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Assessment of phosphorus bioavailability and yield potential of baby corn (*Zea mays* L.) through the combined use of biochar, phosphorus and mycorrhiza in an Inceptisol

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ABSTRACT

A pot experiment was conducted in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences B.H.U., Varanasi, India during kharif season of 2015 to investigate the influence of biochar, phosphorus and mycorrhiza on performance of baby corn in view of phosphorus activity coefficient. The treatments comprised of four levels of biochar i.e. no biochar, rice husk biochar, lantana biochar and parthenium biochar (each applied @ 4.545 g kg^{-1} soil, two levels of mycorrhiza (uninoculated and inoculated) and two levels of phosphorus viz. no P and P @ 50% RD of P. Rrsults revealed that the beneficial effects of biochar could be exploited on phosphorus bioavailability if it was applied along with mycorrhiza. Combined application of lantana biochar (10 t ha^{-1} soil) along with 50% recommended dose of phosphorus and arbuscular mycorrhizal inoculation produced significantly higher baby corn fresh weight and activity coefficient of plant available phosphorus over other treatments. Growth characters and chlorophyll content also increased with biochar, phosphorus and AM fungi inoculation. Application of P was more effective in improving these parameters than those of biochar and AM fungi.

Key words: phosphorus bioavailability, biochar, mycorrhiza

INTRODUCTION

It is a well-known fact that the large portion of added fertilizer phosphorus is converted to plant unavailable forms and resulted in residual buildup of soil phosphorus. Symbiosis interaction between arbuscular mycorrhizal fungi and roots of higher plants is most important (Jeffries *et al.* 2003) for attaining higher yield, higher above-ground productivity and nutrient uptake. Various mechanism of mycorrhizae for increased uptake of phosphorus are physical exploration of soil by mycorrhiza, direct modification of root environment, increased absorption surface, high affinity to phosphorus etc. Heavy tillage, extreme high or low fertility, water logged condition of soil are unfavorable for mycorrhizal growth. Good shelter to the mycorrhiza could be a management option for mycorhhiza. 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.* 2006; Sohi *et al.* 2010). Biochar application can stimulate plant growth by improving soil physical properties (i.e. bulk density, rooting depth, permeability, water holding capacity etc), chemical properties (i.e., nutrient availability, and nutrient retention), and soil biological properties, all contributing toward increased crop productivity (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 objective of this study was to find phosphorus bioavailability from biochar.

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2015 in net house of the Department of Soil Science and Agricultural Chemistry, Institute of

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Agricultural Sciences, Banaras Hindu University, Varanasi, India in factorial completely randomized design with 16 treatment combinations replicated trice. Bulk soil sample (0-15cm) was collected from Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University. Varanasi, India. After collecting, it was ground and passed through 5.0-mm sieve and 10 kg of soil filled in the each polythene lined pot. Soil in each pot was pulverized manually and 5 seeds of maize (variety Malviya Makka 2) were transplanted. After establishment, four plants were maintained. The pots were irrigated and 2 cm of standing water was maintained by daily addition of water. The soil used for experimentation was sandy loam with bulk density 1.63 Mgm-3, pH (1:2.5) 7.6, E.C. 0.21 dsm^{-1}, CEC 11.63 cmol(P^{+}) kg^{-1}, organic carbon 0.34%, available N 135 kg ha^{-1}, available P 22.7 kg ha^{-1} and available K 183 kg ha^{-1}.Two levels of phosphorus (control and 50% RD of P) along with full dose of nitrogen and potassium were applied. Required quantities of fertilizers for each pot were calculated and applied in solution form using urea, KH_2PO_4 and KCl as source of N, P, and K respectively. Half dose of N applied as basal and remaining dose was added at 30 and 45 days after sowing. Full dose of P_2O_5 was applied as KH_2PO_4as per treatments.Three types of biochar viz rice husk biochar (RHB), lantana biochar(LB), and parthenium biochar (PB) were applied corresponding to 10 t ha^{-1}. Required quantities of biochar for 10 kg soil were calculated and the full dose was applied as soil application before sowing the maize seeds. Mycorrhizal treatment (mycorrhiza and without mycorrhiza)was applied @ 5 g pot^{-1}. Mycorrhizal consortia were equally spared on the moist top soil of the pots followed by covering with thin 2-3 cm soil layer.

Model and activity co-efficient analysis: The response of P fertilizer application on baby corn yield can be described by a Mitscherlich equation (Harmsen *et al.* 2001). This equation, based on Liebig's law of the minimum, defines the yield response of any crop to the increasing level of main input factor that is limiting to growth (Harmsen 2000). It can be written as:

$$Y = Y0 + \Delta Y - \Delta Y e^{-\varepsilon Nf}$$

Where, Y = The total dry matter yield or P uptake of the baby corn (g pot^{-1} or mg pot−1 for P uptake), Y0 = The yield or P uptake (g pot^{-1} or mg pot^{-1} for P uptake) without biochar or fertilizer application, ΔY = The difference (g pot^{-1} or mg pot^{-1} for P uptake) between the maximum yield or P uptake Ymax and Y0, that is, Ymax = Y0+ ΔY, ε = an activity coefficient (mg^{-1} pot), which is a measure of plant available P in biochars or fertilizers and Nf = the rate of P applied to the crop (mg pot^{-1}).

Statistical analyses were done under factorial completely randomized design with three replication using SPSS version 16 software.

RESULTS AND DISCUSSION

A critical perusal of the data (Table 1) revealed that a significant increase in plant height at 30 DAT (123 cm) was recorded with the application of phosphorus @ 50% of RDF than the plant height obtained from the treatment which did not supply any phosphorus (110 cm). Application of biochar resulted no significant effect on plant height (30 DAT) when compared to the treatments comprising of no biochar. The inoculation with AM showed significantly higher plant height (119cm) at 30 DAT than uninoculated treatment (115 cm). Almost similar trend was noticed with the plant height recorded at 60 DAT. In comparison to non-mycorrhizal controls, mycorrhizal seedlings usually had higher plant biomass, photosynthetic pigment content and photosynthetic parameters under alkali stress condition (Lin *et al.,* 2017). According to Bridle and Pritchard (2004), 100 per cent recovery of P was obtained in a biochar produced from sewage sludge at 450°C in comparison to 45 per cent of N, which was lost during the same procedure. However, laboratory incubation studies indicated that the availability of P in the biochar is only 13 per cent of total P, much lower than those of the biosolid and dry-pelleted biosolid (Bridle and Pritchard, 2004). According to Bridle and Pritchard (2004), nearly half of the total P in biochar was in HCl-extractable form (i.e. as Ca-bound inorganic P) and was therefore less plant available. Application of P significantly increased number of leaves in baby corn by 10% and 9.2% at 30 DAS and 60 DAS, respectively over P0. Shoot biomass production was increased by mycorrhizal colonization and when plants were grown at the high P level or with micronutrient application (Liu *et al.,* 2000). Significant increase in chlorophyll content (leaf SPAD value, 36.4) at 30 DAT was recorded with the application of AM1 over AM0 (leaf SPAD value, 37.2). AM colonization significantly improved Chlorophyll levels, stomatal behavior, peak fluorescence, maximum PSII photochemical efficiency, prospective photochemical efficiency, higher relative water content and water use efciency of maize under drought stress compared with non-mycorrhizal plants (Zhu *et. al.,* 2012).

Table 1: Effect of phosphorus, biochar and AM on plant height, chlorophyll content and number of leaves of baby corn

Treatment	Number of leaves		Chlorophyll content		Plant height (cm)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Biochar						
Control	11.1	13.1	36.5	39.9	112	122
RHB	11.3	13.3	37.0	41.5	117	125
PB	11.5	13.3	36.5	40.53	119	128
LB	11.5	13.5	37.3	40.7	119	129
SEm ±	0.11	0.12	0.33	0.34	0.37	0.50
CD (0.05)	0.34	0.35	0.94	0.99	1.08	1.45
Phosphorus						
P0	10.8	12.7	36.7	40.5	110	119
P1	11.9	13.9	36.9	40.8	123	133
SEm ±	0.08	0.09	0.23	0.24	0.26	0.36
CD (0.05)	0.24	0.25	0.69	0.70	0.76	1.02
AM fungi						
AM0	11.3	13.3	36.4	39.5	115	125
AM1	11.4	13.3	37.2	41.9	119	128
SEm ±	0.08	0.09	0.23	0.24	0.26	0.36
CD (0.05)	0.24	0.25	0.69	0.70	0.76	1.02

Effect of different types of biochar was non significant on chlorophyll content (leaf SPAD value) at 30 DAT when compared to the control. Application of phosphorus produced non significant increase in chlorophyll content (leaf SPAD value, 36.9) over P0 (36.6). This could happen as phosphorus has no direct role in improving chlorophyll content. Almost similar trend was observed in chlorophyll content recorded at 60 DAT. Arbuscular mycorrhizal fungi (AMF) probably increased Mg uptake which cause increase in total chlorophyll content that subsequently led to higher production of photosynthate and biomassin arbuscular mycorrhizal fungi inoculated maize compared with non-inoculated one under high temperature stress condition(Mathur *et. al.,* 2018).Stomatal physiology was affected by mycorrhizal infection, as shown by decreased stomatal resistances to water and by increased transpirational fluxes and rates of photosynthesis. The effects could be mediated by increased stomatal opening, thus increasing the K+ concentrations in mycorrhizal plants.

Application of AM showed significantly higher baby corn length (9.66 cm) which was 1.4% higher than the treatment without AM (9.53 cm) (Table 2). Significant interaction between phosphorus and biochar was observed for baby corn length.Sole application of biochar was insignificant in increasing baby corn length, but combined application of biochar and AM proved advantageous. Zwetsloot *et al.* (2016)concluded thatwhen maize was inoculated with AM, the root:shoot ratios after bone char additions were greater than those after TSP additions. Without P application, root:shoot ratios of maize with or without root hairs were significantly lower than when other P sources were applied. Application of phosphorus showed significantly higher baby corn fresh weight (28.4 g) of baby corn registering an increase of 29.1% over which did not supply any phosphorus (21.9 g). The treatment which received AM showed significant increase in corn fresh weight which excced by 11.5% over no AM treatment.Phosphorus concentration was higher in the mycorrhizal plant compared to the non mycorrhizal plants when P was not added which in turn increased fresh weight (Zwetsloot *et al.* 2016).Application of phosphorus showed significantly higher dry weight (3.96 g pot^{-1}) of baby corn which exceeded by 21.9% P0.

Table 2: Effect of phosphorus, biochar and AM on corn length, fresh weight, dry weight, straw dry weight, P uptake of baby corn and P activity coefficient

Treatment	Baby corn				Plant available P	
	Baby corn length (cm)	Fresh wt.	Dry wt.	Straw yield (g pot^{-1})	P uptake by cob (mg pot^{-1})	Activity coefficient (mg pot^{-1})
Biochar						
Control	9.63	25.0	3.58	116	39.2	0.0030
RHB	9.58	25.4	3.64	122	41.2	0.0039
PB	9.54	25.2	3.58	125	41.7	0.0042
LB	9.63	25.1	3.61	125	43.0	0.0048
SEm $\pm$	0.05	0.11	0.02	0.35	0.32	-
CD (0.05)	0.14	0.31	0.05	1.00	0.94	-
Phosphorus						
P0	8.66	21.9	3.25	115	35.0	0.0048
P1	10.54	28.4	3.96	129	47.5	0.0076
SEm $\pm$	0.04	0.08	0.01	0.25	0.23	-
CD (0.05)	0.10	0.22	0.04	0.71	0.66	-
AM fungi						
AM0	9.53	23.8	3.58	120	43.2	0.0049
AM1	9.66	26.5	3.62	124	45.7	0.0064
SEm $\pm$	0.04	0.08	0.01	0.25	0.23	-
CD (0.05)	0.10	0.22	0.04	0.71	0.66	-

The treatment which received AM showed insignificant increase of 1.25% in corn dry weight over no AM treatment.Significant interaction between phosphorus and biochar was observed for baby corn dry weight (Table 2).Soil biochar application can potentially replace mineral phosphorus fertilizers and its use efficiency can be improved by plant inoculation with the *Penicillium aculeatum* and arbuscular mycorrhiza may possibly act synergistically with *Penicillium* to improve the uptake of phosphorus present in biochar (Efthymiou *et al.* 2018).Application of phosphorus showed significantly higher straw dry weight (129 g pot^{-1}) of baby corn showing an enhancement of 12.7% over P0 (115 g pot^{-1}). The treatment which received AM showed significant increase of 3.81% in straw dry weight (124 g pot^{-1}) over no AM (120 g pot^{-1}).

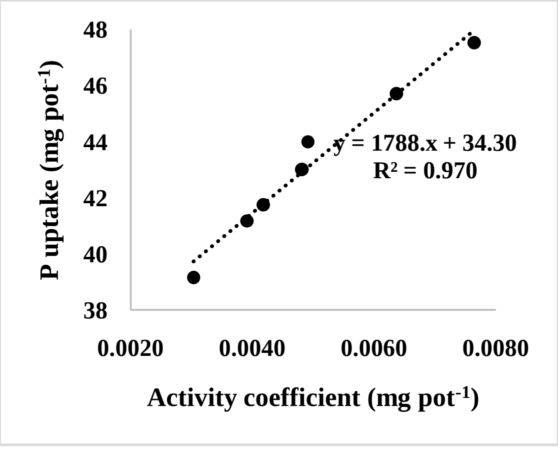

Figure 1: Scatter plot between phosphorus uptake and activity coefficient of phosphorus

Highest activity coefficient for phosphorus bioavailability was recorded with 50% application of phosphorus then inoculation with mycorrhiza followed by lantana biochar application (Table 2). All interactions among the treatments were significant for phosphorus uptake of baby corn. Bornø *et al.* (2018), suggested that the effects of biochar application on soil P dynamics are highly dependent on the initial P sorption capacity of soil and biochar.Phosphorus uptake of baby corn was significantly positively (r = + 0.99) correlated with activity coefficient of phosphorus and when this was plotted in scatter plot, there was 97% linearity between activity coefficient and phosphorus uptake of baby corn (Figure 1).Wheat and clover uptake higheramount of nutrientsvia their roots and mycorrhizal hyphaeand increased crop production when amended with 34 different sources of biochar varying in their nutrient concentrations, particularly for P and N under phosphorus deficient soil (Solaiman, *et. al.,* 2019).

It may be concluded that the application of lantana biochar along with 50% recommended dose of phosphorus and arbuscular mycorrhizal inoculation was found to be most effective in enhancingthe corn yield and activity coefficient of plant available phosphorus over other integrated treatments.

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REFERENCES

Bornø, M.L., Müller-Stöver, D. S. and Liu, F. (2018) Contrasting effects of biochar on phosphorus dynamics and bioavailability in different soil types. *Science of the Total Environment* **627**: 963-974

Bridle, T.R., and Pritchard, D. (2004) Energy and nutrient recovery from sewage sludge via pyrolysis. *Water Science and Technology* **50**(9): 169-175

Efthymiou, A., Jensen, B., and Jakobsen, I. (2018) The roles of mycorrhiza and Penicillium inoculants in phosphorus uptake by biochar-amended wheat. *Soil Biology and Biochemistry*__127__: 168-177

Harmsen, K. (2000) A modified Mitscherlich equation for rainfed crop production in semi-arid areas: 1. Theory. NJAS-Wageningen *Journal of Life Sciences* **48**(3): 237-250

Harmsen, K., Matar, A. E., Saxena, M. C., and Silim, S.N. (2001) Yield response to phosphorus fertilizer in a wheat-lentil rotation in a Mediterranean environment. NJAS-*Wageningen Journal of Life Sciences* **49**(4): 385-403

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): 1–16

Lehmann, J., Gaunt, J. and Rondon, M. (2006) Bio-char sequestration in terrestrial ecosystems–a review. Mitigation and adaptation strategies for global change 11(2): 403-427

Lin, J., Wang, Y., Sun, S., Mu, C. and Yan, X. (2017) Effects of arbuscular mycorrhizal fungi on the growth, photosynthesis and photosynthetic pigments of Leymus chinensis seedlings under salt-alkali stress and nitrogen deposition. *Science of the Total Environment* **576**: 234-241

Liu, A., Hamel, C., Hamilton, R. I., Ma, B. L. and Smith, D. L. (2000) Acquisition of Cu, Zn, Mn and Fe by mycorrhizal maize (Zea mays L.) grown in soil at different P and micronutrient levels. Mycorrhiza **9**(6): 331-336.

Mathur, S., Sharma, M.P. and Jajoo, A. (2018) Improved photosynthetic efficacy of maize (Zea mays) plants with arbuscular mycorrhizal fungi (AMF) under high temperature stress. *Journal of Photochemistry and Photobiology B*: Biology**180**: 149-154.

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

Solaiman, Z. M., Abbott, L. K. and Murphy, D. V. (2019) Biochar phosphorus concentration dictates mycorrhizal colonisation, plant growth and soil phosphorus cycling. *Scientific reports* **9**(1): 5062.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. (2002) Agricultural sustainability and intensive production practices. Nature **418**(6898): 671.

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 & Plant Nutrition* **52**(4): 489-495.

Zhu, X. C., Song, F. B., Liu, S. Q., Liu, T. D., and Zhou, X. (2012) Arbuscular mycorrhizae improves photosynthesis and water status of Zea mays L. under drought stress. *Plant, Soil and Environment* **58**(4): 186-191

Zwetsloot, M.J., Lehmann, J., Bauerle, T., Vanek, S., Hestrin, R. and Nigussie, A. (2016) Phosphorus availability from bone char in a P-fixing soil influenced by root-mycorrhizae-biochar interactions. *Plant and soil* **408**(1-2): 95-105.