

Original Research Article

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## Improving Acquisition of Phosphorus and Other Nutrient Elements by Baby Corn (*Zea mays* L.) through the Combine Use of Biochar, Phosphorus and Arbuscular Mycorrhiza

Arghya Chattopadhyay<sup>1\*</sup>, A.P. Singh<sup>1</sup>, Sumit Rai<sup>1</sup>, Awtar Singh<sup>1</sup> and Ajoy Das<sup>2</sup>

<sup>1</sup>Department of Soil Science and Agricultural Chemistry, Banaras Hindu University, Varanasi- 221 005, India

<sup>2</sup>Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur- 741 252, India

\*Corresponding author

### ABSTRACT

A pot experiment was conducted in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences Banaras Hindu University, Varanasi, India during *kharif* season of 2015 to investigate the effect of biochar, phosphorus and mycorrhiza on performance of baby corn and its quality. The treatments included two levels of phosphorus *viz.* P @ 50% RDF and no P along with full dose of nitrogen and potassium and four levels of biochar. Biochars used were prepared from rice husk, lantana and parthenium each applied @ 4.545 g kg<sup>-1</sup> soil. Two levels of mycorrhiza (inoculated and uninoculated) were also included in the treatments. Investigation indicates that valuable effects of biochar could be obtained if it was applied with mycorrhiza. Combined application of biochar (10 t ha<sup>-1</sup> soil), phosphorus along with mycorrhiza produced significantly higher uptake of nutrients in baby corn. Biochars are highly variable in nutrient composition and availability, which are determined by types of feedstock and pyrolysis conditions. The results suggest that high-ash biochars with phosphorus are potential P sources with high-agronomic efficiency.

#### Keywords

Baby corn, Biochar, Mycorrhiza and Phosphorus.

#### Article Info

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### Introduction

For achieving high yields farmers are compelled to adopt different types of management practices like intensive cultivation and enhanced use of agrochemicals mainly fertilizers and pesticides that cause remarkable change in the environment and under many condition leading to deterioration of soil quality and decline in soil organic carbon at different places of India. Therefore, the task of attaining higher productivity of crops and maintaining soil quality at the same time

could be achieved by integrating new approaches that involve use of low cost organic soil amendments, conditioners. One such sustainable technology is application of biochar. Biochar can enhance growth of plants and improve physical, chemical and biological properties of soil.

Presently, in Europeans countries use of biochar as a soil amendment is going on a large scale, but in India biochar has not been adopted so extensively.

## Materials and Methods

### Study area

The experiment was conducted during *khari* season of 2015 in net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India.

Statistical analysis was done in factorial completely randomized design with 16 treatment combinations replicated thrice other relevant details are given here under.

### Experimental soil

Bulk soil sample (0-15cm) was collected from Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. It was ground and passed through 2.0 mm sieve and 10 kg of pressed soil was filled in each polythene lined pot. Five seeds of maize (variety *MalviyaMakka* 2) were transplanted in each pot and soil in each pot was pulverized manually.

Four plants were maintained after establishment. The pots were irrigated as per need.

The soil used for experimentation was sandy loam with bulk density  $1.63 \text{ Mg m}^{-3}$ , pH (1:2.5) 7.6, E.C.  $0.21 \text{ dsm}^{-1}$ , CEC  $11.63 \text{ cmol(p}^+) \text{ kg}^{-1}$ , organic carbon 0.34%, available N  $135 \text{ kg ha}^{-1}$ , available P  $22.7 \text{ kg ha}^{-1}$  and available K  $183 \text{ kg ha}^{-1}$ .

### Source of biochar and arbuscular mycorrhiza

Arbuscular mycorrhiza and biochar were obtained from the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India).

### Fertilizer application

Phosphorus having two levels viz. no P (P0) and P @ 50% RDF (P1) along with full dose of nitrogen and potassium were applied. Required quantities of fertilizers for each pot (10 kg soil) were calculated and applied in solution form using urea,  $\text{KH}_2\text{PO}_4$  and KCl as source of N, P, and K respectively. So rates of N, P and K for each pot (10 kg soil) were 0.66 g, 0.13 g and 0.17 g respectively corresponding to 150, 30 and  $40 \text{ kg ha}^{-1}$ . Half the dose of N was applied as basal and left over amount was added in two split at 30 and 45 days after sowing. Full dose of  $\text{P}_2\text{O}_5$  was applied as  $\text{KH}_2\text{PO}_4$  in all the 24 pots and it met the  $\text{K}_2\text{O}$  requirement of the crop as it contained 35%  $\text{K}_2\text{O}$ .

### Biochar application

Three types of biochar viz. rice husk biochar (RBH), lantana biochar (LB), and parthenium biochar (PB) were applied corresponding  $10 \text{ t ha}^{-1}$  and one treatment (NB) did not supply any. Required quantities of biochar for 10 kg soil were calculated and the full dose was applied as soil application before sowing the maize seeds.

### Arbuscular mycorrhiza application

Mycorrhizal treatment had two levels *i.e.*, with mycorrhiza (AM1) and without mycorrhiza (AM0). Mycorrhizal consortia were applied @  $5 \text{ g pot}^{-1}$  by spreading over the moist top soil of the pots followed by covering with thin (2-3 cm) soil layer.

### Sampling and analysis

Plant samples after harvesting were dried at  $65\text{-}70^\circ\text{C}$  and nitrogen, phosphorus, and potassium were analyzed following suitable methods as mentioned in the practical manual of Tandon (2001).

## Results and Discussion

### Phosphorus uptake by cob and straw of baby corn

Effect of application of phosphorus, biochar and mycorrhizal inoculation on phosphorus uptake in cob and straw of baby corn varied significantly (Table 1). Application of P1 in soil increased significantly phosphorus uptake by cob and straw and the values exceed by 35.7% and 35.0% over P0. Application of biochar had a significant effect on phosphorus uptake of cob compared to NB. Application of LB showed significantly higher phosphorus uptake in cob and straw and recorded increments were 9.88% and 2.51% respectively compared to NB.

The increased uptake of phosphorus in cob was happening due to the fact that biochar contained remarkable amount of phosphorus. The inoculation with mycorrhiza increased the phosphorus uptake in cob and straw by 24.1% and 14.5%, respectively over AM0. It was probably due to secretion of phosphatase enzyme by mycorrhiza which solubilized inorganic phosphorus and there by increased phosphorus uptake.

Significant interaction between phosphorus and biochar was observed for phosphorus uptake in cob and straw. The application of LB+P1 showed higher phosphorus uptake in cob (50.1 mg pot<sup>-1</sup>) and straw (30.0 g pot<sup>-1</sup>) over the pots which did not receive any biochar and phosphorus. Significant interaction between phosphorus and mycorrhiza was observed for phosphorus uptake in cob. The application of P1+AM1 showed higher phosphorus uptake in cob (52.8 mg pot<sup>-1</sup>) over P0+AM0 (31.5 mg pot<sup>-1</sup>). Significant interaction between biochar and mycorrhiza was observed for phosphorus uptake in cob. The application of LB+AM1 showed higher phosphorus uptake in cob

(48.4 mg pot<sup>-1</sup>) over NB+AM0 (34.7 mg pot<sup>-1</sup>).

Arbuscular mycorrhizal fungi hyphae normally transport P located at greater distances from the root than do non mycorrhizal roots (Tinker *et al.*, 1992). Interaction effect among of phosphorus, mycorrhiza and biochar was found to increase significantly the phosphorus uptake of baby corn. The application of LB+P1+AM1 showed higher phosphorus uptake in cob (57.1 mg pot<sup>-1</sup>) over NB+P0+AM0 (30.0 mg pot<sup>-1</sup>). Greater resin-extractable P from bone char produced at 350°C in comparison to unpyrolyzed bone meal additions to soil was explained by the increase in hydroxyl apatite-like crystals through pyrolysis, which reduces water-extractable P but increases formic extractable P representing plant-available P (Zwetsloot *et al.*, 2016).

### Nitrogen uptake by cob and straw of baby corn

Application of AM1 showed significantly higher nitrogen uptake of cob and straw of baby corn and the increments were 4.05% and 4.65%, respectively over AM0. Effect of application of biochar was found to be non-significant on nitrogen uptake of cob and straw. The application of P1 showed significantly higher nitrogen uptake in cob and straw, the increments being 23.8% and 15.4% respectively over P0. Significant interaction between phosphorus and biochar was observed for nitrogen uptake by cob and straw. The highest uptake of nitrogen by cob (174 mg pot<sup>-1</sup>) was obtained with the application of LB+P1. Straw nutrient uptake recorded highest uptake of nitrogen (3.84 g pot<sup>-1</sup>) when PB and P1 were applied in combination. Arbuscular mycorrhiza and biochar interaction was also significant for nitrogen uptake in cob and straw. The highest uptake of nitrogen in cob was obtained with

the application of LB+AM1 (160 mg pot<sup>-1</sup>). Straw recorded highest uptake of nitrogen (3.7 g pot<sup>-1</sup>) using combined application of PB and AM1.

Ammonium-N acquisition by arbuscular mycorrhizal treated plants has been considered more important than NO<sub>3</sub>-N because of the lower mobility of NH<sub>4</sub> -N in soil compared to NO<sub>3</sub>-N (Marschner and Dell, 1994), although acquisition and hyphal transport of both forms of N may readily occur in arbuscular mycorrhizal fungi treated plants (Subramanian and Charest, 1998).

Arbuscular mycorrhizal fungi hyphae have the capacity to take up and transport N from soil to roots (Bago *et al.*, 1996). Interaction among phosphorus, biochar and arbuscular mycorrhizal application was significant for nitrogen uptake of cob and combined application of phosphorus, lantana biochar and arbuscular mycorrhizal application gave nitrogen uptake to the magnitude of 180 mg pot<sup>-1</sup> compared with uptake of 137 mg pot<sup>-1</sup> with control. George *et al.*, (1992) reported that 30-40% of N in arbuscular mycorrhizal treated plants may be contributed by hyphae.

**Table.1** Nitrogen, phosphorus and potassium uptake by cob and straw of baby corn as affected by different levels of phosphorus, biochar and AM

Treatment	Nitrogen uptake		Phosphorus uptake		Potassium uptake	
	Cob (mg pot <sup>-1</sup> )	Straw (g pot <sup>-1</sup> )	Cob (mg pot <sup>-1</sup> )	Straw (g pot <sup>-1</sup> )	Cob (mg pot <sup>-1</sup> )	Straw (g pot <sup>-1</sup> )
<b>NB</b>	154	3.37	39.2	0.77	54.0	4.24
<b>RHB</b>	155	3.54	41.3	0.83	54.6	4.48
<b>PB</b>	153	3.63	41.8	0.85	54.5	4.60
<b>LB</b>	155	3.63	43.0	0.87	55.9	4.60
<b>SEm±</b>	0.87	0.01	0.32	0.01	0.32	0.02
<b>CD (p ≤ 0.05)</b>	2.50	0.04	0.94	0.03	0.93	0.04
<b>P0</b>	138	3.29	35.0	0.71	48.7	4.19
<b>P1</b>	171	3.79	47.5	0.95	60.8	4.77
<b>SEm±</b>	0.61	0.01	0.23	0.01	0.23	0.01
<b>CD (p ≤ 0.05)</b>	1.77	0.03	0.66	0.02	0.66	0.03
<b>AM0</b>	152	3.46	36.8	0.77	53.1	4.36
<b>AM1</b>	157	3.62	45.7	0.89	56.4	4.61
<b>SEm±</b>	0.61	0.01	0.23	0.01	0.23	0.01
<b>CD (p ≤ 0.05)</b>	1.77	0.03	0.66	0.02	0.66	0.03
<b>P × B</b>	S	S	S	S	S	S
<b>P × AM</b>	NS	NS	S	NS	S	S
<b>B × AM</b>	S	S	S	NS	S	NS
<b>P × B × AM</b>	S	NS	S	NS	NS	S

P0 and P1 means phosphorus @ 0 and 50% RDF respectively; NB, RHB, LB and PB means no biochar, rice husk biochar, lantana biochar and parthenium biochar @ 10 t ha<sup>-1</sup> respectively; AM0 and AM1 means mycorrhiza @ 0 and 5 g pot<sup>-1</sup> respectively. P × B means phosphorus and biochar interaction, P × AM means phosphorus and mycorrhiza interaction, B × AM means biochar and mycorrhiza interaction, P × B × AM means phosphorus, biochar and mycorrhiza interaction. S means significance and NS means non significant.

**Table.2** Sulphur, zinc and iron uptake by cob and straw of baby corn as affected by different levels of phosphorus, biochar and AM

Treatment	Sulphur uptake		Zinc uptake		Iron uptake	
	Cob (mg pot <sup>-1</sup> )	Straw (mg pot <sup>-1</sup> )	Cob (mg pot <sup>-1</sup> )	Straw (mg pot <sup>-1</sup> )	Cob (mg pot <sup>-1</sup> )	Straw (mg pot <sup>-1</sup> )
<b>NB</b>	36.4	1006	0.42	18.2	1.22	80.6
<b>RHB</b>	38.6	1077	0.46	20.0	1.26	85.4
<b>PB</b>	43.3	1156	0.47	21.4	1.25	88.1
<b>LB</b>	42.6	1263	0.49	21.6	1.28	87.6
<b>SEm±</b>	0.68	20.4	0.01	0.48	0.01	0.31
<b>CD (p ≤ 0.05)</b>	1.95	59.0	0.03	1.39	0.04	0.90
<b>P0</b>	33.7	961.6	0.47	18.1	1.09	79.6
<b>P1</b>	46.8	1290	0.45	22.4	1.41	91.3
<b>SEm±</b>	0.48	14.5	0.01	0.34	0.01	0.22
<b>CD (p ≤ 0.05)</b>	1.38	41.7	0.02	0.98	0.03	0.63
<b>AM0</b>	38.5	1054	0.45	16.1	1.13	81.9
<b>AM1</b>	41.9	1198	0.47	24.5	1.38	89.0
<b>SEm±</b>	0.48	14.5	0.01	0.34	0.01	0.22
<b>CD (p ≤ 0.05)</b>	1.38	41.7	0.02	0.98	0.03	0.63
<b>P × B</b>	S	NS	S	S	NS	S
<b>P × AM</b>	NS	NS	S	S	S	NS
<b>B × AM</b>	NS	NS	NS	NS	NS	S
<b>P × B × AM</b>	NS	NS	NS	NS	NS	S

P0 and P1 means phosphorus @ 0 and 50% RDF respectively; NB, RHB, LB and PB means no biochar, rice husk biochar, lantana biochar and parthenium biochar @ 10 t ha<sup>-1</sup> respectively; AM0 and AM1 means mycorrhiza @ 0 and 5 g pot<sup>-1</sup> respectively. P × B means phosphorus and biochar interaction, P × AM means phosphorus and mycorrhiza interaction, B × AM means biochar and mycorrhiza interaction, P × B × AM means phosphorus, biochar and mycorrhiza interaction. S means significance and NS means non significant.

### Potassium uptake by cob and straw of baby corn

From the data given in table 1, it has been found that application of P1 recorded the highest potassium uptake in cob and straw which exceeded P0 by 24.7% and 13.9%. Effect of application of LB was significant in increasing the potassium uptake of cob and straw. Application of LB showed significantly higher potassium uptake in cob and straw and the values were higher by 3.54% and 8.5%, respectively compared to NB. Lehmann *et al.*, (2003) also reported that K uptake in plant increased with biochar application. The inoculation with AM recorded significant increase in potassium uptake by cob (6.23%)

and straw (6.97%) over AM0. Significant interaction between phosphorus and biochar was observed for potassium uptake in cob and straw. The application of LB+P1 showed higher potassium uptake in cob (62.8 mg pot<sup>-1</sup>) over NB+P0 (49.1 mg pot<sup>-1</sup>) and RHB+P1 showed higher potassium uptake in straw (4.77 g pot<sup>-1</sup>) over NB+P1 (3.76 g pot<sup>-1</sup>). Significant interaction between phosphorus and mycorrhiza was observed for potassium uptake in cob and straw. The application of P1+AM1 showed higher potassium uptake in cob by (62.8 mgpot<sup>-1</sup>) and straw (4.87 g pot<sup>-1</sup>) over P0+AM0 (47.4 mg pot<sup>-1</sup>) and P0+AM0 (4.04 g pot<sup>-1</sup>) respectively. Enhanced acquisition of Ca and Mg and usually K has been noted for various



plants colonized with different arbuscular mycorrhizal fungi isolates compared to nonmycorrhizal plants (Siqueira *et al.*, 1990). Significant interaction among phosphorus, mycorrhiza and biochar was observed for potassium uptake in straw. The application of PB+P1+AM1 showed higher potassium uptake in cob (4.97 g pot<sup>-1</sup>) over NB+P0+AM0 (3.56 g pot<sup>-1</sup>). The biochar has ability to retain nutrients thereby reducing leaching resulting in increased nutrient uptake by plants and so higher production (Glaser *et al.*, 2002).

### **Sulphur uptake by cob and straw of baby corn**

Data presented in table 2 indicated that the application of AM1 resulted in significantly higher sulphur uptake of cob and straw and the increments were 8.82% and 13.7%, respectively over AM0. For mycorrhiza treated maize grown in acidic soil, *Glomus intraradices* enhanced S acquisition over nonmycorrhiza treated plants more than *Glomus etunicatum* and *Glomus diaphanum* plants (Clark and Zeto, 1996). *Glomus etunicatum* inoculated switchgrass had 2-fold higher S uptake than uninoculated switch grass (Clark *et al.*, 1999). Effect of application of biochar was found to be significant on sulphur uptake of cob and straw. The application of P1 showed significantly higher sulphur uptake in cob and straw as compared to P0. Significant interaction between phosphorus and biochar was observed for sulphur uptake in cob only. The highest uptake of sulphur in cob was obtained with the application of LB+P1 (51 ppm) compared to NB+P0 (30 ppm).

### **Zinc uptake by cob and straw of baby corn**

A critical observation of the data given in table 2 indicates that the effect of phosphorus on zinc content in cob was non-significant.

Application of P1 significantly decreased Zn content in cob by 3.08% as compared with P0. Acquisition of Zn and Cu in shoots was reported to be reduced when P was increased in soil (Lambert and Weidensaul, 1991). Raju *et al.*, (1990) found that enhanced acquisition of these nutrients occurred even at high levels of soil P. This may happen as phosphorus increased plant dry matter yield, so over all Zn uptake of straw also increased. Application of biochar increased the zinc uptake significantly over control. Application of LB showed significantly higher zinc uptake in cob and straw which exceeded NB by 17.3% and 18.5%, respectively. Inoculation with AM1 significantly increased the zinc uptake in cob exceeding AM0 by 4.43%. AM1 also significantly increased straw Zn uptake (24.5 mg/pot) as compared to no inoculation of AM (16 mg pot<sup>-1</sup>). Significant interaction between biochar and phosphorus was observed for zinc uptake in cob as well as in straw. The highest cob uptake of zinc was obtained with the application of LB+P1 (51.1 mg pot<sup>-1</sup>) whereas the lowest zinc uptake was recorded with the treatment NB+P0 (30.5 mg pot<sup>-1</sup>). These findings are similar to those of Rondan *et al.*, (2007) who have reported increase in zinc uptake increases with biochar addition in common beans as it increases the activity of rhizobacteria. Significant interaction between arbuscular mycorrhizal fungi and phosphorus was observed for zinc uptake in cob and straw both. Arbuscular mycorrhizal treatment without phosphorus increased cob Zn uptake (0.50 mg pot<sup>-1</sup>) in compare to the application of phosphorus (0.45 mg pot<sup>-1</sup>). In case of straw, combined application of arbuscular mycorrhizal fungi and P1 had the advantage over no application of phosphorus and arbuscular mycorrhizal fungi. The contribution of hyphae to enhanced acquisition of Zn in *Glomus mosseae* maize was calculated to be 48% of the total plant Zn in one study (Kothari *et al.*, 1991) and from 16 to 25% in another (Kothari *et al.*, 1991).

Compared to non mycorrhizal treated plants, root Zn was 22% higher in AM plants, indicating that Zn transport from hyphae to roots and from roots to shoots was enhanced (Kothari *et al.*, 1991).

### **Iron uptake by cob and straw of baby corn**

Data presented in table 2 indicated that iron uptake in cob and straw with application of P1 was significantly higher by 28.9% and 14.6%, respectively than that recorded with P0. Application of biochar significantly increased the iron uptake. Inoculation with AM1 significantly increased the iron uptake in cob and straw by 21.8% and 8.71%, respectively over AM0. Significant interaction between mycorrhiza and phosphorus was observed for iron uptake by cob. Arbuscular mycorrhizal fungi with phosphorus application increased the cob Fe uptake ( $1.57 \text{ mg pot}^{-1}$ ) as compared to P0 ( $1.0 \text{ mg pot}^{-1}$ ). Mycorrhizal treated plants grown in alkaline soil exhibited greater differences for Fe acquisition than those grown in acidic soil, and some arbuscular mycorrhizal fungi isolates were more effective in enhancing Fe acquisition than others (Clark and Zeto, 1996). Significant interaction between biochar and phosphorus was observed for iron uptake in straw. Combined application of PB+P1 increased cob Fe uptake ( $92.8 \text{ mg pot}^{-1}$ ) as compared to NB+P0 ( $71.5 \text{ mg pot}^{-1}$ ). Significant interaction between biochar and mycorrhiza was observed for iron uptake in straw. Combined application of PB+AM1 increased baby cob Fe uptake ( $921 \text{ mg pot}^{-1}$ ) as compared to NB and AM0 ( $76.2 \text{ mg pot}^{-1}$ ). Significant interaction among mycorrhiza, biochar and phosphorus was observed for iron uptake in straw. Combined application of PB+P1+AM1 increased cob Fe uptake ( $96.8 \text{ mg pot}^{-1}$ ) as compared to NB+P0+AM0 ( $66.5 \text{ mg pot}^{-1}$ ). Iron acquisition has been associated with root exudation of substances like phytosiderophores (strategy II graminaceous

plants) (Marschner and Römheld, 1994) and organic acids such as citric, oxalic, and phenolics (strategy I dicotyledonous plants) (Marschner, 1995).

In conclusion application of lantana biochar along with 50% recommended dose of phosphorus and arbuscular mycorrhizal inoculation was found to be most effective in enhancing the N, P, K, S, Zn and Fe uptake over other integrated treatments.

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