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Integrated Nutrient Management using Biochar, Farm Yard Manure and Nitrogen Optimization to Improve Yield Attributes of Maize

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ABSTRACT

The use of organic fertilizers (biochar and FYM) is a possible solution to overcome the negative effects of chemical fertilizers and improve crop productivity and soil fertility on a long-term basis. The present study was conducted to evaluate the Integrated effect of biochar, FYM with nitrogen level for improving the yield and yield components of the maize crop. The experiment was conducted at the Agricultural Research Farm of Abdul Wali Khan University, Mardan, Khyber Pakhtunkhwa, in the summer of 2018. The Randomized Complete Block Design (RCBD) was used, having three replications of each treatment. Biochar and FYM were applied at the rate of 15-ton ha-1, 10-ton ha-1, along with nitrogen at the rate of 75 and 150 kg ha-1. Results of the current study found the maximum grain yield 5461 kg ha-1, plant height 234 cm, number of grains ear-1 549, biological yield 14430 kg ha-1 and ear height (116 cm) was best at FYM, 100 % recommended fertilizer. Conclusively, the use of organic source farmyard manure, biochar, along with inorganic nitrogen fertilizer, enhanced the plant growth and development of the maize crop. Further study is needed to investigate the long-term effects of these organic nutrient sources.

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most important cereal grains due to its improved adaptability to a wide variety of environments (Seleiman *et al.,* 2018). Maize is used both as a food for humans and as feed for animals. It also provides raw materials for industries (Tasneem *et al.,* 2004). Maize grain comprises starch (72%), protein (10%), oil (4.8%), fiber (5.8%), sugar (3.0%) and ash (1.7%) (Chaudhry, 1983). It is a rich source of raw material for the industry, where it is being roughly used for the preparation of derivatives like corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, wax, alcohol and tanning material for the leather industry (Crawford et al.1982). In the KPK farming system, its range is the 2nd after wheat in importance (Ali *et al.,* 2012). The green revolution triggered significant growth in crop production, particularly in cereals like maize, wheat and rice in Pakistan, but it also introduced new challenges to the soil, like soil erosion, soil degradation and reduction in organic matter of the soil. These problems are caused by the continuous use of chemical fertilizers (Farhad *et al.,* 2009).

The average potential yield of maize is greater than our average national yield. Several factors are responsible for the low production of maize in Pakistan. One of the most important limiting factors is the fertility level of the soil. The addition of biochar to soil improves soil fertility on a sustainable basis. Biochar is a rich carbon-based compound and is resilient to microbial degradation. Biochar addition to the soil can decrease the nitrogen (N) leaching and volatilization as well as increase NUE (Hiba *et al.,* 2012). Biochar is formed from the pyrolysis of different organic wastes (Lehmann *et al.,* 2003). The combined application of NPs and both animal and plant biochar has a positive influence on sunflower yield (Mahmoud *et al.,* 2020). The application of biochar is very significant for improving degraded soil. Its application improves physical and chemicals properties of soil such as water holding capacity, permeability, bulk density, cation exchange capacity and retention of nutrients availability (Mahmoud *et al.,* 2019; Rana *et al.,* 2021), It also improves biological properties of soil such as microbial biomass, microbial activity, and microbial population thus increasing crop growth and yield (Glaser *et al.,* 2002; Yuam et al., 2011). The influence of biochar on the physical properties of soil mainly depends on the interaction of biochar by the means of physico-chemical properties of soil as well as other factors such as biochar application management and climatic conditions

(Elshayb*et al.*, 2022; Verheijen *et al.*, 2004).

The eldest and easy accessibility of FYM. Because all the essential nutrients were present and easily mineralizable form (Jat *et al.,* 2012). It plays a significant role in productivity and improving soil fertility. Balanced plant nutrition has a positive effect on soil chemical, physical and biological properties and improves soil structure and water holding capacity (Mohankumar and Gowda, 2010). Entirely depend on FYM or combined with synthetic fertilizer can be efficiently utilized for nutrient supplementation (Rasheed *et al.,* 2003). Application of FYM reduces the total dependence on synthetic fertilizer and in combination with P fertilizer, was found effective in enhancing the efficiency of inorganic P fertilizer (Whalen and Chang, 2001). Sewage sludge produced as high biomass yield as synthetic fertilizers. In addition, it improved growth and quality of biomass (Mahmoud et *al.,* 2013). Sludge–peat mix application resulted in the highest leaf area and biomass accumulation of maize (Mahmoud *et al.,* 2012).

Nitrogen is one of the factors that significantly affect the growth, development, quality, and yield of maize crops. The use of urea for improving the yield of a crop is evident since the green revolution due to its great impact (Eid *et al.*, 2020; Rana *et al.,* 2021; Ali *et al.,* 2011a; Habtegebrial et al., 2007). Urea results in an increased 43-68% grain yield and 25-43% biomass in maize crops (Ogola *et al.*, 2002). Application of Nitrogen improves wheat yield on clay loam soils under a flood irrigation system (Gul *et al.,* 2022). Complete dependence on inorganic fertilizers also increased the cost of production. The extreme use of the inorganic N fertilizer not only hastens soil degradation but also creates many ecological hazards (Ali *et al.,* 2011a; Liu et al., 2010). The integration of organic and inorganic fertilizer applications is necessary not only for improving crop production quality but also to ensure soil sustainability (Jaliya *et al.,* 2008; Lungu et al., 2008). Sewage sludge and synthetic fertilizer applications resulted in higher N uptake in maize (Seleiman and Mahmoud Fathy 2014). Better fertilizer use efficiency was gained under the syndicate use of both organic and inorganic materials in soil (Sharif *et al.,* 2002). JA, SA, Pro, and their combination increased the uptake of essential nutrients, such as N, P, and K, that are required for plant growth (Mahmoud *et al.*,2020).

Keeping the above scenario in view, the present study is conducted to investigate the effect of integrated use of biochar, and farmyard manure with nitrogen levels for improving the yield of maize on a sustainable basis without damaging the environment.

MATERIALS AND METHODS

EXPERIMENTAL LOCATION

A field research was designed on "Integrated use of biochar (BC), farmyard manure (FYM) and nitrogen levels for improving yield and yield component of maize" at the Agriculture Research Farm of Abdul Wail Khan University Mardan, Garden Campus. The experimental design was an RCB design having three replications with 36 plots. The plot size was 3m x 2m. Each plot consists of 4 rows with a row-to-row distance of 75 cm and a plant-to-plant distance of 25cm.

EXPERIMENTAL PROCEDURE:

The experimental field was prepared by ploughing twice, followed by planking to break clods and level the soil surface before sowing. Hybrid maize cultivar CS-220 was sown at the seed rate of 25 kg ha-1 on March 5, 2018, using a seed drill. Nutrient management consisted of Diammonium phosphate (DAP), farmyard manure (FYM), biochar (BC), and urea phosphorus and nitrogen sources. Nitrogen was applied in a split dose (sowing, then upon determining a height of 30 cm in plants, and with the last at tasseling) to maximize nitrogen use efficiency. The first irrigation was done 15 days after sowing, followed by weekly irrigations that were dependent on soil moisture and temperatures.

TREATMENT COMBINATION

The treatment combination of the experiment is mentioned in table 1.

TABLE 1: DETAILS OF TREATMENTS USED IN THIS EXPERIMENT.

T1	**Control**
T2	50 % Recommended Fertilizer (HF)
T3	100% Recommended Fertilizer (RF)
T4	15 t ha^{-1} Biochar (BC)
T5	10 t ha^{-1} Farm Yard Manure (FYM)
T6	15 t ha^{-1} BC + 50% HF
T7	10 t ha^{-1} FYM + 50% HF
T8	15 t ha^{-1}+ 100% RF
T9	10 t ha^{-1} FYM + 100% HF
T10	15 t ha^{-1} BC + 100 t ha^{-1} FYM

T11	15 t ha^{-1} BC + 100 t ha^{-1} FYM + 50% HF
T12	15 t ha^{-1} BC + 100 t ha^{-1} FYM + 100% RF

GROWTH TRAITS

The following traits relating to the growth and yield of the crop were recorded.

PLANT HEIGHT (CM)

Data on plant height were recorded by selecting five plants randomly in each plot. The plant height was measured with the help of a meter rod by measuring the plant from the base of the plant to the tip of the tassel and the average was worked out.

EAR LENGTH (CM)

Data on ear height were recorded by selecting five plants randomly in each plot. The ear height was measured with the help of a meter rod by measuring the ear from the base to the tip of the ear and the average was worked out.

NUMBER OF GRAINS COB^{-1}

Data on the number of grains cob^{-1} were recorded by selecting six eras in each plot and by counting all the grains in each cob and then the average grains cob^{-1} was calculated.

GRAIN YIELD (KG HA^{-1})

Data on grain yield (kg ha^{-1}) was taken by threshing the ears of harvested four central rows and then weighing on a digital balance. The grain yield (kg ha^{-1}) was determined by using the following formula:

$$\text{Grain yield} = \frac{\text{Weight of Grain}}{\text{No. of Rows} \times \text{Row to Row Distace} \times \text{Row Lenght}} \times 1000$$

BIOLOGICAL YIELD (KG HA^{-1})

Data on biological yield (kg ha^{-1}) were recorded by harvesting four central rows on physiological maturity and then kept for sun drying. Complete loss of the green color was used as a sign of maturity. The dried crops were weighed on digital balance. The biological yield (kg ha^{-1}) was calculated using the following formula:

$$ilgicl\ il = \frac{\text{Weight of Plant}}{\text{No. of Row} \times \text{Row to Row Distance} \times \text{Row Lenght}} \times 1000$$

STATISTICAL ANALYSIS

The statistical analysis of data was done by the ANOVA (Analysis of Variance) method for

RCBD design with a factorial experiment. The Means were compared by Least Significant Differences (LSD) 5% test for the significant "F" values. In order to calculate the ANOVA and LSD value statistical software Statistics (8.1) was used.

RESULTS

PLANT HEIGHT (CM)

Figure 1 (a) presents the plant height of maize. The analysis of data shows that the plant height of the maize crop was significantly affected by biochar, farmyard manure and nitrogen fertilizer. The highest plant height was noted in plots treated with BC, FYM, 100 % recommended fertilizer (234 cm), followed by the plots treated with FYM, 100 % recommended fertilizer (231 cm); however, the lowest plant height was noted in control plots (189 cm).

NUMBER OF GRAINS EAR^{-1}

Data related to the number of grains ear^{-1} are shown in Figure 1 (b). The statistical analysis revealed that the number of grains ear^{-1} was significantly influenced by nitrogen fertilizer, FYM and biochar. The maximum grains ear^{-1} was recorded in plots treated with biochar, farmyard manure and 100% recommended fertilizer (549), followed by BC, FYM, 50 % recommended fertilizer (539), while the minimum number of grains ear^{-1} was recorded in control plots (495).

EAR LENGTH (CM)

Data regarding the Ear length of maize are shown in Figure 1 (c). The statistical analysis shows the significant effect of biochar, FYM and N fertilizer on the ear length of the crop. The maximum ear length was noted in plots treated with 100 % recommended fertilizer and farmyard manure (116 cm), followed by BC, 100 % recommended fertilizer (108 cm), which are statistically similar to BC, FYM, 50 % recommended fertilizer. while the minimum ear length was noted in plots treated with biochar (97 cm).

GRAIN YIELD (KG HA^{-1})

Data related to grain yield of maize are presented in Figure 1 (d). The analysis shows that Nitrogen fertilizer, farmyard manure and biochar significantly affect the grain yield of maize. FYM + 100 % of recommended nitrogen fertilizer, biochar + FYM observed maximum grain yield (5461 kg ha^{-1}) followed by FYM, 100 % recommended fertilizer (5257 kg ha^{-1}); however, the minimum grain yield was recorded in plots that were treated with BC, FYM (3997 kg ha^{-1}).

The application of biochar with nitrogen can increase the grain yield.

BIOLOGICAL YIELD (KG HA^{-1})

Data regarding biological yield kg ha^{-1} are shown in Figure 1 (e). The statistical analysis revealed that the biological yield of the maize crop was significantly affected by FYM, N fertilizer and BC. The highest biological yield was recorded in plots that were treated with 100 % recommended fertilizer, BC, FYM (14430 kg ha^{-1}), followed by the plots treated with 100 % recommended fertilizer (13628 kg ha^{-1}), while the lowest biological yield was recorded in control plots (9554 kg ha^{-1}). Biochar has a long-term effect that affects the growth parameters of maize. Delayed maturity, silking, and tasseling affect the economic position of the crop.

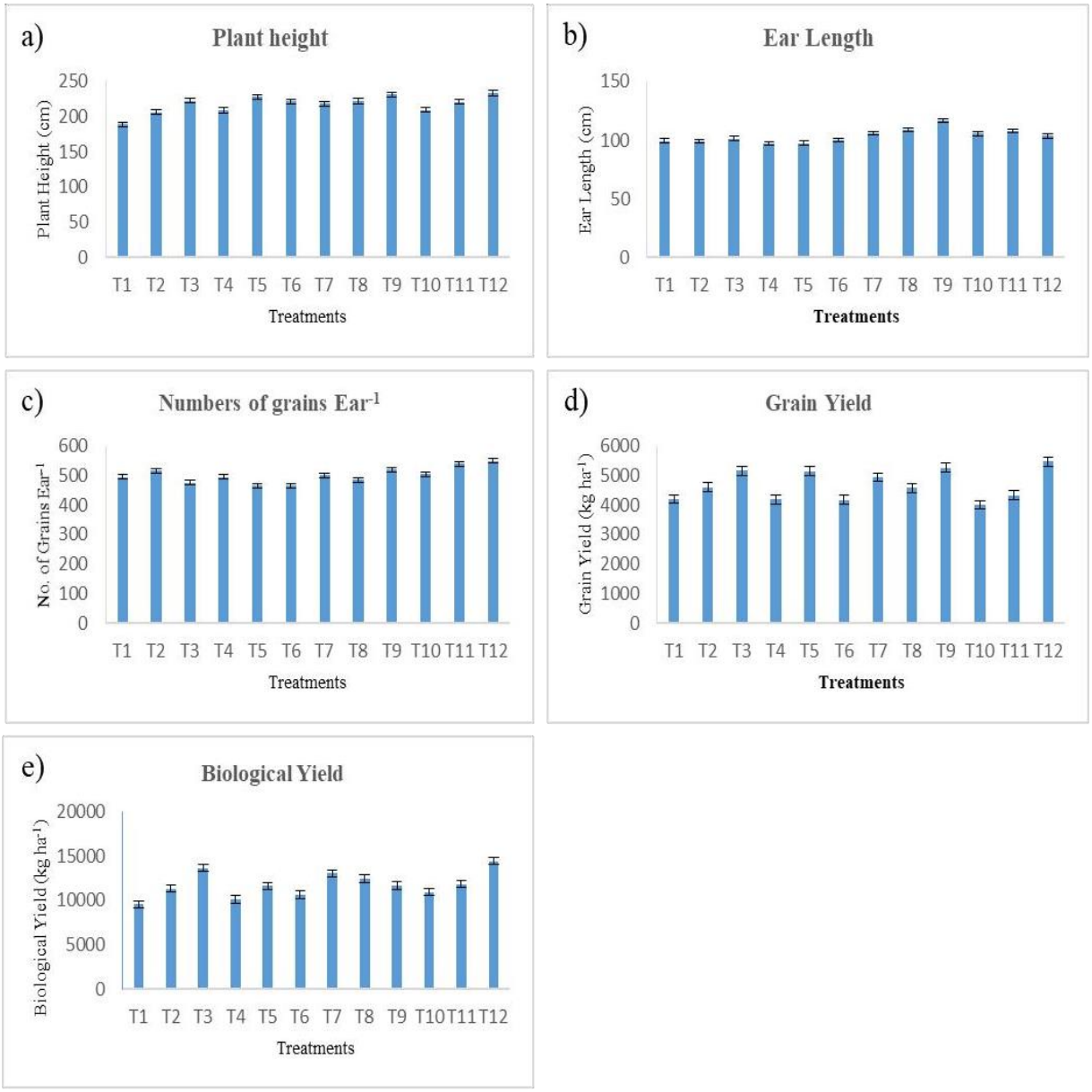

Figure 1: The Graphs represent different yield traits (y-axis) of Maize in response to various treatments. The Graph (a) shows Plant height, (b) Ear length, (c) Grain Yield and (d) Biological Yield , respectively. Furthermore, the treatments are present on (x-axis) following sequence T1= Control, T2= 50% of Recommended fertilizer (HF), T3= 100% of Recommended fertilizer (RF), T4= 15 t ha^{-1} Biochar (BC), T5= 10 ton Farm Yard Manure (FYM), T6= 15 t ha^{-1} BC+50% HF , T7= 10 t ha^{-1} FYM+50% HF, T8= 15 t ha^{-1} Biochar+100% RF, T9= 10 t ha^{-1} FYM+100% RF, T10= 15 t ha^{-1} BC+10 t ha^{-1} FYM, T11= 15 t ha^{-1} BC+10 t ha^{-1} FYM+50% HF, T12= 15 t ha^{-1} BC+10 t ha^{-1} FYM+100% RF.

DISCUSSIONS

The integrated use of organic amendments such as biochar, farm yard manure (FYM) and mineral nitrogen has emerged as a prominent approach for maximizing the growth and yield of maize as well as improving soil health and sustainability (Imran, 2024). Recently, several studies shown that the combination of biochar and nitrogen fertilizer improves the physicochemical properties of soil, i.e., increased organic carbon, nutrient retention, and water-holding capacity, while greatly enhancing maize productivity via large nutrient uptake, dry matter accumulation, and grain yield, as compared to the elicitation of either of the two amendments applied independently (Oladele *et al.,* 2019). Also, the application of FYM with nitrogen fertilizers results in greater improvement of some of the key yield parameters, such as height, cob length, and grain yield, alongside building carbon sequestration within the soil and enhancing its physical properties, especially at greater rates of application (Peng *et al.,* 2021).

In the current study, the increased plant height (figure 1 "a") by the addition of biochar, farmyard manure, and nitrogen fertilizers occurs due to improved soil fertility, nutrient availability, and improved soil physical properties (Guatam *et al.,* 2017). The synergistic effect of these amendments provides a greater environment for maize growth through increasing soil organic matter, nutrient retention, and developing roots, increasing Plant height (Gao *et al.,* 2020). For instance, a field experiment conducted in Western Ethiopia showed that the combined application of maize cob biochar and mineral fertilizer significantly increased the plant height of Maize (Zerssa *et al.,* 2021). Another study confirmed that biochar application not only enhances the nutrient content of the soil but also improves maize plant height due to enhanced nutrient use efficiency and higher soil microbial activity (Song *et al.,* 2019).

Due to increased soil fertility, better nutrient availability, and improved soil physical properties, biochar, farmyard manure, and nitrogen fertilizer application would lead to an increase in the number of grain spikes (figure 1 "b") (Agegnehu *et al.,* 2016). Their combination uses increased organic carbon, total nitrogen, and essential nutrients in the soil, resulting in dry matter and reproductive development in maize (Geng *et al.,* 2019). It has been shown that biochar, when combined with nitrogen fertilizer, improves water retention and nutrient uptake in soil, which further results in an increase in grain yield, yield components (Naeem *et al.,* 2018). A field experiment spanning over three years confirmed that increased application of biochar

resulted in the maximum number of grains per row, along with more overall maize yield (Minhas *et al.,* 2020)

An increase in ear length (figure 1 "c") due to biochar, farmyard manure (FYM), and nitrogen fertilizer application can also be considered from another angle, namely nutrient availability and soil conditions (Singh *et al.,* 2020). Organic amendments like FYM and biochar foster soil structure, moisture retention, and nutrient supplies, all of which promote longer ear formation (Singh *et al.,* 2022). The coordinated release of nutrients through these sources ensures complete ear elongation. In confirmation with these results are observations suggesting that the integrated application of biochar and organic manures greatly enhanced maize ear length due to improved soil fertility and nutrient uptake (Sarwar *et al.,* 2023). Complementary findings also noted that the application of nitrogen fertilizers and organic amendments more positively affected ear size and maize productivity (Gul *et al.,* 2021).

The improvement in maize grain and Biological Yield (figure 1 "d and e") through the concurrent use of farmyard manure, biochar, and nitrogen fertilizer can also be attributed to such improvements in soil fertility, greater nutrient availability, and increased carbon stocks, all benefiting crop growth and productivity (Agegnehu *et al.,* 2017). Studies indicated that biochar incorporated with nitrogen fertilizer considerably improves soil enzyme activity and organic carbon content for higher maize yield relative to sole application (Sun *et al.,* 2023). Some Studies also report on the use of rates of biochar to increase maize biomass by more than 20% from that of the control, particularly when combined with fertilizers and other organic amendments (Naeem *et al.,* 2018). Another report confirmed that biochar and organic inputs used in combination would significantly increase both biomass and grain yields in maize through soil structure improvement and plant nutrition (Arif *et al.,* 2021). Research has similarly found that the integrated use of biochar and nitrogen fertilization improves soil physicochemical properties and crop yields above and beyond either one alone (Naeem *et al.,* 2018).

CONCLUSION AND RECOMMENDATION

The current study concluded that application of 15 t ha^{-1} biochar, 10 t ha^{-1} FYM and 150 kg ha^{-1} nitrogen fertilizer has shown a prominent effect on the yield and yield components of the maize crop. As compared to sole nitrogen. Plant height, grain ear $^{-1}$, Biological and grain yield

kg ha^{-1} were best at BC, FYM, 100 % recommended fertilizer. while ear height was noted best at BC, FYM, 50 % recommended fertilizer. So, it was recommended to farmers the use of organic sources, biochar and FYM, along with nitrogen for the good health of the plant and soil environment on a sustainable basis. Further study is needed to investigate the long-term effects of these organic nutrient sources.

COMPLIANCE WITH ETHICAL STANDARDS

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Agegnehu, G., Nelson, P.N. and Bird, M.I., 2016. Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols. Soil and Tillage Research, 160, pp.1-13.

Agegnehu, G., Srivastava, A.K. and Bird, M.I., 2017. The role of biochar and biochar-compost in improving soil quality and crop performance: A review. Applied soil ecology, 119, pp.156-170.

Agric stat of Pakistan. 1999-2000. Ministry of food, agriculture and livestock.government of pakistan, islamabad.

Akbar, f., wahid, a., akhtar, s., ahmad, a. N. & chaudhary, f. M. J. P. J. B. 1999. Optimization of method and time of nitrogen application for increased nitrogen use efficiency and yield in maize. 31, 337-341.

Akhtar, m. & silva, j. J. P. J. O. S. S. 1999. Agronomic traits and productivity of sweet corn affected by nitrogen and intercropping.

Ali, k., khalil, s. K., munsif, f., rab, a., nawab, k., khan, a. Z., kamal, a. & khan, z. H. J. S. J. O. A. 2012. Reponse of maize to various nitrogen sources and tillage practices. 28.

Ali, k., munsif, f., zubair, m., akbar, h., shahid, z. H. M., din, i. U. & khan, n. J. S. J. O. A. 2011a. Management of organic and inorganic nitrogen for different maize varieties. 27.

Ali, k., munsif, f., zubair, m., hussain, z., shahid, m., din, i. U. & khan, n. J. S. J. A. 2011b. Management of organic and inorganic nitrogen for different maize varieties. 27, 525-529.

Alkharabsheh HM, Seleiman MF, Battaglia ML, Shami A, Jalal RS, Alhammad BA, Almutairi KF, Al-Saif AM. 2021. Biochar and Its Broad Impacts in Soil Quality and Fertility,

Nutrient Leaching and Crop Productivity: A Review. Agronomy. ; 11(5):993. https://doi.org/10.3390/agronomy11050993

Amjad, a. 1998. Effect of nitrogen and magnesium on growth yield and quality of hybrid maize. M. Sc. Thesis, department of agron., university of agriculture, faisalabad.

Arif, M., Ali, S., Ilyas, M., Riaz, M., Akhtar, K., Ali, K., Adnan, M., Fahad, S., Khan, I., Shah, S. and Wang, H., 2021. Enhancing phosphorus availability, soil organic carbon, maize productivity and farm profitability through biochar and organic–inorganic fertilizers in an irrigated maize agroecosystem under semi‐arid climate. Soil Use and Management, 37(1), pp.104-119.

Bocchi, s. & tano, f. J. E. J. O. A. 1994. Effects of cattle manure and components of pig slurry on maize growth and production. 3, 235-241.

Chan, k., van zwieten, l., meszaros, i., downie, a. & joseph, s. J. S. R. 2008. Using poultry litter biochars as soil amendments. 46, 437-444.

Chaudhry, a. J. A. F., pakistan 1983. Agronomy in "maize in pakistan" punjab agriculture coordination board univ.

Crawford, t. W., rendig, v. V. & broadbent, f. E. J. P. P. 1982. Sources, fluxes, and sinks of nitrogen during early reproductive growth of maize (zea mays l.). 70, 1654-1660.

Dolan, m., clapp, c., allmaras, r., baker, j., molina, j. J. S. & research, t. 2006. Soil organic carbon and nitrogen in a minnesota soil as related to tillage, residue and nitrogen management. 89, 221-231.

Eid MAM, Abdel-Salam AA, Salem HM, Mahrous SE, Seleiman MF, Alsadon AA, Solieman THI, Ibrahim AA. 2020. Interaction Effects of Nitrogen Source and Irrigation Regime on Tuber Quality, Yield, and Water Use Efficiency of Solanum tuberosum L. Plants. ; 9(1):110.

Elshayb OM, Nada AM, Sadek AH, Ismail SH, Shami A, Alharbi BM, Alhammad BA, Seleiman MF.2022. The Integrative Effects of Biochar and ZnO Nanoparticles for Enhancing Rice Productivity and Water Use Efficiency under Irrigation Deficit Conditions. Plants. 11(11):1416.

Farhad, w., saleem, m., cheema, m. & hammad, h. J. J. A. P. S. 2009. Effect of poultry manure levels on the productivity of spring maize (zea mays l.). 19, 122-125.

fertilizer on soil physicochemical properties, nitrogen use efficiency and upland rice (Oryza

sativa) yield grown on an Alfisol in Southwestern Nigeria. International Journal of Recycling of Organic Waste in Agriculture, 8, pp.295-308.

Frederick, j. R. & camberato, j. J. J. A. J. 1995. Water and nitrogen effects on winter wheat in the southeastern coastal plain: ii. Physiological responses. 87, 527-533.

Gao, C., El-Sawah, A.M., Ali, D.F.I., Alhaj Hamoud, Y., Shaghaleh, H. and Sheteiwy, M.S., 2020. The integration of bio and organic fertilizers improve plant growth, grain yield, quality and metabolism of hybrid maize (Zea mays L.). Agronomy, 10(3), p.319.

Gautam, D.K., Bajracharya, R.M. and Sitaula, B.K., 2017. Effects of biochar and farm yard manure on soil properties and crop growth in an agroforestry system in the Himalaya. Sustainable Agriculture Research, 6(4).

Geng, Y., Cao, G., Wang, L. and Wang, S., 2019. Effects of equal chemical fertilizer substitutions with organic manure on yield, dry matter, and nitrogen uptake of spring maize and soil nitrogen distribution. PloS one, 14(7), p.e0219512.

Glaser, b., lehmann, j., zech, w. J. B. & soils, f. O. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. 35, 219-230.

Gul RK, Alkharabsheh HM, Akmal M, AL-Huqail AA, Ali N, Alhammad BA, Anjum MM, Goher R, Wahid F, Seleiman MF, Hoogenboom G. 2022. Split Nitrogen Application Rates for Wheat (Triticum aestivum L.) Yield and Grain N Using the CSM-CERES-Wheat Model. Agronomy. 2022; 12(8):1766. https://doi.org/10.3390/agronomy12081766

Gul, H., Rahman, S., Shahzad, A., Gul, S., Qian, M., Xiao, Q. and Liu, Z., 2021. Maize (Zea mays L.) productivity in response to nitrogen management in Pakistan. American Journal of Plant Sciences, 12(8), pp.1173-1179.

Habtegebrial, k., singh, b., haile, m. J. S. & research, t. 2007. Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (eragrostis tef (zucc.) Trotter) and soil properties. 94, 55-63.

Imran, 2024. Integration of organic, inorganic and bio fertilizer, improve maize-wheat system productivity and soil nutrients. Journal of Plant Nutrition, 47(15), pp.2494-2510.

Jaliya, m., falaki, a., mahmud, m., sani, y. J. A. J. O. A. & science, b. 2008. Effect of sowing date and npk fertilizer rate on yield and yield components of quality protein maize (zea mays l.). 3, 23-29.

Jat, g., sharma, k., jat, n. J. A. O. P. & research, s. 2012. Effect of fym and mineral nutrients on physio-chemical properties of soil under mustard in western arid zone of india. 14, 167-166.

Khaliq, t., ahmad, a., hussain, a. & ali, m. J. P. J. B. 2009. Maize hybrids response to nitrogen rates at multiple locations in a semiarid environment. 41, 207-224.

Khan, i., hassan, g., malik, n., khan, r., khan, h. & khan, s. J. P. D. 2016. Effect of herbicides on yield and yield components of hybrid maize (zea mays). 34, 729-736.

Lehmann, j. J. F. I. E. & environment, t. 2007. Bio-energy in the black. 5, 381-387.

Lehmann, j., da silva, j. P., steiner, c., nehls, t., zech, w., glaser, b. J. P. & soil 2003. Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the central amazon basin: fertilizer, manure and charcoal amendments. 249, 343-357.

Li, h., han, y. & cai, z. J. G. 2003. Nitrogen mineralization in paddy soils of the taihu region of china under anaerobic conditions: dynamics and model fitting. 115, 161-175.

Liang, b., lehmann, j., solomon, d., kinyangi, j., grossman, j., o'neill, b., skjemstad, j., thies, j., luizao, f. & petersen, j. J. S. S. S. O. A. J. 2006. Black carbon increases cation exchange capacity in soils. 70, 1719-1730.

Liu, e., yan, c., mei, x., he, w., bing, s. H., ding, l., liu, q., liu, s. & fan, t. J. G. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest china. 158, 173-180.

Lungu, o., dynoodt, r. J. A. J. O. F., agriculture, nutrition & development 2008. Acidification from long-term use of urea and its effect on selected soil properties. 8, 63-76.

Mahmoud F.S, Alotaibi M.A, Alhammad B.A, Alharbi B.M, Refay Y, Badawy S.A. 2020. Effects of ZnO Nanoparticles and Biochar of Rice Straw and Cow Manure on Characteristics of Contaminated Soil and Sunflower Productivity, Oil Quality, and Heavy Metals Uptake. Agronomy 2020, 10, 790. https://doi.org/10.3390/agronomy10060790

Mahmoud F.S, Arja S, Frederick L.S, Pirjo M. 2012. Feedstock quality and growth of bioenergy crops fertilized with sewage sludge,Chemosphere,89 (10)1211-1217,

Mahmoud F.S, Arja S, Seija J, Päivi E, Helinä H, Frederick L.S, Pirjo S.A. M, 2013. Biomass yield and quality of bioenergy crops grown with synthetic and organic fertilizers,Biomass and Bioenergy, 59, 477-485.

Mahmoud F.S, Refay Y, Al-Suhaibani N, Al-Ashkar I, El-Hendawy S, Hafez EM.2019.

Integrative Effects of Rice-Straw Biochar and Silicon on Oil and Seed Quality, Yield and Physiological Traits of Helianthus annuus L. Grown under Water Deficit Stress. Agronomy. 9(10):637.

Mahmoud, R.S, Mahmoud F.S, Bushra A. A, Basmah M.A and Heba I.M 2020. Minimizing Adverse Effects of Pb on Maize Plants by Combined Treatment with Jasmonic, Salicylic Acids and Proline. J. Agronomy. 10(5), 699; https://doi.org/10.3390/agronomy10050699

Makinde, e., ayoola, o. J. A. J. O. F., agriculture, nutrition & development 2010. Growth, yield and npk uptake by maize with complementary organic and inorganic fertilizers. 10.

Minhas, W.A., Hussain, M., Mehboob, N., Nawaz, A., UL-Allah, S., Rizwan, M.S. and Hassan, Z., 2020. Synergetic use of biochar and synthetic nitrogen and phosphorus fertilizers to improves maize productivity and nutrient retention in loamy soil. Journal of plant nutrition, 43(9), pp.1356-1368.

Mohankumar, a. & gowda, n. N. J. A. J. O. S. S. 2010. Effect of different organic manures and inorganic fertilizers on available npk, microbial density of the soil and nutrient uptake of brinjal (solanum melongena l.). 5, 291-294.

Munir, m. A., malik, m. A. & saleem, m. F. J. P. J. O. B. 2007. Impact of integration of crop manuring and nitrogen application on growth, yield and quality of spring planted sunflower (helianthus annuus l.). 39, 441.

Naeem, M.A., Khalid, M., Aon, M., Abbas, G., Amjad, M., Murtaza, B., Khan, W.U.D. and Ahmad, N., 2018. Combined application of biochar with compost and fertilizer improves soil properties and grain yield of maize. Journal of Plant Nutrition, 41(1), pp.112-122.

Naeem, M.A., Khalid, M., Aon, M., Abbas, G., Amjad, M., Murtaza, B., Khan, W.U.D. and Ahmad, N., 2018. Combined application of biochar with compost and fertilizer improves soil properties and grain yield of maize. Journal of Plant Nutrition, 41(1), pp.112-122.

Naeem, M.A., Khalid, M., Aon, M., Abbas, G., Amjad, M., Murtaza, B., Khan, W.U.D. and Ahmad, N., 2018. Combined application of biochar with compost and fertilizer improves soil properties and grain yield of maize. Journal of Plant Nutrition, 41(1), pp.112-122.

Ogola, j., wheeler, t. & harris, p. J. F. C. R. 2002. Effects of nitrogen and irrigation on water use of maize crops. 78, 105-117.

Oladele, S., Adeyemo, A., Awodun, M., Ajayi, A. and Fasina, A., 2019. Effects of biochar and

nitrogen fertilizer on soil physicochemical properties, nitrogen use efficiency and upland rice (Oryza sativa) yield grown on an Alfisol in Southwestern Nigeria. International Journal of Recycling of Organic Waste in Agriculture, 8, pp.295-308.

Peng, J., Han, X., Li, N., Chen, K., Yang, J., Zhan, X., Luo, P. and Liu, N., 2021. Combined application of biochar with fertilizer promotes nitrogen uptake in maize by increasing nitrogen retention in soil. Biochar, 3, pp.367-379.

Pirdashti, h., motaghian, a. & bahmanyar, m. A. J. J. O. P. N. 2010. Effects of organic amendments application on grain yield, leaf chlorophyll content and some morphological characteristics in soybean cultivars. 33, 485-495.

Rana Roy, Avelino Núñez-Delgado, Shirin Sultana, Jinxin Wang, Ammara munir, Martin L. Battaglia, Tanwne Sarker, Mahmoud F. Seleiman, Milon Barmon, Ruiqi Zhang. 2021. Additions of optimum water, spent mushroom compost and wood biochar to improve the growth performance of Althaea rosea in drought-prone coal-mined spoils, Journal of Environmental Management, 295,113076.

Rasheed, m., hussain, a., mahmood, t. J. I. J. O. A. & biology 2003. Growth analysis of hybrid maize as influenced by planting techniques and nutrient management. 5, 169-171.

Sarwar, N., Abbas, N., Farooq, O., Akram, M., Hassan, M.W., Mubeen, K., Rehman, A.U., Shehzad, M., Ahmad, M. and Khaliq, A., 2023. Biochar integrated nutrient application improves crop productivity, sustainability and profitability of maize–wheat cropping system. Sustainability, 15(3), p.2232.

Sharif, m., khattak, r. A., sarir, m. J. C. I. S. S. & analysis, p. 2002. Effect of different levels of lignitic coal derived humic acid on growth of maize plants. 33, 3567-3580.

Singh, b., singh, b. P. & cowie, a. L. J. S. R. 2010. Characterisation and evaluation of biochars for their application as a soil amendment. 48, 516-525.

Singh, R., Srivastava, P., Bhadouria, R., Yadav, A., Singh, H. and Raghubanshi, A.S., 2020. Combined application of biochar and farmyard manure reduces wheat crop eco-physiological performance in a tropical dryland agro-ecosystem. Energy, Ecology and Environment, 5, pp.171-183.

Singh, V.K., Malhi, G.S., Kaur, M., Singh, G. and Jatav, H.S., 2022. Use of organic soil amendments for improving soil ecosystem health and crop productivity. Ecosystem

Services.

Song, D., Xi, X., Zheng, Q., Liang, G., Zhou, W. and Wang, X., 2019. Soil nutrient and microbial activity responses to two years after maize straw biochar application in a calcareous soil. Ecotoxicology and environmental safety, 180, pp.348-356.

Steiner, c., teixeira, w. G., lehmann, j., nehls, t., de macêdo, j. L. V., blum, w. E., zech, w. J. P. & soil 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered central amazonian upland soil. 291, 275-290.

Sun, J., Lu, X., Wang, S., Tian, C., Chen, G., Luo, N., Zhang, Q. and Li, X., 2023. Biochar blended with nitrogen fertilizer promotes maize yield by altering soil enzyme activities and organic carbon content in black soil. International Journal of Environmental Research and Public Health, 20(6), p.4939.

Tasneem, k., tariq, m., kamal, j., masood, a. J. I. J. O. A. & biology 2004. Effectiveness of farmyard manure, poultry manure and nitrogen for corn productivity. 1560-8530.

Uzoma, k., inoue, m., andry, h., fujimaki, h., zahoor, a., nishihara, e. J. S. U. & management 2011. Effect of cow manure biochar on maize productivity under sandy soil condition. 27, 205-212.

Verheijen, f., jeffery, s., bastos, a., velde, m. & diafas, i. J. O. F. O. P. O. T. E. C., luxembourg 2004. A critical scientific review of effects on soil properties, processes and functions.

Whalen, j. K. & chang, c. J. J. O. E. Q. 2001. Phosphorus accumulation in cultivated soils from long-term annual applications of cattle feedlot manure. 30, 229-237.

Yuan, j.-h., xu, r.-k. & zhang, h. J. B. T. 2011. The forms of alkalis in the biochar produced from crop residues at different temperatures. 102, 3488-3497.

Zerssa, G.W., Kim, D.G., Koal, P. and Eichler-Löbermann, B., 2021. Combination of compost and mineral fertilizers as an option for enhancing maize (Zea mays L.) yields and mitigating greenhouse gas emissions from a Nitisol in Ethiopia. Agronomy, 11(11), p.2097.