application of 30 kg P_2O_5 ha^{-1} also improved these parameters significantly over control. Inoculation with arbuscular mycorrhizasimilarly proved beneficial in respect of these parameters over no inoculation. Application of lantana biochar along with arbuscular mycorrhizal inoculation and 30 kg P_2O_5 ha^{-1} was found to be most effective in enhancing the soil physical, chemical and biological properties.

Keywords: Arbuscular mycorrhiza, baby corn, biochar, phosphorus, soil enzymatic activity

INTRODUCTION

It is a well-known fact that the large portion of added fertilizer phosphorus is converted to plant unavailable forms and contributes to residual buildup of soil phosphorus. For achieving higher nutrient uptake, water relations and higher above-ground productivity, symbiosis interaction between arbuscular mycorrhizal fungi and roots of higher plants is most important (Jeffries *et al.* 2003). Mycorrhiza adopt various mechanisms for increased uptake of phosphorus and some of those are physical exploration of soil by mycorrhizal hyphae, increased diffusion zone and absorption surface, high affinity to phosphorus and direct modification of root environment. Heavy mining activity, extreme high or low fertility condition of soil, very dry, saline, waterlogged conditions are unfavorable condition for mycorrhizal growth. These problems could be managed to some extent by providing good shelter to the mycorrhiza. Thus for ensuring the agricultural sustainability and ecosystem services new incentives and policies will be crucial that may meet the demands without compromising environmental and public health (Tilman *et al.* 2002). One such sustainable technology that involve cost effective use of organic soil amendments and good shelter material for mycorrhiza; is the application of biochar as it is highly porous. Biochar is the pyrolised product of crop straw or other organic residues use as amendment in croplands and had been proposed to be an countermeasure to rise SOC stock and improve soil fertility, environmental sustainability and mitigation of climate change in agriculture (Lehmann *et al.*2003; Sohi *et al.* 2010). Biochar application can stimulate plant growth by improving soil physical properties (*i.e.,* bulk density, rooting depth, permeability and water holding capacity etc), chemical properties (*i.e.,* nutrient availability and nutrient retention) and soil biological properties, all contributing toward increased crop productivity (Lehmann *et al.* 2006; Yamato *et al.* 2006). Maize (*Zea mays* L) is the queen of cereal and one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Baby corn has gained popularity which is grown for young cobs to be used for vegetable soup and salad and very rich in minerals, vitamins and phosphorus. Thus the current investigation was under taken to show the effect of biochar, phosphorus and mycorrhiza application on baby cornyield and soil properties in an Inceptisol of Varanasi.

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MATERIALS AND METHODS

The greenhouse experiment was conducted during *Kharif*-2015 at Banaras Hindu University, India. Phosphorus (P) deficient bulk soil sample (0–15cm) was collected from research farm of the Institute of Agricultural Sciences and passed through 2.0 mm sieve and 10 kg soil was filled in forty eight polythene lined earthen pots. Treatmentswere four levels of biochar (NB–No biochar, RHB–Rice husk biochar @ 10 t ha^{-1}, PB–Parthenium biochar @ 10 t ha^{-1} and LB–Lantana biochar @ 10 t ha^{-1}) and two levels of phosphorus (control and30 kg P_2O_5 ha^{-1}) in combination with two levels of arbuscular mycorrhiza (without inoculation and mycorrhiza @ 5 g pot^{-1}) along with full dose of nitrogen and potassium. The experiment was laid down in factorial completely randomized design(factorial CRD).Five seeds of baby corn (variety- *Malviya Makka 2*) were sown in each pot and covered with 2 cm soil layer and after establishment four plants were maintained in each pot. Full dose of biochar and mycorrhizal consortia were applied as soil application before sowing of the maize seeds. The recommended dose of nitrogen150 kg ha^{-1} and 40 kg K_2O ha^{-1}were applied through urea and dihydrogen phosphate (52% P_2O_5 and 35% K_2O). Half dose of N, along with full dose of P and K was applied as basal and rest amount of N was added in two splits at 30 and 45 DAS.Post-harvestsoil samples were collected andanalyzed for bulk density,water holding capacity; soil reaction,organic carbon and electrical conductivity as per procedures outlined by Sparks*et al.*(1996).Available N, P and K in soil were estimated by adopting standard procedures. Periodical soil sampling was done at 30 days and 60 days after sowing (DAS) and analyzed for soil microbial biomass carbon (SMBC) by fumigation-extraction method (Vance *et al.* 1987); dehydrogenase activity (Casida *et al.* 1964) and alkaline phosphatase activity (Tabatabai 1982). Statistical analysis was done under factorial completely randomized design with three replicationsusing SPSS version 16.0 software. Least significance difference test was performed forassessing the significance difference between the treatments at $p \leq 0.05$.

RESULTS AND DISCUSSION

Yield

Application of phosphorus showed significantly higher dry weight (3.96 g pot^{-1}) of baby corn which exceeded by 21.9% over control. Significant interaction between P and biochar was observed for baby corn dry weight and highest baby corn dry weight (4.02 g pot^{-1}) was obtained in the treatment of lantana biochar + 30 kg P_2O_5 ha^{-1}, while the lowest dry weight (3.30 g pot^{-1}) was recorded in no biochar + no phosphorus. Combined application of biochar and arbuscular mycorrhizaproved advantageous and 3.69 g pot^{-1} baby corn dry weight was obtained in lantana biochar + arbuscular mycorrhiza. Interaction effect among the arbuscular mycorrhiza, phosphorus and biochar was significant and resulted in increased baby corn dry weight (24.73%) over control (Fig. 1). Highest baby corn dry weight (4.11 g pot^{-1}) was obtained in lantana biochar + 30 kg P_2O_5 ha^{-1} + arbuscular mycorrhiza.Application of phosphorus showed significantly higher straw dry weight (130 g pot^{-1}) of baby corn showing an enhancement of 12.74% over control (115g pot^{-1}).The treatment which received arbuscular mycorrhizashowed significant increment of 3.81% in straw dry weight (125 g pot^{-1}) over control(120g pot^{-1}).Significant interaction between phosphorus and biochar was observed for straw dry weight. The highest straw dry weight (130 g pot^{-1}) was obtained in the treatment of rice husk biochar + 30 kg P_2O_5 ha^{-1}, while the lowest straw dry weight (104 g pot^{-1}) was recorded in the treatment of no biochar + phosphorus. Combined application of biochar and arbuscular mycorrhizaproved advantageous and 128 g pot^{-1} straw dry weight was found in parthenium biochar + arbuscular mycorrhiza over no biochar + no arbuscular mycorrhiza (113g pot^{-1}). Finding of this experiment was lined with those finding of Randon *et al.* (2007).

Physico-chemical properties of soil

Data (Table 1) indicated that the effect of phosphorus on soil bulk density was non-significant. However, application of lantana biocharand parthenium biochar significantlydecreased the soil bulk density compared to no biochar application.

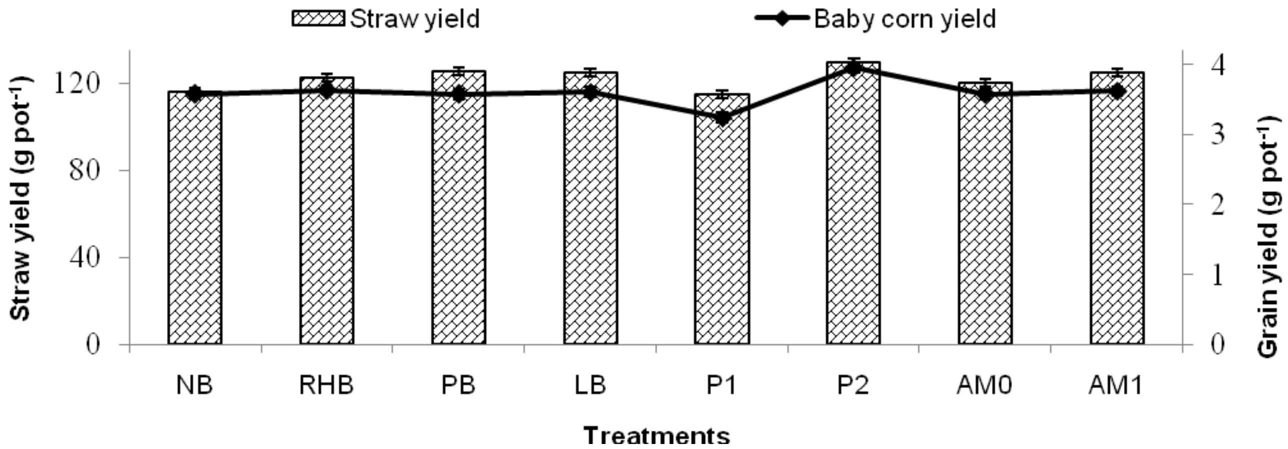

Figure 1: Effect of P, biochar and AM fungi on baby corn and straw dry weight

The effect ofmycorrhizalinoculation on soil bulk density (1.35 Mg m^{-3}) was found to be substantial as compared to no inoculation (1.31Mg m^{-3}). The application of 30 kg P_2O_5 ha^{-1} showed significant influence on soil water holding capacity (WHC) when compared with control. Application of biochar showed significantly higher WHC than control (Table 1). Application of lantana biochar resulted significantly higher WHCby 2.63% over no biochar. Water holding capacity increased with application of arbuscular mycorrhiza (45.26%) over the control (45.02%). The highest water holding capacity was observed with combined application of lantana biochar + 30 kg P_2O_5 ha^{-1}(45.92%). Dugan *et al.* (2010) also reported that the maize stover biochar and saw dust biochar increased the WHC of soil. Water holding capacity increased due to the fact that small pores in biochar retain moisture and there are largely absent in coarse texture soils (Downie *et al.*2009).Application of phosphorusshowed significant influence on soil pH over control (Table 1).

Table 1: Effect of different levels of phosphorus, biochar and AM fungi on physic-chemical properties of post-harvest soil

Treatment	BD (Mg m^{-3})	WHC (%)	pH	EC (dS m^{-1})	OC (g kg^{-1})	Avl. N (kg ha^{-1})	Avl. P (kg ha^{-1})	Avl. K (kg ha^{-1})
Biochar (B)								
NB	1.31	31.1	6.7	0.35	3.40	217	13.4	145.5
RHB	1.42	43.5	7.3	0.48	4.63	239	19.6	144.7
PB	1.37	50.0	7.4	0.48	4.64	248	21.3	152.1
LB	1.38	48.0	7.3	0.49	4.73	257	20.0	164.8
SEm ±	0.02	1.76	0.05	0.01	0.08	6.5	0.75	3.2
CD (0.05)	0.07	5.07	0.14	0.02	0.22	18.7	1.95	9.4
Phosphorus (kg ha^{-1})								
0	1.36	43.7	7.1	0.43	4.17	237	15.7	148.4
30	1.37	42.6	7.2	0.47	4.53	243	21.3	155.0
SEm ±	0.02	1.24	0.04	0.01	0.05	4.6	0.53	2.3
CD (0.05)	0.05	3.58	0.10	0.02	0.15	13.2	1.53	6.7
Arbuscular mycorrhiza (AM)								
No AM	1.36	43.5	7.2	0.44	4.27	238	17.0	152.5
AM	1.37	42.8	7.1	0.46	4.43	243	20.5	150.9
SEm ±	0.02	1.24	0.04	0.01	0.05	4.6	0.53	2.3
CD (0.05)	0.05	3.58	0.10	0.02	0.15	13.2	1.53	6.7
P × B	NS	NS	NS	S	S	NS	NS	S
P × AM	NS	NS	NS	NS	NS	NS	NS	S
B × AM	NS	NS	NS	S	S	NS	NS	NS
P × B × AM	NS	NS	NS	S	S	NS	NS	NS

NB–No biochar, RHB–Rice husk biochar, PB–Parthenium biochar, LB–Lamtana biochar

Soil application of biochar resulted in significant increase in soil pH. Van Zweiten *et al.* (2010) suggested that biochar derived from poultry litter facilitates liming in soil resulting in rise of pH of acidic or neutral soils. The effect of biochar was statistically non-significant in increasing EC of the soil (Table 1). Application of biochar, P and mycorrhiza had no significant effect on soil EC.Application of parthenium biochar and lantana biochar significantly increased organic carbon by 2.1 and 1.8%, respectively compared to no application of biochar. The inoculation with arbuscular mycorrhiza showed non-significant effect on organic carbon. The increase in soil organic carbon with biochar might have resulted from recalcitrant nature of carbon found in biochar which is largely resistant to decomposition (Lehmann *et al.* 2003). Sukartono *et al.* (2011) also reported that biochar application increased soil OC content.

Available nutrients in soil

Application of arbuscular mycorrhiza increased significantly the available N content of the soil by 3.5% over no inoculation. This was probably due to the fact that biochar has good adsorption capacity and can fix nitrogen. Theinoculation with arbuscular mycorrhiza increased the available P in soil over no inoculation (Table 1). Similar results were also reported by Rondan *et al.* (2007).No significant effect of arbuscular mycorrhizaon available K of the soil was noticed (Table 1). Biochar application increased the available potassium content of soil, but the increase was statistically non-significant. Similar result was also reported by Rondan *et al.* (2007).

Table 2: Effect of different levels of phosphorus, biochar and AM fungi on microbial propertiesof post harvest soil

Treatment	Alkaline phosphatase activity (µg PNP g^{-1} soil h^{-1})		Dehydrogenase activity (µg TPF g^{-1} soil $24h^{-1}$)		SMBC (µg C g^{-1}dry soil)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Biochar (B)						
NB	145	172	33.8	54.2	117	167
RHB	154	177	43.3	64.4	139	190
PB	158	187	47.2	67.6	148	199
LB	154	183	42.7	62.8	157	216
SEm $\pm$	1.43	2.04	1.32	1.36	6.52	6.09
CD (0.05)	4.11	5.88	3.79	3.93	18.7	17.5
Phosphorus (kg ha^{-1})						
0	149	172	37.8	58.0	137	187
30	157	187	45.7	66.5	143	199
SEm $\pm$	1.01	1.44	0.93	0.97	4.61	4.31
CD (0.05)	2.90	4.16	2.68	2.78	13.2	12.4
Arbuscular mycorrhiza (AM)						
No AM	151	181	40.0	60.4	138	193
AM	154	179	43.5	64.1	143	193
SEm $\pm$	1.01	1.44	0.93	0.97	4.61	4.31
CD (0.05)	2.90	4.16	2.68	2.78	13.2	12.4
P × B	NS	S	NS	NS	NS	S
P × AM	S	S	S	S	NS	NS
B × AM	NS	NS	NS	NS	NS	NS
P × B × AM	NS	NS	NS	NS	NS	NS

Soil biological properties

Application of 30 kg P_2O_5 ha^{-1} decreased alkaline phosphatase activity at 30 (157 µg PNP g^{-1} h^{-1}) and 60 DAS (187µg PNP g^{-1} h^{-1}) the values decreased by 5.4 and 8.7% over control at 30 (149 µg PNP g^{-1} h^{-1}) and 60 DAS (172µg PNP g^{-1} h^{-1}), respectively (Table 2). Application of biochar had significant effect on the alkaline phosphatase activity at 30 and 60 DAS. The lantana biochar treatment showed 154 and 183 µg PNP g^{-1} h^{-1} alkaline phosphatase activities over no biochar (145 and 172 µg PNP g^{-1} h^{-1}) at 30 and 60 DAS, respectively. Application of arbuscular mycorrhizaat 30 and 60 DAS also significantly increased alkaline phosphatase activity over no inoculation. The interaction effectamong P, biochar and arbuscular mycorrhizawas found non-significantly for increasing the alkaline phosphatase activity at 30 and 60 DAS.Application of 30 kg P_2O_5 ha^{-1} increased dehydrogenase activity at 30 (45.73 µg TPF g^{-1} h^{-1}) and 60 DAS (66.55 µg TPF g^{-1} h^{-1}) and the increments were 20.9 and 14.6% over control at 30 (37.82 µg TPF g^{-1} h^{-1}) and 60 DAS (58.05 µg TPF g^{-1} h^{-1}), respectively (Table 2). Application of biochar was found to have significant effect on the dehydrogenase activities at 30 and 60 DAS. The lantana biochar showed 42.7 and 62.8 µg TPF g^{-1} h^{-1} dehydrogenase activities over no biochar (33.8 and 54.8 µg TPF g^{-1} h^{-1}) at 30 and 60 DAS, respectively.Ameloot *et al.* (2013) showed that the type of biochar alone has a significant effect on soil enzymatic activity. Application of arbuscular mycorrhizaat 30 (43.5 µg TPF g^{-1} h^{-1}) and 60 DAS (64.1 µg TPF g^{-1} h^{-1}) also significantly increased dehydrogenase activities over no inoculation. Interaction effect between P and biochar was significant in increasing dehydrogenase activities both at 30 and 60 DAS. Application of 30 kg P_2O_5 ha^{-1} increased SMBC (Table 2) at 30 (143µg C g^{-1}dry soil) and 60 DAS (199µg C g^{-1}dry soil) which recorded an increase of 4.4 and 6.4% over control at 30 (137µg C g^{-1}dry soil) and 60 DAS (187µg C g^{-1}dry soil), respectively. The lantana biochar showed 157 and 216µg C g^{-1}dry soilSMBC over no biochar (117 and 167µg C g^{-1}dry soil) at 30 and 60 DAS, respectively. Application of arbuscular mycorrhiza also significantly increased SMBC over the treatment which did not receiveany arbuscular mycorrhiza at 30 (143µg C g^{-1}dry soil) and 60 DAS (193µg C g^{-1}dry soil). Biochar had positive effect on mycorrhizal association when applied to soil (Warnock *et al.* 2007).Steiner *et al.* (2008) reported similar results. Interaction effect between P and biochar was found to be significantly increasing SMBC both at 30 and 60 DAS.

From the present investigation, it may be concluded that application of lantana biochar along with arbuscular mycorrhizal inoculation and phosphorus was found to be most effective in enhancing the yield of baby corn, soil physical, chemical and biological properties.

REFERENCES

Ameloot, N., Graber, E.R., Verheijen, F.G. and De Neve, S. (2013) Interactions between biochar stability and soil organisms: review and research needs. *European Journal of Soil Science* **64**: 379–390.

Casida Jr, L.E., Klein, D.A. and Santoro, T. (1964) Soil dehydrogenase activity. *Soil Science* **98**: 371–376.

Downie, A., Crosky, A. and Munroe, P. (2009) Physical properties of biochar.Biochar for environmental management.*Science and technology,* edited by J. Lehmann and S. Joseph, Earthscan Ltd., London.

Dugan, E., Verhoef, A., Robinson, S. and Sohi, S. (2010) Bio-char from sawdust, maize stover and charcoal: Impact on water holding capacities (WHC) of three soils from Ghana.In 19th World Congress of Soil Science, Symposium **4**: 9–12.

Jeffries, P., Gianinazzi, S., Perotto, S., Turnau, K. and Barea, J.M. (2003) The contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. *Biology and Fertility of Soils* **37**: 1–16.

Lehmann, J., da Silva, J.P., Steiner, C., Nehls, T., Zech, W. and Glaser, B. (2003) Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments.*Plant and Soil* **249**: 343–357.

Lehmann, J., Gaunt, J. and Rondon, M. (2006) Bio-char sequestration in terrestrial ecosystems–a review.*Mitigation and Adaptation Strategies for Global Change***11**: 403–427.

Rondon, M.A., Lehmann, J., Ramírez, J. and Hurtado, M. (2007) Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. *Biology and Fertility of Soils* **43**: 699–708.

Sohi, S.P., Krull, E, Lopez-Capel, E. and Bol, R. (2010) A review of biochar and its use and function in soil. *Advances in Agronomy* **105**: 47–82.

Sparks, D.L. (1996) Methods of soil analysis.Part 3-Chemical Methods.Soil Science Society of America Inc., American Society of Agronomy Inc., Madison Wisconsin, USA.

Steiner, C., Das, K.C., Garcia, M., Förster, B. and Zech, W. (2008) Charcoal and smoke extract stimulate the soil microbial community in a highly weathered xanthic Ferralsol. *Pedobiologia***51**: 359–366.

Sukartono, U.W, Nugroho, W.H. and Kusuma, Z. (2011) Simple biochar production generated from cattle dung and coconut shell. *Journal of Basic and Applied Science Research* **1**:1680–1685

Tabatabai, M.A. (1982) Soil enzymes.Methods of Soil Analysis.Part 2. Chemical and microbiological properties,American Society of Agronomy Inc., Madison, Wisconsin, USA, PP 903–947.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002) Agricultural sustainability and intensive production practices. *Nature* **418**: 671.

Van Zwieten, L., Kimber, S., Morris, S., Chan, K.Y., Downie, A., Rust, J. and Cowie, A. (2010) Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant and Soil* **327**: 235–246.

Vance, E.D., Brookes, P.C. and Jenkinson, D.S. (1987) An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry* **19**: 703–704.

Warnock, D.D., Lehmann. J., Kuyper, T.W. and Rillig, M.C. (2007) Mycorrhizal responses to biochar in soil–concepts and mechanisms.*Plant and Soil* **300**: 9–20.

Yamato, M., Okimori, Y., Wibowo, I.F., Anshori, S. and Ogawa, M. (2006) Effects of the application of charred bark of Acacia mangium on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia.*Soil Science and Plant Nutrition* **52**: 489–495.