

Integration of Biochar with Organic and Inorganic Sources of Phosphorous for Improving Maize Productivity

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ABSTRACT
A field trial was carried out at New Developmental Farm of The University Agriculture, Peshawar, Pakistan during summer 2012, in order to study the integration of biochar with organic and inorganic sources of phosphorous for improving maize productivity. Therefore the field experiment was conducted in randomized complete block design with split plot arrangement havin three replications. Two levels of biochar (0 and 25 t ha^{-1}) were allotted to main plots, while two organic sources (Farmyard manure (FYM) and poultry manure (PM)) and the ratios of (organic vs SSP) were applied to the field in such a combination that 100%, 75%, 50% and 25% of P was obtained from the organic sources and the rest was compensated from the inorganic source SSP and vice versa for making a total of 100 kg P ha^{-1}. Plots treated with 25 tones biochar ha^{-1} produced maximum grains ear^{-1} (366), 1000 grains weight (285.6 g) and grain yield (4013 kg ha^{-1}) as compared with control plots. Both organic sources (Farmyard manure (FYM) and poultry manure (PM)) had not significant effect on all parameters. The ratios showed that integration of phosphorous 50 % from organic and 50 % from inorganic phosphorous had maximum ear plant^{-1} (1.31), grains row^{-1} (27), rows ear^{-1} (14.8), grains ear^{-1} (374), 1000 grains weight (295.2) and grain yield (4330 kg ha^{-1}). The interaction between biochar, organic sources and the ratios of (organic vs SSP) revealed that application of biochar at the rate of 25 t ha^{-1} with 50 % from organic and 50 % from inorganic phosphorous had maximum 1000 grains weight and grain yield. For greater improvement in the yield and yield component of maize it is recommended that plots treated with 25 tones biochar ha^{-1} and integrated use of phosphorous 50% from organic and 50% from inorganic source seems to be the best choice for maize grower in the agro-climatic condition of Peshawar valley.
Keywords: Maize (***Zea mays*** L.)*, biochar, FYM, PM, ratios (organic vs SSP), grain yield, yield components*

INTRODUCTION

Maize (*Zea mays* L.) is an exhaustive and multipurpose cereal crop that provides food for human, feed for animals, and raw material for the industries (Khaliq *et al*., 2004). In 2010 it was cultivated on an area of 981 ha with a total production of 3658 tones in Pakistan while during the same season its area of cultivation and production in Khyber Pakhtunkhwa was 512 ha and 1468 tones respectively (MINFAL 2010). Maize belongs to the group of crops which has high growth rate, producing large quantity of organic material and therefore, has a higher demand of phosphorus.

Phosphorus is one of the major plant nutrients. It contributes to plant biomass production as a macronutrient (Goldstein et al., 1988). It is a fundamental nutrient for plants and animals, because of its essential role in many physiological and biochemical processes (Mathews et al. 1998). It is a structural component of nucleic acids, many co-enzymes, phospho-proteins and phospho-lipids (Ozanne, 1980). P is one of the least available mineral nutrients in most of the cropping systems all over the world (Takahashi and Anwar, 2007). Indeed, the second most important nutrient required by plants, the phosphorus is highly inaccessible for most of the plants (Holford, 1997). Soils of Pakistan are generally alkaline and calcareous in nature, where maize crop mostly suffers from P deficiency. About 80 to 90 % soils from arid and semiarid regions of the world, including Pakistan, are deficient in available phosphorus (Memon et al., 1992). The use of organic materials as fertilizers for crop production has received attention for sustainable crop productivity (Naeem *et al.,* 2009). Organic manures alone cannot supply sufficient P for optimum growth but have certain characteristics that increase the availability of P to the crops (Reddy et al.,1999). To achieve sustainability in high production systems, only the integrated use of organic and inorganic fertilizers can play a vital role (Gosh *et al.*, 2004). Application of inorganic P fertilizer in combination with farm yard manure (FYM) was found effective in enhancing the effectiveness of inorganic P fertilizers (Organic manures may convert relatively unavailable native and residual P to inorganic available form (Whalen and Chang, 2001). The use of organic sources like farmyard manure produced equivalent or increased plant biomass and grain yield of maize as the application of mineral fertilizers alone (Khanum et al., 2001). Poultry manure (PM) also has long been recognized the most desirable organic fertilizer. It improves soil fertility by adding both major and essential nutrients as well as soil organic matter which improve moisture and nutrient retention (Farhad et al. 2009).

Biochar is variable-charge organic matter, high surface area, highly porous, that has the potential to increase soil water-holding capacity, cation exchange capacity (CEC), surface sorption capacity and positive effects on soil microorganisms when added to soil (Liang et al, 2006). Biochar application to soils has an estimated residence time which ranges from hundreds to thousands of years (Lehmann 2007). Such a remarkable retentive property of charcoal is also one of the major factors ascribed for better crop production with inorganic or organic fertilizer plus charcoal combinations over inorganic or organic fertilization alone (Steiner et al., 2007). Amending soil with charcoal in soil is not a new agricultural practice. However, how charcoal improves soil fertility has received attention among scientists only recently. Enriching soils with charcoal improves crop productivity and various soil properties (Glaser et al., 2002). Biochar as soil amendment needs to be studied in different climate and soil types (Steiner et al. 2007). There fore this research is design to find out the integration of biochar with organic and inorganic sources of P for improving maize productivity.

MATERIALS AND METHODS

This research was carried out at New Developmental Farm of The University of Agriculture, Peshawar (34^{o} 00' N, 71^{o} 30' E, 510 MASL) Pakistan during kharif 2012. The experiment was carried out in randomized complete block design with split plot arrangement having three replications. Two levels of biochar (0 and 25 t ha^{-1}) were allotted to main plots, while two organic sources (Farmyard manure (FYM) and poultry manure (PM)) and ratios (organic vs SSP) were applied to the field in such a combination that 100%, 75%, 50% and 25% of P was obtained from the organic sources and the rest was compensated from the inorganic source SSP and vice versa for making a total of 100 kg P ha^{-1} were allotted to sub plots. A sub plot size of 4 m x 3.5 m was used. Each sub plot consists of 5 rows having 70 cm row-to-row distance. Both the organic and inorganic P fertilizers were applied one week before sowing of maize crops. A sample of the FYM and PM were analyzed to determine the N and P content, which was then used to compute the amount of the material to add to the respective plots. The analyzed sample of FYM contain (0.71%) N and (0.45%) P while PM contains (2.12%) N and (1.92%) P. Nitrogen in the form of urea was applied at the rate of 150 kg ha^{-1}, half dose was applied at sowing time and the remaining half was applied at 6th leaf stage. Crop was sown in the 4th week of June at seed rate of 30 kg ha^{-1} using maize cultivar Azam. Number of ears plant^{-1} was counted in ten plants selected randomly in each subplot. Number of grains row^{-1} five ears were selected from each plot number of grain row^{-1} were counted and averaged. Number of row ear^{-1} five ears were selected from each plot number of row ear^{-1} were counted and averaged. Number of grains ear^{-1} was recorded by selecting five ears randomly from each plot counted no of grains ear^{-1} and averaged. Thousand grains weight (g) were recorded from three seed lot and weighted with the help of electronic sensitive balance. Three central rows in each sub plot were harvested, sun dried and threshed. Grain weight was taken with the help of electronic balance and then converted into kg ha^{-1} by the following formula.

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Grains weight in four rows (kg)} \times 10{,}000\ \text{m}^2}{\text{No of rows x Row length x R-R}}$$

Data collected were analyzed statisticallyly according to the procedure relevant to RCB design. Upon significant F-Test, LSD test was used for mean comparison to identify the significant components of the treatment means (Jan et al., 2009).

RESULTS AND DISCUSSION

Ears plant^{-1}

Data regarding number of ears plant^{-1} are presented in table 1. Analysis of the data showed that ratios (organic vs SSP) and control vs rest had significantly affected ears plant^{-1} while biochar, organic sources and all the interaction had not significant effect on ears plant^{-1}. The mean values of control vs rest contrast indicated that rest plots resulted in higher number of ears plant^{-1} (1.26) as compared with control plots which produced (1) ears plants^{-1}. Plots which received total of the phosphorus 50% from organic and 50% inorganic source produced higher (1.31) number of ears plant^{-1} while lower (1.22) number of ears plant^{-1} was produced when plots get 100% of phosphorus from organic source. The possible reason might be that, with application of poultry manure plus mineral fertilizer, plants received large amount of nutrients throughout their growth period and nourished properly which resulted in higher number of ears plant^{-1}. These results are in accordance with those of Shah and Arif (2000) who also observed that number of cobs plant^{-1} increased with the addition of organic and inorganic fertilizers. Shah et al., (2009) also reported that combination of organic and inorganic fertilizer increased number of ears plant^{-1}.

Grains row^{-1}

Data presented in table 1 indicated that the ratios (organic vs SSP), control vs rest and the interaction of B x R had significantly affected grains row^{-1} while organic sources and levels of biochar had no significant effect on grains row^{-1}. The mean values of control vs rest contrast indicated that rest plots resulted in higher (25.8) grains row^{-1} as compared with control plots which produced (21) grains row^{-1}. Ratios indicated that plots which received half of the P 50% from organic and 50% inorganic sources resulted higher (27.0) number of grain rows^{-1} while lower (24.8) number of grains row^{-1} was produced when plots get 100% of phosphorus from organic source. The increase in number of grains row^{-1} may be due to integrated used of phosphorus from both organic and inorganic sources. These results are also similar to the findings of Zhang et al. (1998) who reported that precise application of manure and mineral fertilizer to maize crop can be as effective as commercial N fertilizer for yield response. Interaction of biochar and the ratios showed in fig. 2 that grains row^{-1} increased significantly as the level of biochar increase from 0 t to 25 t ha^{-1} with integrated used of phosphorus 50% from organic and 50% from inorganic source SSP further increased in inorganic source SSP grains row^{-1} sharply decreased.

Rows ear^{-1}

Statistical analysis of the data indicated in table 1 that ratios (organic vs SSP) and control vs rest had significantly affected rows ear^{-1} while biochar, organic sources and all the interaction had not significant effect on rows ear^{-1}. Control plots resulted in lower number of rows ear^{-1} (11.6) as compared with rest plots which produced (13.9) rows ear^{-1}. Ratios indicated that plots which received half of the P 50% from organic and 50% inorganic sources resulted higher (14.8) number of rows ear^{-1} while lower (13.2) number of rows ear^{-1} was produced when plots get 100% of phosphorus from organic source. These results are also similar to the findings of Zhang et al. (1998) who reported that precise application of manure and mineral fertilizer to maize crop increased (14%) rows ear^{-1} as compared with those plots which obtained 100% of phosphorus from organic source.

Grains ear^{-1}

Data presented in table 1 indicated that the levels of biochar, ratios (organic vs SSP), control vs rest and the interaction between B x R had significantly affected grains ear^{-1} while organic sources had not significant effect on grains ear^{-1}. Plots treated with biochar 25 t ha^{-1} produced maximum (366) number of grains ear^{-1} as compared with control plots. These results are in agreement with Joseph et al. (2009) who studied that significant differences in grains ear^{-1} were recorded among biochar levels. Less (320) grains ear^{-1} were noted in control plots when biochar levels were enhanced from 0 to 30 t ha^{-1}, number of grains increased from 220 to 370 ear^{-1}. The mean values of control vs rest contrast indicated that rest plots resulted in higher (358) grains ear^{-1} as compared with control plots which produced (325) grains ear^{-1}. Ratios indicated that plots which received half of the P 50% from organic and 50% inorganic sources resulted higher (374) number of grain ear^{-1} while lower (346) number of grains ear^{-1} was produced when plots obtained 100% of phosphorus from organic source. The increased in the number of grain ear^{-1} might be due to the synergistic effect of organic and inorganic phosphorous fertilizers while grains ear^{-1} was observes in organic source of phosphorous might be due to the low mineralization of nutrients from organic source Ayoola and Adeniyan (2006). Interaction of biochar and the ratios showed in fig. 2 that grains ear^{-1} increased significantly as the level of biochar increase from 0 t to 25 t ha^{-1} with integrated used of phosphorus 50% from organic and 50% from inorganic source SSP further increased in inorganic source SSP grains ear^{-1} sharply decreased.

Thousand grains weight (g)

Mean values in table 1 showed that 1000 grains weight was significantly increase with increasing biochar levels. Maximum (285.6 g) grains weight was produced when plots treated with 25 tones biochar ha^{-1} while minimum (250.5 g) grains weight was recorded in control plots. These results agree with those of Inyang et al. (2010) who reported that increasing biochar application significantly increased the 1000 grains weight. The mean values of control vs rest contrast indicated that rest plots resulted in heavier (278.6 g) grains weight as compared with control plots which produced (245.5 g) grains weight. Ratios indicated that plots which received half of the P 50% from organic and 50% inorganic sources resulted heavier (295.2 g) grain weight while lower (256.5 g) grains weight was produced when plots obtained 100% of phosphorus from organic source. These result support the finding of zafar et al 2011, they reported that highest 1000 grain weight was recorded where combined application of phosphorous 50% from inorganic and 50 % from organic source was carried out, they also report that 1000 grain weight in integrated treatments of PM with FYM and compost were also higher than their sole application. Interaction between B x S x R indicated in fig. 3 that 1000 grains weight increased significantly with increasing biochar level from 0 t to 25 t ha^{-1} with both organic sources. But a linear increased for 1000 grains weight was recorded when supplied biochar 25 t ha^{-1} and integrated used of phosphorus 50% from organic (FYM or PM) and 50% from inorganic source SSP further increased in inorganic source SSP 1000 grains weight sharply decreased.

Grain yield (kg ha^{-1})

Mean value of biochar levels indicated that plots treated with 25 t ha^{-1} produced maximum (4013 kg ha^{-1}) grain yield while minimum (3660 kg ha^{-1}) grain yield was produced in control plots. Similar results were reported by Hammes and Schmidt. (2009) who reported that biochar addition to soils can stimulate microorganism activity in the soil which is the primary source of nutrients as result grain yield is increased as compared with control plots. The mean values of control vs rest contrast indicated that rest plots resulted in maximum (3880 kg ha^{-1}) grain yield as compared with control plots which produced (2904 kg ha^{-1}) grain yield. Ratios indicated that plots which received half of the P 50% from organic and 50% inorganic sources resulted maximum (4330 kg ha^{-1}) grain yield while minimum (3517 kg ha^{-1}) grain yield was produced when plots obtained 100% of phosphorus from organic source. The possible reason for increased in the grain yield might be due to the balance supply of nutrient from organic and inorganic source of phosphorous. These result confirm the finding of Zafar et al. (2011) who reported that use of (50%) mineral phosphorous applied with poultry manure (50%) resulted in higher maize grain yields when compared to 100% inorganic phosphorous. This is also in agreement with finding of Adamu and Leye., (2012). They reported that integrated use of poultry dropping and inorganic fertilizer resulted in higher maize grain yield. Interaction between B x S x R indicated in fig. 4 that grain yield increased significantly with increasing biochar level from 0 t to 25 t ha^{-1} with both organic sources. But a linear increased for grain yield was recorded when supplied biochar 25 t ha^{-1} and integrated used of phosphorus 50% from organic (FYM or PM) and 50% from inorganic source SSP further increased in inorganic source SSP grain yield sharply decreased.

Table I. Number of ears plant^{-1}, grains row^{-1}, rows ear^{-1}, grains ear^{-1}, thousand grains weight (g) and grain yield (kg ha^{-1}) of maize as affected by integration of biochar with organic and inorganic sources of phosphorus

Treatment	Ear plant^{-1}	Grains row^{-1}	Rows ear^{-1}	Grains ear^{-1}	1000 grains weight (g)	Grain yield (kg ha^{-1})
Biochar (t ha^{-1})						
0	1.26	25.7	13.9	353b	250.5b	3760b
25	1.27	25.9	14.1	366a	285.6a	4013a
Control vs Rest						
Control	1.00b	24.0b	12.6b	334b	252.5b	2904b
Rest	1.26a	25.8a	13.9a	358a	278.6a	3880a
Organic Sources						
FYM	1.26	25.8	14.0	357	279.8	3875
Poultry manure (PM)	1.27	25.9	14.0	362	278.3	3898
Ratios (Organic vs SSP)						
100:0	1.22c	24.8c	13.2c	346c	259.5c	3517c
75:25	1.26b	25.7b	13.9b	357b	278.3b	3847b
50:50	1.31a	27.0a	14.8a	374a	295.2a	4330a
25:75	1.27b	25.9b	14.1b	360b	283.2b	3851b
LSD (0.05)	0.03	0.73	0.60	10.76	8.2	116.2
Interaction						
B x S	ns	ns	ns	ns	ns	ns
B x R	ns	*	ns	*	ns	ns
S x R	ns	ns	ns	ns	ns	ns
B x S x R	ns	ns	ns	ns	*	*

Means in the same category followed by different letters are significantly different at

P ≤0.05 levels. ns = non-significant

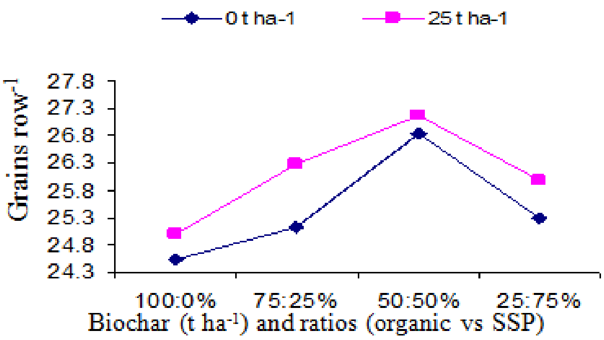

Fig. 1. Grains row^{-1} of maize is affected by Biochar and ratios (organic vs SSP).

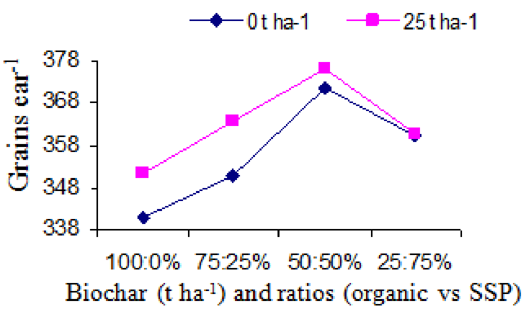

Fig. 2. Grains ear^{-1} of maize is affected by Biochar and ratios (organic vs SSP).

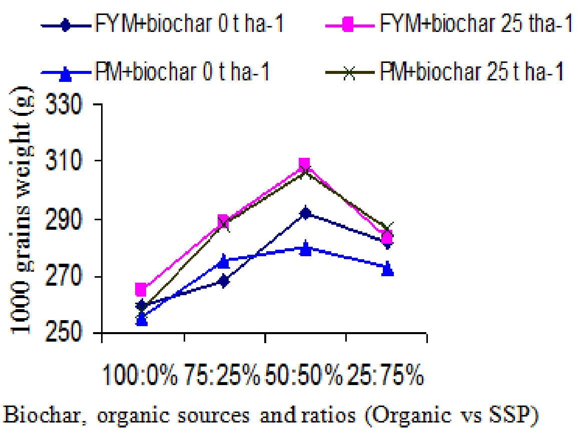

Fig. 3. 1000 grains weight of maize is affected by biochar, organic sources and ratios.

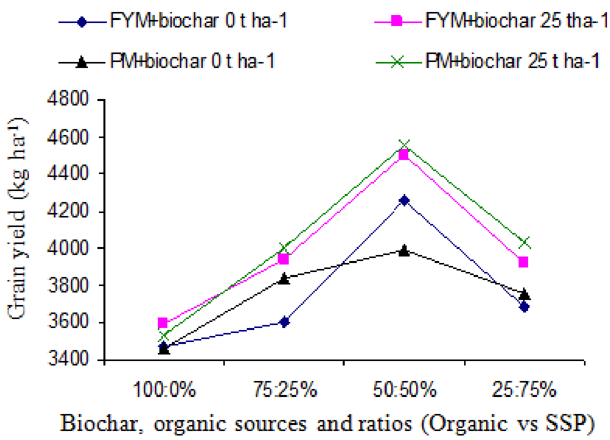

Fig. 4. Grain yield of maize is affected by biochar, organic sources and ratios.

CONCLUSION AND RECOMMENDATIONS

The results obtained from the present study indicated that application of biochar at the rate of 25 t ha^{-1} and integrated use of phosphorous 50% from organic (FYM or PM) and 50% from inorganic source SSP increased the yield and yield components of maize as compared with either sole application of organic and inorganic phosphorus sources. The results of the present study can be used for better P management practices to improve maize productivity. Plots treated with biochar 25 t ha^{-1} and integrated use of phosphorous 50% from organic (FYM or PM) and 50% from inorganic source SSP is recommended for improving yield and yield components of maize under the conditions of the current study area.

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