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A Review of Combined Use of Biochar with Nitrogen Fertilizer as an Instrument for Improving Maize Yield and Soil Fertility

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ABSTRACT

The decline of soil fertility is one of the major problems around the world for producing crops and ensuring food security. Therefore, the review's objective was to examine how biochar and inorganic nitrogen fertilizers affect soil physicochemical characteristics, as well as maize production and growth parameters. Similarly, biochar is a product of the thermochemical decomposition of biomass produced under limited oxygen. It has potential benefits in agriculture, such as improving soil fertility, water retention. The nutrient composition of biochar produced is determined by the type of feedstock used and the pyrolysis conditions. A study showed **that adding biochar and nitrogen fertilizer decreased soil bulk density and enhanced water-holding capacity and soil chemical properties like pH, nitrogen, phosphorus, potassium, organic carbon, calcium, ECEC, and base saturation. Moreover, the review reported that the addition of N fertilizer and biochar greatly promoted crop N uptake and N content, which then increased leaf photosynthetic efficiency, dry matter accumulation, and grain yields. The findings discovered that when the rate of biochar and nitrogen increased, crop productivity and soil properties also increased significantly. It is concluded that applying biochar along with nitrogen fertilizer increased maize crop productivity as well as soil attributes more than applying biochar and nitrogen fertilizer separately. Therefore, farmers and agricultural experts should consider incorporating these practices into their land management strategies to improve overall agricultural sustainability.**

Keywords: biochar, nitrogen, soils, yield, rate, maize, growth, combination of biochar, application

INTRODUCTION

The low yield of crop is due to reduced soil fertility, fluctuating rainfall, pest pressure, poor farming practices, and limited availability of high-quality seeds (Katungi et al., 2010). Moreover, soil acidity is one of the problems constraining crop productivity (Mesfin, 2007). Accordingly, the major problems associated with soil acidity are the toxicity of aluminum (Al) and magnesium (Mn) and the poor availability of essential plant nutrients (Kochian et al., 2004). This highlights the importance of efficient nitrogen management practices that ensure optimal crop yields while minimizing environmental damage (Jaynes et al., 2001). Therefore, it is crucial to develop and implement sustainable nitrogen management strategies to address this issue.

Biochar is used as a carbon-rich soil amendment material to improve soil characteristics, prevent nutrient loss, and promote agricultural production (Cui et al., 2020). The pyrolysis

process at relatively high temperatures (300–700 ° C) and low oxygen levels (Lehmann and Joseph, 2009) also produces it. Due to its high carbon content and recalcitrant chemical composition (Cheng et al., 2008), biochar has considerable promise as a climate change mitigation tool (Woolf and Lehmann, 2012). This substance is frequently referred to as a "win-win-win" scenario because it produces energy from renewable materials and sequesters carbon on a long-term basis while improving soil fertility indicators (Laird, 2008). An analysis by Woolf et al. (2010) estimates that overall, biochar has the potential to sequester 12% of human CO2-Ce emissions. Various residual biomasses, including manure, crop residues, wood residues, forest, green, and agricultural wastes, as well as industrial wastes, are used to make biochar (Novotny et al., 2015).

As different research indicates, biochar application to the soils can increase crop productivity and also improve soil attributes. For example, Peng et al. (2021) findings suggest that biochar compound fertilizers can increase carbon stability and nitrogen retention in soil, improve N uptake by maize, while the loss of nitrogen is minimized, and thus may have an important potential for improving the agroecosystem and ecological balance. The study showed that maize yield increased from 28% to 140% after applying 20 t/ha of biochar compared to untreated soil (Major et al., 2010). In comparison to applying biochar and nitrogen fertilizer separately, applying the two together increased grain yield, nitrogen use efficiency, water holding capacity, and soil physicochemical parameters (Oladele et al., 2019). Research by Khan et al. (2021) has shown that the application of biochar can promote growth by increasing chlorophyll content in wheat, thereby increasing yield. Wilson (2014) further explained that from the past to the present, there are several processes in which biochar acts in the soil, with numerous and diverse layers. As per Zhang et al. (2012), 20 and 40 t/ha of biochar mixed with nitrogen fertilizer enhanced maize production by 8.8 and 12.1%, respectively. According to Wang et al. (2016), 80 tons of biochar per acre increased soybean plant development. As a result, the objective of this review was to examine the impacts of biochar and inorganic nitrogen fertilizers on soil physicochemical properties as well as maize production and growth indices.

OVERVIEW OF BIOCHAR

Biochar is a product of thermochemical decomposition when heated to temperatures usually between 300 and 1000 °C with limited oxygen (Domene et al., 2014). It has potential benefits in agriculture, such as improving soil fertility, water retention, and reducing greenhouse gas emissions (Jeffery et al., 2017; Major et al., 2018; Wu et al., 2018), but more research is needed to understand its long-term effects. It has a large surface area, is highly porous, black in color, lightweight, and has a high pH. The nutrient composition of biochar produced depends on the type of feedstock and pyrolysis conditions (Shareef et al., 2018). Pyrolysis is classified as fast or slow depending on the temperature and duration of heating. Both positive and negative effects on soil quality and crop yield have been reported (Bass et al., 2016; Burrell et al., 2016).

The Soil's Chemical Properties are Affected by Applying Biochar

In general, soil with adequate structure, bulk density, porosity, organic matter, and soil pH provides the ideal environment for enhanced root system growth and microbial multiplication, resulting in increased crop yields. Likewise, biochar treated at a dose of 20 t/ha without fertilizer considerably decreased bulk density by 12% and enhanced porosity by 12%,

according to Tokova et al. (2020). In addition, applying biochar to the soil changed its microbes, rooting patterns, aeration, water-holding capacity, and bulk density (Zafar et al., 2018). Thus, according to a study by Sarfraz et al. (2017) on alkaline calcareous soil in Pakistan, adding biochar considerably lowers soil pH while increasing electrical conductivity, cation exchange capacity, and total organic carbon at greater rates. In other study, applying various rates of biochar to acidic soil raises the carbon content by 35.0%, organic matter content by 35.1%, and nitrogen content by 35.1% over the control treatment (Bayu et al., 2016).

Biochar, to be considered, is used as soil amendments. Similarly, in a study conducted by Bhattarai et al. (2015) in Nepal from November 2014 to May 2015, there was a large rise in the N, P, and K, pH, organic matter, organic carbon, and particle densities, but a decrease in the bulk density was observed. The high adsorption capacity of biochar, which reduces nutrient loss while increasing the available nutrient content and promoting crop growth, enhances the physicochemical attributes of the soils (Wang et al. 2010; Chen et al. 2013). In a different study, adding biochar raised the pH, cation exchange capacity, and organic carbon content of the soil by 46%, 20%, and 27%, respectively; the use of biochar also decreased bulk densities by 29% and improved porosity by 59% (Singh et al., 2022).

Maize Growth and Grain Yield are Affected by Applying Biochar

Biochar has the potential to improve soil attributes (physical, chemical, and biological), resulting in increased crop growth and production. Accordingly, adding 20 t/ha of biochar improved maize yield from 28% to 140% when compared to untreated soil (Major et al., 2010). In addition, they noted that biochar was applied at rates of 8 and 20 t/ha, which decreased exchangeable Al and Fe and markedly boosted maize production. According to Kuppusamy et al. (2016), biochar particles have a large specific surface area, which makes them effective soil modifiers for enhancing crop yield, raising nitrogen use efficiency, and reducing soil acidity. These effects lead to significantly higher agricultural production and better soil quality.

Maize grain yield rose by 150% and 88% over an untreated plot when biochar was applied at greater rates of 15 and 20 t/ha, respectively (Uzoma et al., 2011). As reported by (Yan et al., 2022) from a study conducted on the soil quality and maize yield in Mollisols of Northeast China from October 2017 to October 2020, higher amounts of biochar application can increase maize crop yield, while lower amounts of biochar application tend to reduce maize crop yield.

According to Rawat et al. (2019), plant growth and development in biochar-amended soil are directly related to nutrients released from biochar material and indirectly to favorable responses owing to biochar application, such as nutrient savings or increased fertilizer-use efficiency. As a result, past studies have noted a considerable rise in plant height and stem diameter (Mensah and Frimpong, 2018).

Maize Growth and Grain Yield are Affected by Applying Combined Biochar and Nitrogen Fertilizer

According to the study by Sarfraz et al. (2017), indicated that the interaction between nitrogen levels and biochar rates had a substantial impact on maize plant height, fresh biomass, and dry weight. As their research findings showed that the maximum mean maize plant height, shoot

fresh weight, and dry weight were recorded with an application rate of biochar 1% (w/w) and nitrogen 50%, respectively, while the minimum mean maize plant height, shoot fresh weight, and dry weight were recorded in the control (44.91cm, 90.33g, and 21.4g). According to these authors, the treatment at rate of (biochar 1% (w/w) + N 50%) increased maize plant height and dry weight above the control by 75.3% and 78.8%, respectively. Li et al. (2023) report the addition of N fertilizer and biochar greatly promoted crop N uptake and N content, which increased leaf photosynthetic efficiency, dry matter accumulation, and grain yields. They discovered that the highest yields (14,928 kg/ha) were obtained by combining 276 kg/ha N fertilizer with 15 t/ha of biochar and the highest NUE value (46.3%) was obtained by combining 204 kg/ha N fertilizer with 30 t/ha biochar. I general, Zhang et al. (2012) discovered that 20 and 40 t/ha biochar mixed with nitrogen fertilizer enhanced maize production by 8.8 and 12.1%, respectively.

Maize Growth and Grain Yield are Affected by Applying Nitrogen Fertilizer

As reported by Sharifi and Namvar (2016), the highest N rate (225 kg/ha) produced the highest plant height (185.2cm), whereas plots with no N application produced the lowest value (151.2cm). According to data from Woldesenbet et al. (2016), the application of 69 and 92 N kg /ha resulted in the highest number of leaves per plant (17.2) while the application of no nitrogen resulted in the lowest number of leaves per plant (15.8).Their findings indicated that plant height increased as nitrogen levels rose; hence, the tallest plant (360.66cm) was grown using 92 N kg/ha, and the shortest (347.33cm) using no nitrogen treatment. In other study, Investigations conducted on maize crops in the Central Rift Valley of Ethiopia indicated that a higher number of ears (1.33 per plant) was seen in treatments that received more nitrogen (100 N kg/ha and 125 N kg/ha), while the control treatment had the lowest number of ears (Tadesse and Kim, 2015).

Over the 2019 and 2020, growing seasons, the highest values of grains/row (43.7 and 42.1 grains), grains/ear (477.7 and 487.3 grains), and grain yield (4.7 and 4.8 t/ha) were recorded from the nitrogen level of 366 kg N/ha, whereas the lowest values of grains/row (38.0 and 39.1 grains), grains/ear (417.7 and 425.3 grains), and grain yield (3.5 and 3.4 t/ha) were observed from the nitrogen level of 192 N kg/ha (Gheith et al, 2022). Furthermore, nitrogen rates substantially increased the grain yield, ranging from 4744.8 kg/ha of control treatment to 7355.5 kg/ha at an application of 225 N kg/ha (Sharifi and Namvar, 2016). Results of Fosu-Mensah and Mensah (2016) showed that the grain yield of Obatanpa maize in Ghana rose significantly ($p < 0.01$) with the use of N fertilizer, reaching 80 N kg/ha.

Soil Properties are Affected by Applying Combined Biochar Along with Inorganic Nitrogen Fertilizer

Biochar is very important for the improvement of soil properties in general. As a result, Oladele et al. (2019) discovered that adding biochar to N fertilizer decreased soil bulk density and enhanced water holding capacity as well as soil chemical properties like pH, nitrogen, phosphorus, potassium, organic carbon, calcium, ECEC, and base saturation. In addition, as reported by Tokova et al. (2020), biochar application at a rate of 10 t/ha in conjunction with 108 N kg/ha reduced bulk density and increased plant availability of water. The findings showed that applying N fertilizer and biochar together might dramatically lower the pH of the

soil and raise its levels of available phosphorus, potassium, mineral nitrogen, and organic carbon (Li et al., 2023).

CONCLUSION

Biochar is a product of the thermochemical decomposition of biomass produced under limited oxygen. It has potential benefits in agriculture, such as improving soil fertility, water retention. The nutrient composition of biochar produced is determined by the type of feedstock used and the pyrolysis conditions. A study showed that adding biochar and nitrogen fertilizer decreased soil bulk density and enhanced water-holding capacity and soil chemical properties like pH, nitrogen, phosphorus, potassium, organic carbon, calcium, ECEC, and base saturation. Moreover, the review reported that the addition of N fertilizer and biochar greatly promoted crop N uptake and N content, which then increased leaf photosynthetic efficiency, dry matter accumulation, and grain yields. The findings discovered that when the rate of biochar and nitrogen increased, crop productivity and soil properties also increased significantly. It is concluded that applying biochar along with nitrogen fertilizer increased maize crop productivity as well as soil attributes more than applying biochar and nitrogen fertilizer separately. Therefore, farmers and agricultural experts should consider incorporating these practices into their land management strategies to improve overall agricultural sustainability.

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