INTEGRATION OF ORGANIC AND INORGANIC NUTRINTS SOURCES FOR IMPRING MAIZE YIELD AND SOIL PROPERTIES

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ABSTRACT

Incorporation of organic sources of nutrients in agriculture field has the potential to be a major factor in maintaining soil fertility and productivity. The present experiments were designed to evaluate the effect of different organic (biochar, legumes residues and humic acid) and inorganic amendments (NPK) on the growth and yield of maize and soil physico-chemical properties. The experiments consisted of organic and inorganic amendments namely: (1) Biochar (5 and 10 ton ha^{-1}), (2) legumes residues (5 and 10 ton ha^{-1}), humic acid (5 kg ha^{-1}) and NPK (full and half dose). A controlled treatment was included in the experiments. All the treatments were replicated three times in RCB design at New Developmental Farm of the University of Agriculture Peshawar Pakistan during summer 2018-2019. Maize variety Azam and hybrid CS-220 were used in the experiment. Data were recorded on plant height, thousand grain weight, number of grains ear^{-1}, grain yield, and biological yield, soil organic C, soil total N and soil P after maize harvest. All the growth, yield and soil parameters were significantly affected by different soil amendments over control. During the course of the study it was noted that BC in combination with legumes residues and full doe of NPK increased maize thousand grain weight by 16% and 23% respectively over control. Moreover, humic acid at the rate of 5 kg ha^{-1} in integration with half NPK increased maize thousand grain weight, grain yield and biological yield by 21%, 18 and 11% respectively which was statistically similar with the integration of humic acid with half NPK and half legume residues. On the other hand, integration of BC or legumes residues with half NPK improved soil P and organic C as compared to sole application of NPK or BC or legume residues. Integration of BC at the rate of 10 ton ha-1 in combination with half NPK resulted in 23 and 27% increase in soil P and C while 9 and 21% increase in soil P and C was observed in plots treated with half NPK and legumes residues. Overall, the integration of organic and inorganic source of nutrients resulted in higher yield and yield components of maize along with positive impact on soil properties and hence its recommended for improving maize yield and soil properties on sustainable basis.

Keywords: Biochar, Maize, Legumes, Yield and Humic acid

INTRODUCTION

Increasing agriculture production on sustainable basis is the pre request of the day and challenge for agriculture scientists. The agriculture productivity is continuously held back due to continuous reduction in soil quality and poor nutrient use efficiency in most of the developing countries (Jones et al. 2013). These problems further aggravate food insecurity in these including Pakistan due to increasing rate of population. Therefore, there is an urgent need of revising the current agro-ecosystem trends in order to correct the high extent of constraints present in the system together with nutrients supply, demand and recycling (Lal2013).Incorporation of organic materials, recycling of the organic nutrients back to the soil and integration of organic and inorganic nutrients is a sustainable approach in improving soil physical, chemical and biological properties (Grimay et al. 2008).

Nitrogen (N) is among the scarcest nutrient required by the plants in larger quantity (Kawabiah et al. 2003) and is mainly concerned with the different growth processes of the plants specially vegetative growth of the crops (Wojnowska et al. 1995). Similarly phosphorus (P) among different macro nutrients is facing the issue of quantitative and qualitative supply worldwide (Cordell et al. 2010).Most of the Pakistan's soils (approximately 90%) are deficient in P and N(Alam et al. 1994). The deficiency of P and N in soils is mostly due to the P fixation in the soils (Otinga et al. 2013) and higher losses of N through plant uptake, leaching or volatilization. There is urgent need to determine measures for increasing efficiency of P and N fertilizers due to alarming boost in the prices of P and N fertilizers in Pakistan. Biochar, a pyrolysed organic matter, is presently gaining importance in sustainable crop production throughout the world. It has the ability to get better soil fertility by improving soil nutrient and water holding capacity and improves soil biological and physical properties (Spokas et al. 2012). It also has the capability to improve soil quality by increasing soil water holding and exchange capacities (AEC/CEC) and availability of nutrients like P, N, calcium and sulfur (Mann 2002).Biochar can increase crop growth at least for short time when applied with other nutrients (Lehmann et al. 2003).

Alleviating nutrient deficiencies for getting higher crop yields through application of higher doses of inorganic fertilizers are neither economically nor agronomically sustainable. Therefore, application of organic manures as fertilizers is gaining attention for increasing crop productivity and soil fertility on sustainable basis (Naeem et al. 2009). Biochar is also an organic amendment, and there is evidence that adding biochar to soil with low P availability in Pakistan increases grain yields and can improve response to inorganic P or N fertilizers (Asai et al. 2009). Biochar itself can have high ion exchange capacity besides directly discharge of soluble P (Liang et al. 2006). Moreover, incorporation of crop residues to agriculture field has the potential to be a primary factor in maintaining soil fertility and productivity particularly in nitrogen and organic matter limiting environments (Ali et al., 2015). In the present day situations, most of the soils are unable to uptake the plant nutrients present in the soil due to various reasons like very acidic or alkaline conditions, dryness, water logging etc. So to overcome, the use of Humic acids is the best solution to promote sustainable agriculture. With the absence of humic acid in soils, the nutrients we apply through fertilizers will be inaccessible to plants, so it's totally a waste of money and time of the farmer. Thus, application of Humic acid play a very important role in nutrient uptake and maize growth (XX et al.,). However, clear experimental evidence to support this view, however, is still lacking. Keeping in view the significance of biochar, humic acid and crop residues and limited information on its role in crop production, the current experiment is designed to evaluate the effect of different organic (biochar, humic acid and crop residues) and inorganic amendments (NPK) on the growth and quality of maize and soil properties of maize.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at New Developmental Farm of the University of Agriculture Peshawar during summer 2018 and summer 2019. The experimental site located at 31°1`21``N, 71°28`5``E has subtropical climate with average annual rainfall of 350 mm most of which occur during August and December. The average temperature in summer is 40°C and winter is 18°C. The soil is silty clay loam and alkaline in reaction and low in organic matter (less than 0.5%). The soil is lacking in most of the macronutrients like N and P (23.72±1.75 and 3.2±0.5 $mg.kg^{-1}$), respectively.

Experimental Materials and Design

The experiment was a randomized complete block design (RCBD) having three replications. The experimental factors included two application rates of biochar i.e. 5 and 10 tons ha^{-1}, crop residues at the rate of 5 and 10 ton ha^{-1}, humic acid at the rate of 2.5 and 5 kg ha^{-1} and NPK at the rate 150, 100 and 60 kg ha^{-1} respectively. Two maize varieties were used in the experiment (Azam and CS-220). Biochar and crop residues were applied two weeks before cowing as per treatment design. A complete summary of the treatments are presented in Table 1. The biochar in partial powder form with small pieces of size less than 2 cm was broadcasted uniformly in the respective treatment plots and mixed in the soil with the help of rotavator.

The plot size was 5 by 4.2 m having well-built bunds around each plot were used in order to avoid dispersal of biochar and organic residues among the plots. The field was thoroughly ploughed with a disc harrow followed by two times ploughing with cultivator along with planking to achieve uniform soil tilth for both crops. Weeding was done twice in the growth season (i.e. 20 and 40 days after emergence) with help of hoe for maize crop. Insecticide (Chloropyrephos) was sprayed in 0.006% concentration to control stem borer attack in maize crop. The maize cultivar 'Azam' and hybrid CS-220 were sown at seed rate of 30 kg ha^{-1} and thinning was done after one week of emergence and uniform plant population of 65000 ha^{-1} was maintained. Data were recorded on thousand grain weight, number of grains per cob, plant height, grain yield, biological yield, grain N content, soil N, C and P content. Four central rows were harvested, sun dried, weighed for recording data on biological yield of maize and wheat crops. The ears of maize were shelled and weighed to record grain yield. The soil organic carbon was determined through

Walkley-Black procedure as described by Nelson and Sommers (1996). The soil P content was determined by AB-DTPA extractable P procedure suggested by Soltanpour and Schwab (1977).

Statistical Analysis

The data were combined over seasons for soil organic carbon, pH, EC and soil P content however data on biological and grain yield of maize and wheat crops were not combined over seasons. The ANOVA techniques suitable for randomized complete block design and combined analysis were used. The least significant difference test was applied when F-test was significant using the procedure described by Jan et al. (2009).

Soil analysis before the start of experiment

Three core samples were randomly taken on the entire field at 0-15cm depths before sowing. The soil samples were bulked, air-dried soon after collection and were passed through 2mm sieved mesh to remove crop residues, stones or earth worms. The mechanical analysis of the soil was done by the hydrometer method (Bouycous, 1951). The percentage of sand, silt and clay was read on a textural triangle to determine the soil texture and percentage of silt, sand and clay in the experimental site. Table 1 presents the physico-chemical properties of experimental site before launching the field experiments.

Table 3.1 Basic soil characteristics (physico-chemical properties) before the start of experiment.

Soil physical properties	Unit	Value at the depth of (0-15cm)
Sand	%	24.39
Silt	%	67.20
Clay	%	8.44
Soil texture Class	-	Silt loam
Soil bulk density	-	0.27
Soil chemical properties		
pH	-	7.6
EC	d Sm^{-1}	0.56
Soil P	mg kg^{-1}	2.18
Sol total N	%	0.045
Sol K	mg kg^{-1}	83.25
Organic matter	%	0.73

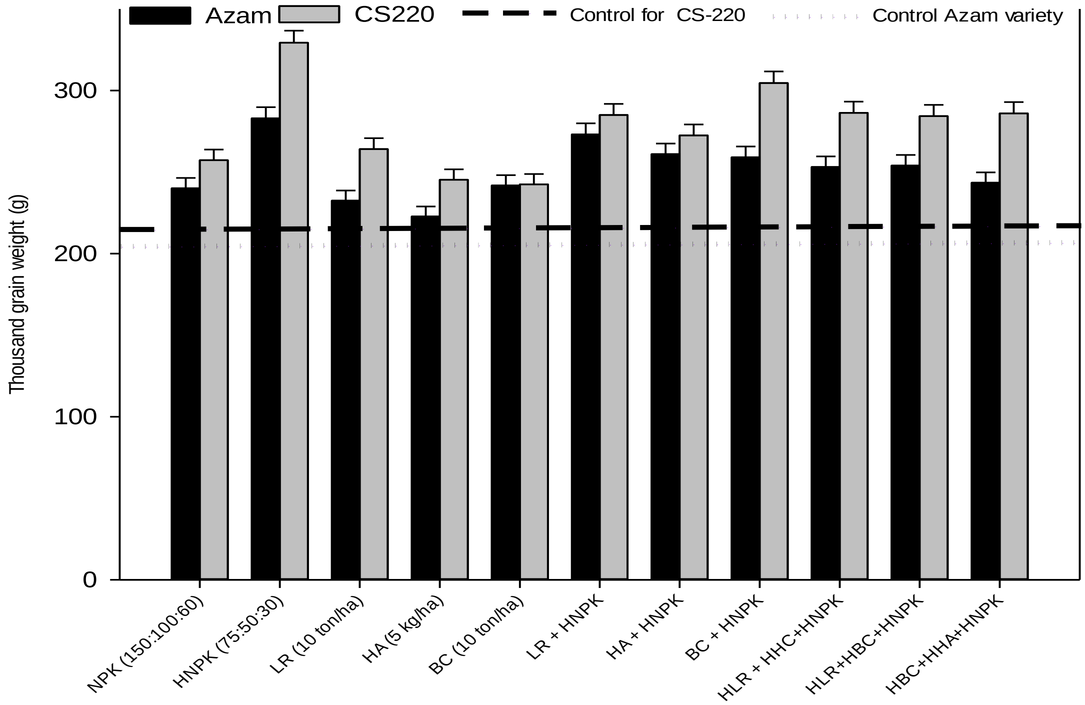
RESULTS AND DISCUSSION

Crop related parameters:

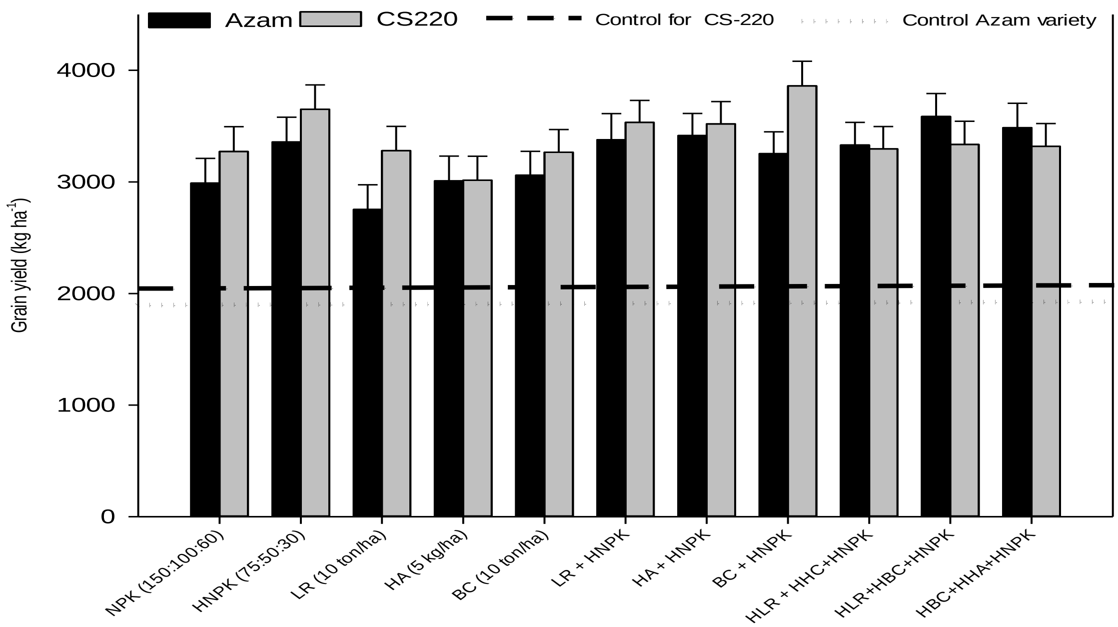
Overall, all amended plots significantly affected growth and yield parameters of maize over control irrespective of variety or hybrid sowing. The influence of treatments on plant height of maize is shown in figure 1. Hybrid CS-220 resulted in taller plants as compared to Azam variety in all treated plots. Among the treatments, interestingly plots treated with half NPK produce taller plants followed plots treated with half residues, half BC and half NPK. Short stature plants were measured in control plots. Significant variation in number of grain ear-1 was found as a result of different soil amendments. Overall, hybrid CS-220 performed superior than maize variety Azam in term of grains ear-1. CS-220 resulted in higher number of grains ear-1 as compared to Azam variety irrespective of the treatment application. However, humic acid in combination with half NPK resulted in higher number of grains ear followed by plots treated with BC in combination with half NPK. Among the treatments, lower number of grains were counted in ears collected from plots treated with NPK only. Furthermore, thousand grains weight of maize were significantly affected by all treatments and hybrid vs variety sowing. Heavier grains were observed in plots sown with CS-220 as compared to variety regardless of soil amendments. However, plots treated with half NPK produced higher grain weight followed by plots treated with BC and half NPK (Figure 2). Grain yield of maize is important parameters and is directly influenced by different soil amendments. The influence of organic and inorganic soil amendments on grain yield of maize is shown in figure 3. Overall, all treated plots resulted in higher grain yield of maize as compared to control plots (Line over the bars shows control values). Similarly, hybrid CS-220 resulted in higher grain yield over Azam variety irrespective of the soil amendments. Moreover, grain yield was higher in plots treated BC in combination with NPK (Full dose). Biological yield of maize is the sum of all photosynthetic activities that is directly affected by nutrients sources and application rate. In the current course of the study, maize biological yield was significantly affected by all treatments over control (Fig.4). Similarly, CS-220 resulted in higher biological yield of maize as compared to Azam variety in all treated plots. Maximum biological yield was recorded in plots treated with BC in combination with NPK sown with CS-220 followed plots treated with half NPK. In control plots, the performance of Azam variety was superior over CS-220. Similar results are reported by (Liu *et al.*,2010) who investigated that the increase in number of grain ear^{-1} by residues amended plots might be accorded to more photosynthetic activities of plant as a result of adequate N supply by these treatments. From these results it can be observed that maize grain weight was increased with residues as compared to control. Higher grain weight from BC and residues treated plots and sole N applied plots may be due to rapid mineralization and timely release of macro and micro nutrients into the soil from FYM. Chan et al. (2007) noted similar results who found increased grain weight with application of organic manures at different rates. The results are also in line with the findings of Kumar and Puri (2001) who concluded that residues in integration with mineral N fertilizer could be a best possible option for improving maize yield and yield components. Integrated N management plots improved biological yield of maize as compared to control. This greater biological yield of maize in integrated N applied plots might be due to the slow release and timely availability of N from organic sources which were less subjected to losses as compared to mineral N which is lost from soil more rapidly. Similarly, Uzoma et al. (2011) reported significant increase in biomass production of maize due to integrated N management production. It also increased maize yield by 32% as compared to control treatments. Wheat produced more tillers when it was planted in high FYM incorporated plots. This increase can be attributed to the beneficial effect of nutrients released from the decomposition of FYM especially nitrogen. The minimum tillers in control plots probably may be due to the exhaustive effects of wheat in terms of nutrient absorption that led to nutrient deficiency and poor crop performance (Ali *et al.,* 2011). In addition, Hussein et al. (2007) have also witnessed that N application at higher rate had promoted growth of most maize parameters and augmented thousand grain weight of maize. The increase in biological yield of maize over control could be attributed to the efficient N uptake by maize and synergetic effect of N on plant growth. Bakht et al. (2007) are of the view that application of N at higher rate might be useful in increasing various growth and yield components of maize crop in Peshawar. The results of Hussain& Shah (2002) also corroborate our results, they argued that nitrogen application convincingly enhanced wheat grain yield. Besides, our findings are in consonance with Bazitov (2000) and Bhagat*et al.,* (2001) who reported higher tillers plant^{-1}, spike length, spikelets spike^{-1} and higher thousand grain weight due to N fertilization and all these components collectively resulted in higher grain yield per unit area of wheat. Likewise, maqsood and Shehzad (2013) attributed higher thousand grain weight to higher rate of N fertilizer than control.

Soil related parameters

Soil physio-chemical properties are directly affected different soil amendments specially the incorporation of crop residues and biochar. Overall, soil carbon was improved by all treatments over control however, higher soil carbon was measured in samples collected from plots treated BC either alone or in combination with crop residues (Fig.5). Similarly, by comparing plots of hybrid with azam variety, it was found that C% was higher in plots sown with CS-220 as compared to Azam variety. The influence of organic and inorganic soil treatment on soil P after maize harvest is shown in figure 6. All soil amendments significantly affected soil P content and higher soil P was recorded in treated plots as compared to control irrespective of nutrients sources. Incorporation of biochar at the rate of 10 ton ha-1 resulted in higher soil P content which was statistically at par with plots treated with legumes residues and half NPK. Among the treated plots, the application of sole NPK resulted in lower soil P after maize harvest. Data regarding soil total N is presented in figure 8. Overall, soil total N after maize harvest was lower in control plots. Moreover, soil total N was negatively affected by biochar application and among the treated plots, lower soil N was recorded in plots treated with BC alone or in combination with other treatments. The higher soil total N was recorded in plots treated with humic acid at the rate of 5 kg ha^{-1} followed by plots treated with legumes residues in combination with NPK. The findings of the experimental results indicated that all studied properties of soil were significantly affected by BC, legumes residues and humic acid application. Application of biochar increased soil C content by 65% after maize harvest. This increase was measured in comparison with no BC plots. Likewise soil total N content was increased by 24% after maize harvest respectively in crop residues treated plots over control. Soil P content is essential plant nutrient and directly affect plant grain yield and plant P uptake. Positive improvement in soil P content was observed by legumes residues, BC and HA application. Plant biomasses have shorter span of life in the soils than biochar, which is more stable. It is believed that biochar have an average residence time of 10,000 years in soils once applied (Swift, 2001), which are several folding higher than any other organic matter. Likewise, Verheijen et al. (2010) are of the view that the residence times for wood biochar in soil is in the order of 10^{-} 1000 times longer than other soil organic matter (Residues and compost). Therefore, biochar supplement to soil can act as a potential sink of carbon. Given a certain amount of carbon that cycles annually through plants, almost half of it can be taken out of its natural cycle and separated in a slower biochar cycle. Several factors such as parent material, soil types and temperature of pyrolysis determine biochar stability (Lehmann and Joseph, 2009).Though, the N and C content in BC is not the fundamental parameter to measure actual availability of these nutrients for microbes to cause de-nitrification or N immobilization, however, still it is believed BC application drastically effect soil N content initially. Gundale and DeLuca (2007) are of the view that few components contained in BC would contribute to nitrogen immobilization, however BC may increase N mineralization by absorbing organic molecules that have high C:N from soil solution. Addition of HA to salt affected and normal soil increased the phosphatase activity under laboratory conditions, which may partially explain for beneficial effect of HA on crop growth (Brannon and Sommers, 1985; Sposito, 1989). Other researchers like Blagodatsky and Richter (1998) and Liang et al. (2003) have also reported that organic matter increases soil microbial biomass and some soil enzymatic activities such as urease, alkaline phosphatase and β-glucosidase. The saline soil showed values of enzymatic activities lower than those observed in other non-saline areas (Tejada et al., 2005), which indicated that biochemical quality 'salting-out' effect which involves a decrease in enzyme release through dehydration, thus altering the enzyme 'catalytic site'. The effect depends on the concentration of the salts and on the chemical composition of the enzymes itself (Garcia et al., 2000). Moreover, if it is accepted that soil salinity disperse the clays contained therein, the extra-cellular enzyme would be less protected and perhaps denatured by proteolysis (Garcia et al., 2000).



NPK= Nitrogen Phosphorus and Potash; LR= Legumes Residues; HA = Humic acid; BC= Biochar
** H means half of the repectives dose of NPK, LR, HA and BC*



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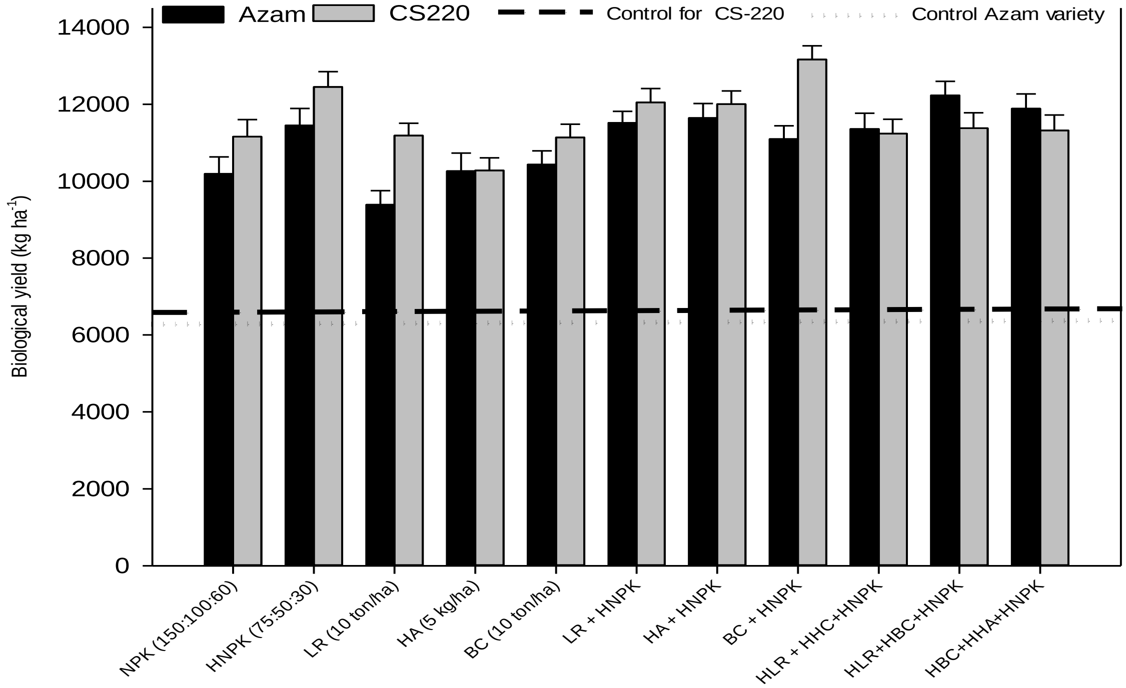

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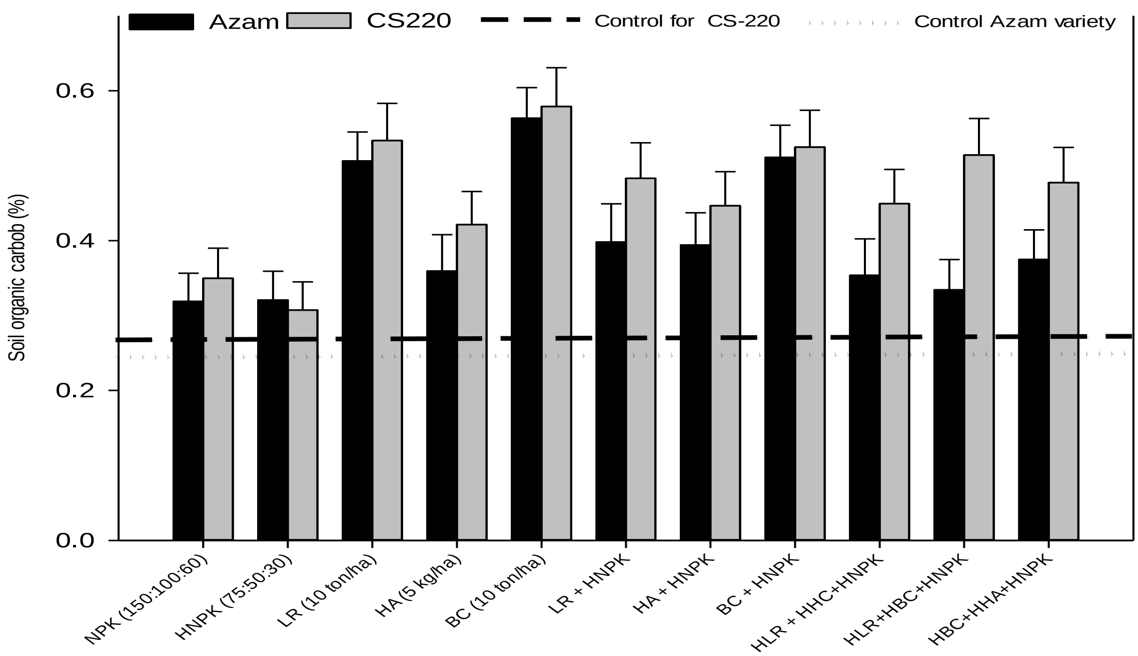

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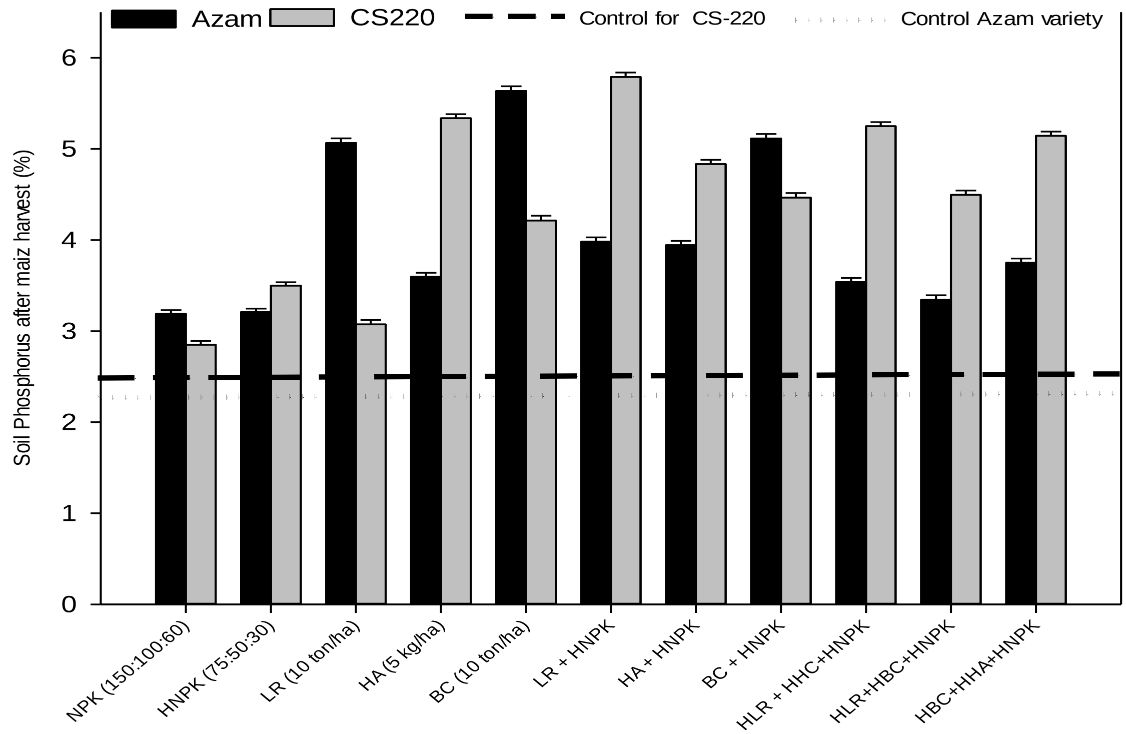

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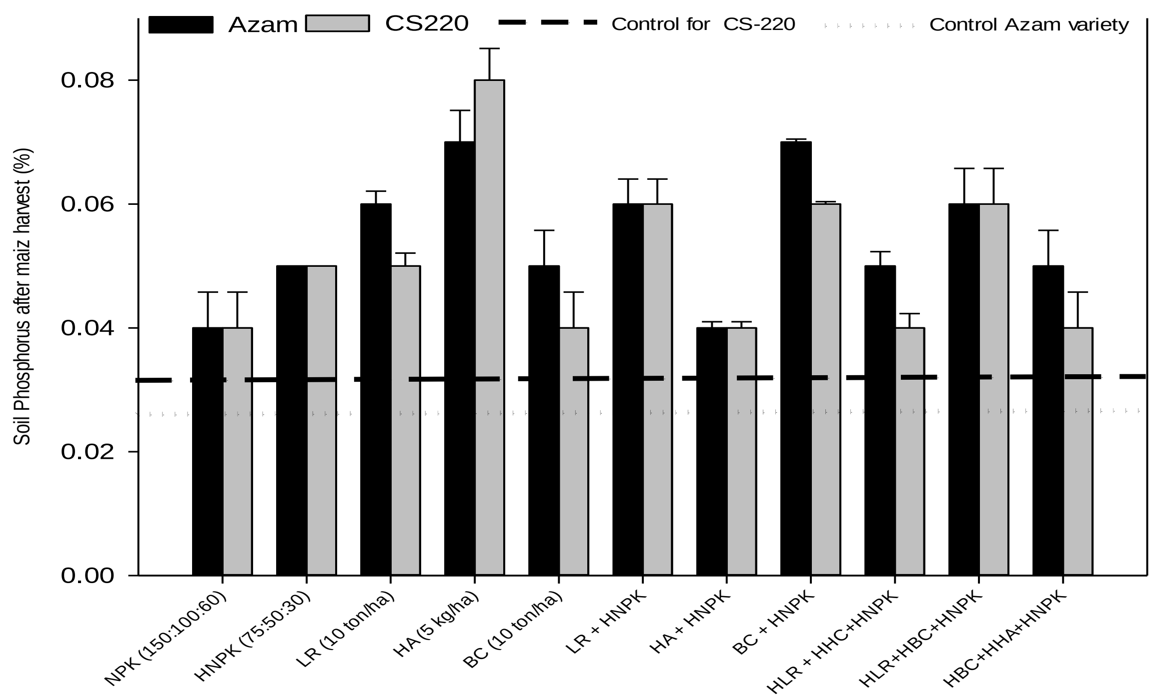

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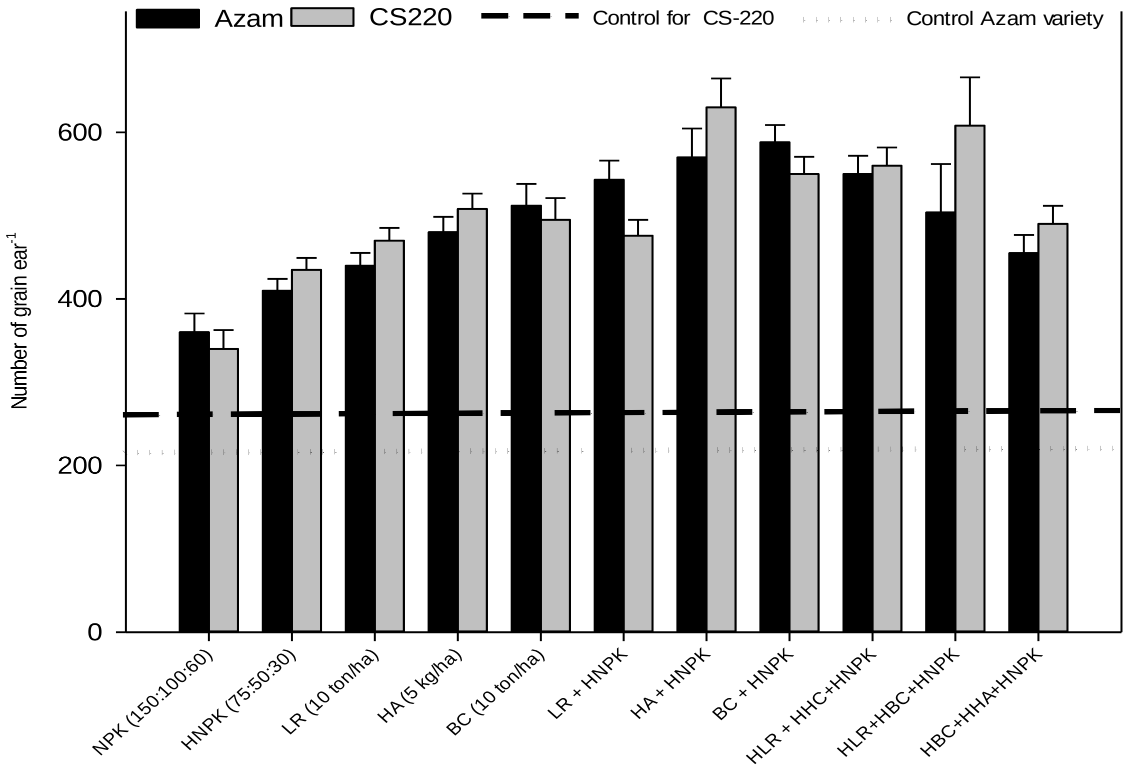

NPK= Nitrogen Phosphorus and Potash; LR= Legumes Residues; HA = Humic acid; BC= Biochar
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CONCLUSION

Upon the results obtained from the experiments, the following conclusions are made:

Application of biochar or crop residues at the rate of 5 t ha^{-1} in combination with half NPK increased maize yield and soil phosphorus and organic matter content. NPK alone at the rate of 150, 100 and 60 resulted in higher plant height and biological yield over control.

Data availability

The data that support the findings of this study are listed in the article and are available from the corresponding authors upon reasonable request.

Declaration of Interest

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. The authors certified that there is no conflicts of interest associated with this publication, and there has been no significant financial support for publishing this work that could have influenced its outcome. As corresponding Author, I conform that the manuscript has been read and approved for submission by all the named authors.

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