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The impact of biochar and mineral fertilizers on photosynthetic pigments and relative water contents of okra, *Abelmoschus esculentus* (L.) Moench

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Abstract

The study aims to assess the impact of biochar and mineral fertilizers (NPK) on photosynthetic pigments and relative water contents of okra under field conditions. Six treatments (control, biochar 1%, N80P50K50 kg/ha, N120P75K75 kg/ha, biochar +N80P50K50+B kg/ha and biochar +N120P75K75+B kg/ha) were used in the experiment. After sixty days photosynthetic pigments and relative water contents of okra were measured. The data showed that mineral fertilizers and biochar treatments had a positive impact on photosynthetic pigments such astotal chlorophyll, chlorophyll a, chlorophyll b, and carotenoid contents of leaves in okra. A maximum of photosynthetic pigments content was recorded with biochar and NPK (120:75:75 kg/ha) treatment, which also resulted in enhanced total chlorophyll, chlorophyll a, chlorophyll b, and carotenoid contents of leaves in okra compared to other treatments. A combination of biochar and NPK (120:75:75 kg/ha) application mostly enhanced relative water content.

1. Introduction

In recent years, there has been a growing interest in the utilisation of medicinal plants, which are employed in the majority of the world to obtain compounds with therapeutic qualities (Yeginbay *et al.,* 2024). Due to the existence of several significant bioactive chemicals and the bioactivities that go along with them, okra, *Abelmoschus esculentus* (L.) Moench, a vegetable and herbal crop, has both nutraceutical and medicinal qualities (Elkhalifa *et al.,* 2021). The vegetable crop okra (*A. esculentus*) is widely grown and has medicinal properties in addition to excellent nutritional importance. As such, it may be used in conjunction with other nutraceuticals. The mucilage, seed, and pods of the okra fruit all contain significant bioactive components that give the plant its therapeutic qualities. Okra's phytochemicals have been researched for their potential medicinal effects on a range of chronic conditions, including digestive, cardiovascular, and type 2 diabetes. They have also been explored for their antifatigue, liver detoxifying, antibacterial, and chemopreventive properties. Furthermore, okra mucilage has been extensively employed in pharmaceutical applications, including plasma volume expanders and plasma substitutes. Okra is regarded as a vegetable crop that is readily accessible, reasonably priced, and has a range of nutritional qualities and possible health advantages. The lack of study on the pharmacokinetics and bioavailability of okra has hampered its broad usage in the nutraceutical business, despite various reports on its medicinal advantages and potential nutraceutical relevance (Islam, 2019). Pyrolysis of biomass in an oxygen-limited environment yields biochar. According to studies by Ippolito *et al.* (2020); Leng *et al.* (2020); Ye *et al.* (2020), and others, biochar with a bigger specific surface area, pore structure, a lot of surface functional groups, and nutrient properties (such as C, N, P, K, S, Ca, and Mg) may enhance soil sustainability. Because of its distinct structure, biochar has been demonstrated in the majority of studies to be a useful agricultural technique for enhancing soil and water quality in agricultural fields are as well as for raising crop production and optimising fertilizer usage. According to El-Naggar *et al.* (2019), the porous physical structure of biochar creates a sorption capacity to inorganic nitrogen and may permit the gradual release of nutrients to enhance plant development. According to Ali *et al.* (2020), biochar has an effect on the nitrogen in the soil and is predicted to improve photosynthesis and leaf nitrogen. The addition of biochar to soil improves photosynthesis, a crucial activity that influences agricultural output. The use of biochar enhances nitrogen buildup and, as a result, increases leaf nitrogen content and photosynthesis. When 40 t ha^{-1} of biochar was added, the photosynthetic rate rose. This rate rise was brought about by increased nitrogen formation in the leaves (Abideen *et al*., 2020).

According to a study conducted by Kujur *et al.* (2023), it was indicated that NPK application significantly boosts the levels of chlorophyll a, chlorophyll b, and carotenoids in okra plants, which are crucial for photosynthesis. The increase in chlorophyll is attributed to enhanced nitrogen availability from NPK, which is essential for chlorophyll

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synthesis and overall plant health (Wamalwa *et al.,* 2019). The NPK promotes the synthesis of carotenoids, which play a vital role in protecting plants from oxidative stress and enhancing photosynthetic efficiency (Shabbir *et al.,* 2016). Increased crop yields result from the combination of biochar with NPK fertilizer, which increases plant physiological performance, decreases nutrient loss, and improves fertiliser use efficiency (Shamim *et al.,* 2015; Ofori *et al.,* 2021; Phares *et al.,* 2022; Wu *et al.,* 2023). The combination enhances the qualities of the soil, increases the availability of nutrients, and retains moisture better, all of which benefit crop development and yield (Apori *et al*., 2021).The objectives of the study were to determine the effects of the combined application of biochar and NPK fertilizer on photosynthetic pigments and relative water contents of okra under field conditions.

2. Materials and Methods

2.1 Soil and biochar

The typical irrigated grey soil collected from Durmon Experimental Field Station of the Institute of Genetics and Plant Experimental Biology, Uzbekistan. The studied soil had the following agrochemical properties: Soil organic carbon-0.960%, nitrogen-0.091%, phosphorus-0.170%, and potassium-0.69% (Jabborova *et al.,* 2021a). The chemical compositions of Municipal solid waste biochar were analyzed by Jabborova *et al.* (2023a).

2.2 Experimental design

The effect of biochar and mineral fertilizers on photosynthetic pigments and relative water contents of okra was conducted under Durmon Experimental Field Station of the Institute of Genetics and Plant Experimental Biology, Uzbekistan. Experimental treatments included six treatments:

T1-Control

T2-N80P50K50 kg/ha

T3-N120P75K75 kg/ha

T4-Biochar alone

T5-N80P50K50 + Biochar kg/ha

T6-N120P75K75 + Biochar kg/ha

Photosynthetic pigments and relative water contents of leaves in okra were determined after sixty days (Figure 1).

Figure 1: Okra plant grown in a field condition.

2.3 Photosynthetic pigmentsand relative water content measurement

The total chlorophyll, chlorophyll a, chlorophyll b, and carotenoid contents of leaves of okra were determined by Hiscox and Israelstam (1979). A fresh leaf (50 mg) of the okra sample was cut and dissolved in 5 ml of dimethyl sulfoxide in test tubes. The test tubes were incubated at 37^{o}C for 4 h. Then, absorbance of the extract was determined at 470 nm, 645 nm, and 663 nm using a spectrophotometer (SP-UV1100). The relative water content of leaves in okra was measured by the method of Barrs and Weatherley (1962). Fresh leaf (100 mg) of okra sample was placed in Petri plates and added water in plates for 4 h. The relative water content of leaves in okra was measured after 4 h.

2.4 Statistical analysis

ANOVA was used to examine experimental data with the IBM SPSS Statistics 20. Analysis of variance (ANOVA) was conducted to compare the significant or insignificant difference in the effect of treatments on photosynthetic pigments and relative water contents of okra using Duncan's Multiple Range test with the least significant difference at a 5% level of significance (p<0.05).

3. Results

3.1 Photosynthetic pigments

The data on chlorophyll content in okra showed that treatments with biochar and mineral fertilizers improved chlorophyll levels compared to the control (Figure 2). The application of NPK at a rate of 80:50:50 kg/ha increased leaf chlorophyll content by 38% over the control. NPK at 120:75:75 kg/ha led to a 45% increase in chlorophyll content compared to the control. Biochar alone enhanced chlorophyll content by 17%. The combination of biochar and NPK (80:50:50 kg/ha) resulted in a 41% increase in chlorophyll content over the control. Notably, combining biochar with NPK at 120:75:75 kg/ha significantly boosted chlorophyll content, resulting in a 49% higher level compared to the control.

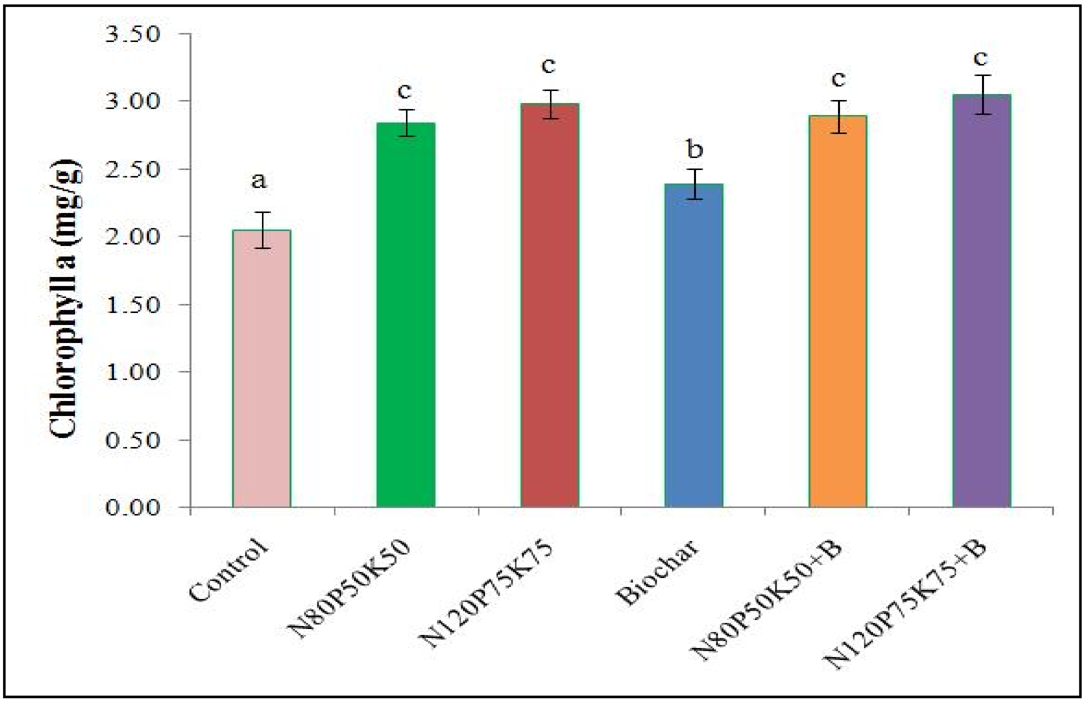

Figure 2:Chlorophyll a content of okra as influenced by biochar and mineral fertilizers.

Mineral fertilizers and biochar increased chlorophyll b content in okra plants (Figure 3). Biochar alone boosted the chlorophyll b content of leaves by 16% compared to the control. NPK treatments at 80:50:50 kg/ha and 120:75:75 kg/ha significantly enhanced chlorophyll b content by 24% and 54%, respectively. The combination of biochar and NPK (80:50:50 kg/ha) increased chlorophyll b content by 40% over the control. The most pronounced effect was observed with the combined biochar and NPK (120:75:75 kg/ha) treatment, which resulted in a 60% higher chlorophyll b content compared to the control.

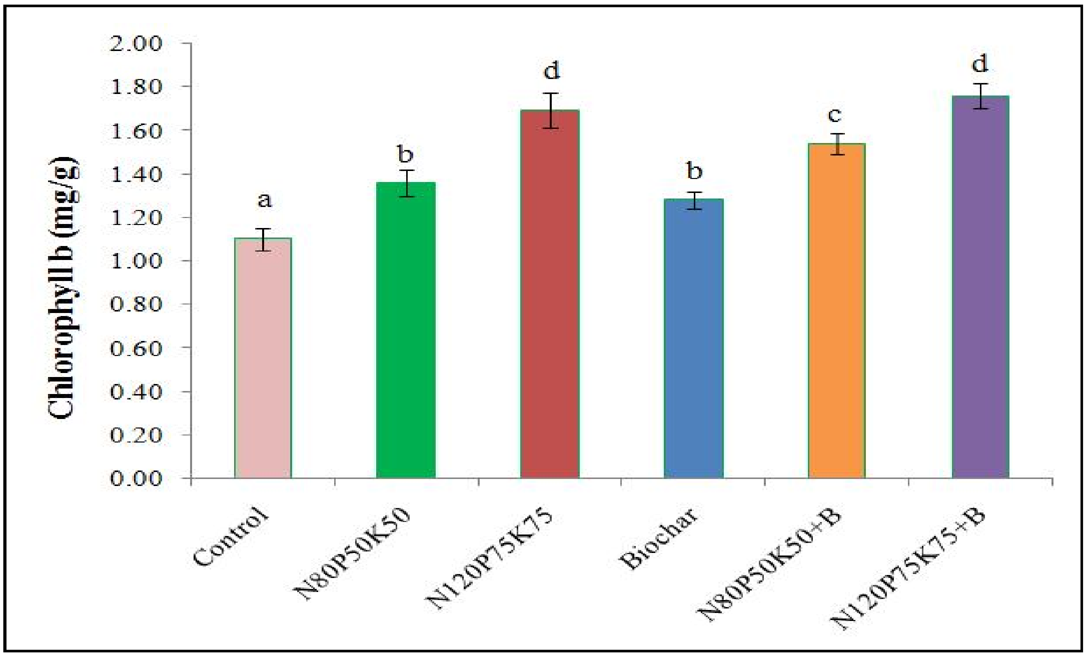

Figure 3:Chlorophyll b content of okra as influenced by biochar and mineral fertilizers.

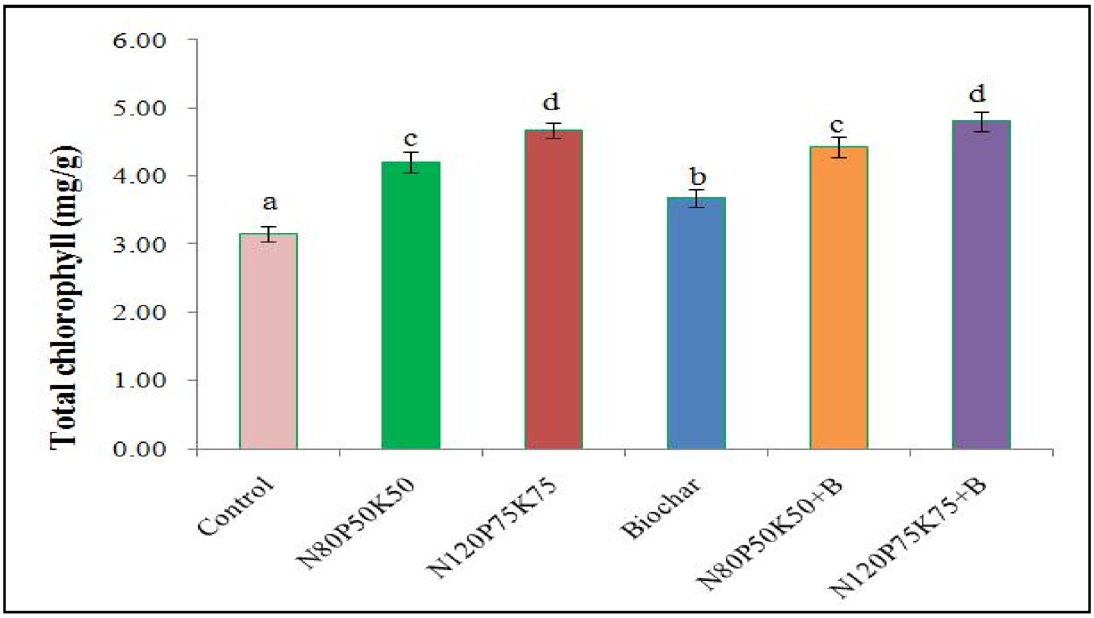

Figure 4: Total Chlorophyll content of okra as influenced by biochar and mineral fertilizers.

Our results showed that the total chlorophyll content of okra leaves was improved by the application of mineral fertilizers and biochar (Figure 4).

Biochar alone significantly increased the total chlorophyll content of okra leaves by 17% compared to the control. Mineral fertilizers, such as NPK at 80:50:50 kg/ha and 120:75:75 kg/ha, enhanced total chlorophyll content by 33% and 48%, respectively. The combination of biochar and NPK (80:50:50 kg/ha) further increased total chlorophyll content by 41% over the control. The most significant improvement was observed with the combined biochar and NPK (120:75:75 kg/ha) treatment, which boosted total chlorophyll content by 53% compared to the control (Figure 4).

Mineral fertilizers and biochar treatments positively influenced the carotenoid content of okra leaves (Figure 5). Biochar alone increased carotenoid content by 19% compared to the control. NPK treatments at 80:50:50 kg/ha and 120:75:75 kg/ha significantly boosted carotenoid levels by 35% and 54%, respectively. The combination of biochar and NPK (80:50:50 kg/ha) resulted in a 39% increase in carotenoid content. The highest improvement was observed with the combined biochar and NPK (120:75:75 kg/ha) treatment, which raised carotenoid content by 57% compared to the control.

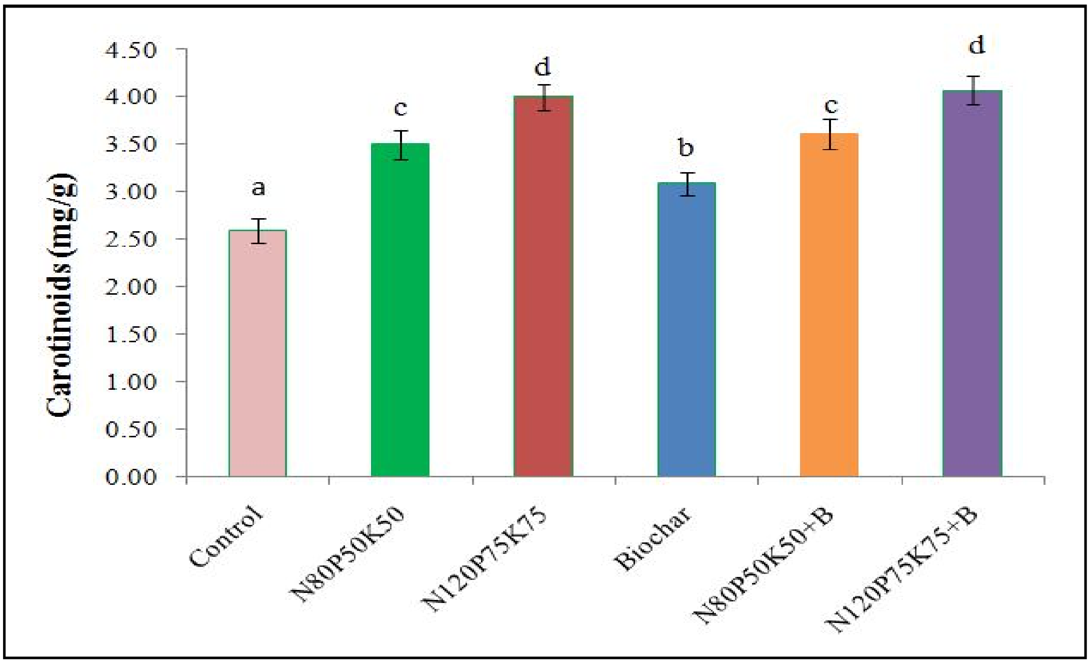

Figure 5: Carotenoid content of okra as influenced by biochar and mineral fertilizers.

3.2 Relative water content

Data in Figure 6 showed that the combination of mineral fertilizers and biochar significantly increased the relative water content of okra leaves. Biochar alone enhanced the relative water content by 16% compared to the control. NPK treatments at 80:50:50 kg/ha and 120:75:75 kg/ha increased the relative water content by 14% and 19%, respectively. The combination of biochar and NPK (80:50:50 kg/ha) further boosted the relative water content by 27%, while the combination of biochar and NPK (120:75:75 kg/ha) resulted in a 31% improvement compared to the control.

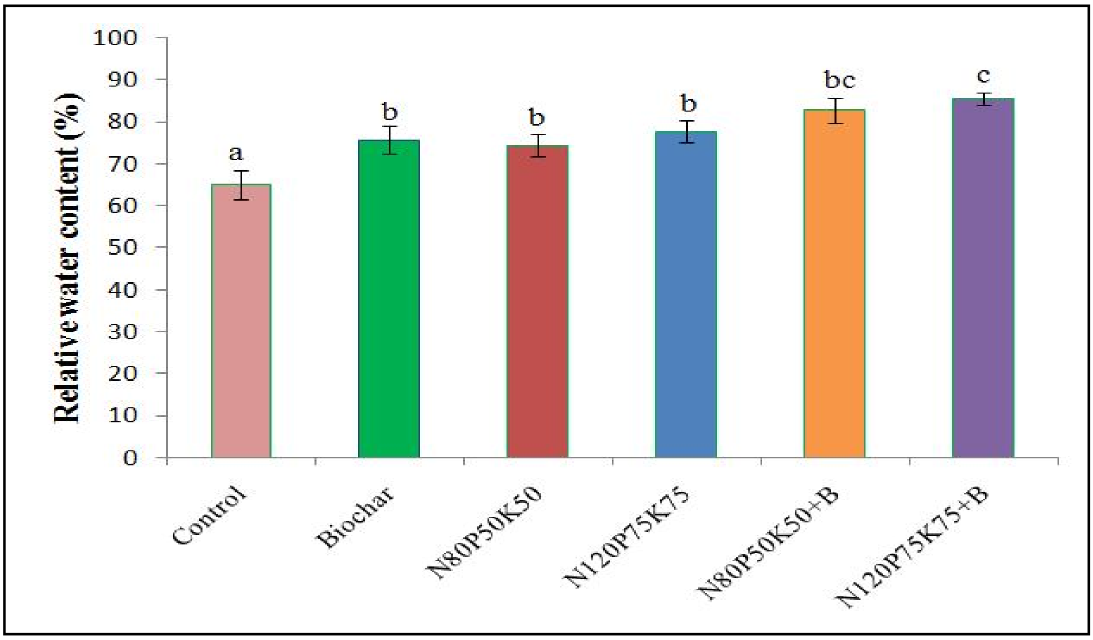

Figure 6: Relative water content of okra as influenced by biochar and mineral fertilizers.

4. Discussion

The results of this study demonstrate that the chlorophyll content of okra leaves, a key factor in photosynthesis and overall plant health, was significantly enhanced by the application of both mineral fertilizers and biochar. Among the treatments, NPK fertilizers, especially at higher rates (120:75:75 kg/ha), achieved the most substantial increase in chlorophyll a concentration, with a 45% rise over the control. The addition of biochar further enhanced this effect, leading to an increase in chlorophyll a of up to 49% compared to the control (Apori *et al.,* 2021). This suggests that biochar may enhance the effectiveness of mineral fertilizers by improving nutrient availability and retention in the soil, leading to increased chlorophyll production. Under the influence of biochar and NPK fertilizers, chlorophyll b content in okra leaves also rose significantly alongside chlorophyll a. The combination of biochar with higher rates of NPK (120:75:75 kg/ha) resulted in a notable 60% increase in chlorophyll b content, whereas biochar alone only caused a modest 16% increase (Shamim *et al.,* 2015). Similar findings were reported by El Kinany *et al.* (2019), who observed that compost application improved both chlorophyll levels and leaf mineral nutrition, particularly macro elements.

This significant improvement highlights the potential of integrated nutrient management systems, which combine chemical fertilizers with organic amendments like biochar, to enhance crops' photosynthetic capacity under stress conditions (Haider *et al.,* 2015; Xiao *et al.,* 2016). Similarly, the research found that both mineral fertilizers and biochar treatments significantly boosted the total chlorophyll content in okra leaves. The combination of mineral fertilizers and biochar is expected to have a synergistic impact that improves soil moisture retention and nutrient availability (Ye *et al.,* 2016; Peng *et al.,* 2021). Biochar application increased the chlorophyll contents, stomatal conductance, photosynthetic rate, and relative water contents of various crops (Jabborova *et al.,* 2021b; Jabborova *et al.,* 2021c; Jabborova*et al.,* 2022; Jabborova *et al.,* 2023b; Patani *et al.,* 2023; Jabborova *et al.,* 2024). In a different research, when okra (*A. esculentus*) was subjected to drought stress, biochar enhanced photosynthesis and WUE compared to the control (Batool *et al.,* 2015).

The application of biochar alongside mineral fertilizers also enhanced the carotenoid content and relative water content of okra leaves. The greatest increase in carotenoids, essential for photoprotection and antioxidant activity, was observed with the combination of NPK (120:75:75 kg/ha) and biochar, resulting in a 57% rise. This combined treatment also significantly boosted leaf chlorophyll content, gas exchange attributes, and nutrient concentrations, such as nitrogen (N), phosphorus (P), and potassium (K) in both shoots and grain yield of maize (Naeem *et al.,* 2018). Similarly, Phares *et al.* (2022) reported that combining biochar with inorganic NPK fertilizer (45:30:30) improved maize grain yield.

5. Conclusion

Combining mineral fertilizers with biochar significantly improved the photosynthetic pigments and relative water content in okra leaves.

The NPK application at a rate of 120:75:75 kg/ha was particularly effective in enhancing various photosynthetic pigments, such as total chlorophyll, chlorophyll a, chlorophyll b, and carotenoids. Both the NPK application at 120:75:75 kg/ha combined with biochar and the NPK application at 80:50:50 kg/ha with biochar also increased the relative water content of okra leaves. This indicates that integrating mineral fertilizers with biochar can be highly beneficial for cultivating okra under field conditions. These findings highlight the potential of using biochar in conjunction with traditional fertilizers to boost photosynthetic pigment levels, improve water retention, and enhance overall crop yield.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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