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EVALUATING THE ROLE OF BIOCHAR AND HUMIC ACID IN ENHANCING LENTIL PERFORMANCE UNDER FIELD CONDITIONS

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ABSTRACT

Lentil (*Lens culinaris* Medik.) is a crucial legume crop recognized for its impressive nutritional value, ability to enrich soil, and flexibility in adapting to different agro-climatic conditions. This study investigates the impact of biochar (4%) and humic acid (1%) on the quality of lentil yields and their biochemical parameters in field settings. We looked at important agronomic traits, including emergence percentage, plant height, the number of primary, secondary, and tertiary branches, root length, and the number of pods and seeds per plant. We also measured chlorophyll content as a sign of plant health. The findings revealed that biochar application significantly enhanced all the parameters compared to the control and humic acid treatments. Biochar not only improved soil fertility but also boosted microbial activity and facilitated better nutrient uptake, leading to improved plant growth and yield. Although humic acid also had a positive effect, it was less significant than that of biochar. In summary, biochar at a 4% concentration showed superior results in enhancing both yield attributes and biochemical traits in lentils. These results suggest that biochar is a promising soil amendment for increasing lentil productivity and could be a key strategy.

Key words : Seed priming, Organic agents, Abiotic stress, Pulses and Sustainable agriculture.

Introduction

Lentil (*Lens culinaris* sub sp. culinaris), is a nutritious self-pollinated crop and it is diploid (2n = 2x = 14), lentil is pulse crop and mainly cultivated in America and it used as human food and feeding animal. It is most ancient crop has played a significant role in human life and diets since early civilization due to its nutritional value and adaptability, it thrives well in semi-arid environments and it is grown more than 44 countries (Hamid Khazaei *et al*., 2019). It is commercially categorized into two main market classes based on seed characteristics: red and green, the large green lentil primarily export and consumed Europe, middle east and South America (Muehlbauer *et al*., 2009). In India, lentil generally grown in winter season and in rain fed areas. Lentil plants produce small, lens-shaped seeds enclosed in pods containing one to three seeds (Bansal *et al*., 2023). Seed color and size vary by variety, with red and green being the most commercially important. Their short growth cycle and low water requirements make lentils ideal for crop rotation, especially in dryland farming. They also enhance soil fertility by fixing atmospheric nitrogen through symbiosis with *Rhizobium* bacteria. In 2019–2020, India cultivated lentils on 1.32 million hectares, producing 1.18 lakh tonnes with 894/ kg/ha productivity (DAC and FW, 2020). Canada led globally, producing 32.34 lakh tonnes from 21.75 lakh hectares, with 1,487/ kg/ha yield, contributing 40% of global area and 51% of total production, lentil play crucial role improving soil productivity and decrease the need of fertilizers (Ali and Gupta *et al*., 2012). India contributes more than 31% overall in world production, due to its top production makes it top consumer and top producer (Rai *et al*., 2012). Lentils is nutrient-dense legume crop which have approx 25% high quality protein and have 60% carbohydrates including 11-15% dietary fiber support digestive health it contains low fat 1-2%. Additionally, lentil have significant amount of Mg, K, P, and B-vitamins.

The seed priming is pre-sowing activity which increase the different seed quality parameters such as germination percentage seed vigour, legume particularly (Rao *et al.,* 2023). Recently compounds like biochar and humic acid widely used due to its availability to enhanced the quality and quantity of the agricultural food crop (Atefeh Rashidifard *et al.,* 2020). In plant life cycle seed germination is the most important period. Seed priming is the method for increasing quality of seed and germination of seeds, biochar and humic acid both the compounds and organic and eco-friendly, Recent research on lentils highlights the importance of sustainable practices (Raza *et al*., 2024). It aims to boost yield, enhance nutritional quality and increase resilience to environmental stress, all while supporting the goals of food security and ecological sustainability (Patel *et al*., 2022). Micronutrients such as zinc, iron, and boron play a crucial role in the growth of lentils, yet they often fall short in Indian soils due to high pH levels and a lack of organic matter. Humic acid comes to the rescue by chelating these essential nutrients, making them more accessible for plants. This process not only boosts plant uptake but also enhances growth, yield and nutritional quality (Bhatt *et al*., 2022).

This study aims to fill the gap in which role of humic acid and biochar increasing germination percentage, physio-biochemical parameters like Chlorophyll, and yield quality attributes by seed priming. By optimizing these organic inputs, the study seeks to develop a sustainable, cost-effective approach to enhance lentil performance, particularly in nutrient-deficient soils of South Asia. The results are anticipated to offer important insights for researchers, farmers, and policymakers who are working to enhance pulse production in environmentally sensitive and resource-limited agriculture.

Materials and Methods

The study was carried out through both field and laboratory experiments to evaluate treatment effects under controlled and natural conditions in Amity Institute of Organic Agriculture (AIOA), Amity University, Noida. IPL - 316 variety of lentil was taken from ICAR - IARI, New Delhi and this variety of lentil was used in this experiment. After standardization with humic acid and biochar with different concentration, the final priming carried out with three treatments *viz*., T_1= Biochar 4%, T_2= Control and T_3= Humic Acid 1% these were used to evaluate physio-biochemical parameters, yield and associated traits, including plant productivity, seed weight, and other agronomic performance indicators. In normal condition all the parameters are observed in laboratory, the experiment was designed with three different treatments, all set up in a randomized block design (RBD) and make five replications. Each plot covered an area of 24 m², with plants spaced 30 cm apart in rows and 10 cm between each plant, this setup helped ensure that the plants were evenly distributed, allowing for a precise evaluation of how each treatment performed in actual field conditions.

Field parameters

Emergence Percentage (ISTA 2023)

The emergence percentage of lentil seedlings was recorded at regular intervals from 7 to 15 DAS after sowing with the help of pen and notebook to evaluate early establishment and vigour under different seed priming treatments. Observations were made by counting emerged seedlings manually regular from (7-15) DAS. Treated seeds showed earlier and more uniform emergence compared to control. Most emergence occurred between 11 and 13 DAS, with minimal change by 15 DAS indicated stabilization. Emergence percentage reflect seed vigour, water uptake, and metabolic activites, demonstrating the effectiveness of priming treatments increase early seedling growth.

Plant height

Plant height in lentil was measured at regular intervals—30, 60, 90 and 120 days after sowing (DAS) with the help of scale and black cloth. We monitored how plants grew under various seed priming treatments. At each interval, we randomly selected five plants and measured their height from the ground to the top of the main shoot using a standard measuring scale. This non-destructive approach allowed us to track their linear growth over time. By 30 days after sowing (DAS), the plant height indicated early establishment and showed how priming affected cell division and elongation. At 60 DAS, during the peak of vegetative growth, the height measurements revealed ongoing growth and improvements in photosynthesis and water uptake due to the treatments. By 90 DAS, as the plants approached maturity, the height data reflected the cumulative growth and the lasting impact of the treatments. Finally, at 120 DAS, we gathered measurements that painted a complete picture of the crop’s development.

Primary, Secondary and Tertiary branches

To assess the impact of different seed priming treatments on plant architecture, the number of primary, secondary, and tertiary branches in lentil plants was recorded manually. Vigorous and healthy plants were selected from each replication for consistent observation. Primary branches arising directly from the main stem were counted first, followed by secondary branches emerging from the primary and finally tertiary branches from the secondary ones. These branching levels are vital indicators of canopy development, photosynthetic efficiency, and reproductive potential. Accurate tagging and manual counting ensured consistency across treatments. The data provided insights into internal growth responses influenced by priming agents, contributing to the understanding of plant structure and potential yield formation under varied treatment conditions.

Root length

Root length is measured with help of black cloth and measuring scale manually, we're looking at how lentil seedlings develop their roots and grow underground under various seed priming treatments. Roots are essential for absorbing nutrients and water, so their length is a key sign of how strong the seedlings are and how healthy the plants will be. To get precise measurements, we used a standard scale against black chart paper, which helped us clearly see and align even the smallest root structures. We took care to spread the roots out to prevent bending or overlapping, ensuring we could measure from the base to the tip without any issues. This non-destructive method allowed us to consistently observe root elongation. Once we collected the data, we analyzed it to find treatment-related differences in root growth, providing us with valuable insights into how seed priming impacts early root development, anchorage potential, and the plant's ability to access soil resources during those initial growth stages.

Number of Pods / plant

In this study, we looked at how many pods each plant produced under three different field treatments: T_1 (Biochar 4%), T_2 (Control), and T_3 (Humic Acid 1%). The goal was to see how these organic amendments affect the reproductive development of lentils. We picked selected healthy plants from each replication and counted the mature pods by hand after harvest. The treatments were applied following standard protocols. This measurement was designed to uncover how soil amendments influence pod formation, helping us understand the effects of biochar and humic acid on lentil productivity in real field conditions.

Number of Seeds / Plant

The number of seeds per plant is recorded manually with the help of black cloth we looked at how many seed each plant produced under three treatment we applied. Primary goal for recording number of seed per plant to see the effect of organic amendments biochar and humic acid on development of lentil. This measurement was designed to uncover how soil amendments influence seed, helping us understand the effects of biochar and humic acid on lentil productivity in field conditions.

Biochemical parameters

Chlorophyll content

To determine chlorophyll and related pigments content, samples are collected from young seedlings. 1gram fresh leaf was taken and macerated using 5.0 ml of 80% acetone, after that sample transferred into Eppendorf tube then centrifuge the samples at 10000 rpm for 10 minutes. Then put the sample into spectrophotometer at different wave length *viz*., 470, 645, 652 and 663 to take the readings (Arnon *et al*., 1949).

$$\text{Chl a} = 12.9(Ab_{663}) - 2.69\ (Ab_{645}) \times V/1000 \times W$$

$$\text{Chl b} = 22.9\ (Ab_{645}) - 4.68\ (Ab_{663}) \times V/1000 \times W$$

$$\text{Total Chl} = \text{Chl a} + \text{Chl b}$$

Results and Discussion

During this research we used organic amendments which improve the physio-chemical parameters and also improve the yield quality attributes, these chemicals break down the dormancy, increase water absorption and facilitate germination (Ajouri *et al*., 2004).

Field parameters

Emergence percentage

In our study, there were notable differences in seed emergence rates among the various treatments, the biochar 4% (T_1) treated field show significantly high emergence percentage at 85.33 % (Fig. 1A), which is followed by the humic acid (T_2) field with 80 % (Fig. 1B) while the control treated (T_3) field recorded lowest in these treatment at 70% (Fig. 1C). Biochar improved soil conditions that favor germination (Lehmann and Joseph, 2015). These results clearly indicate that both types of soil amendments can enhance early plant growth, with biochar being the most effective. Overall, the study reinforces the idea of using organic amendments particularly biochar to boost germination and support sustainable agricultural practices (Mohan *et al*., 2014). Biochar enhanced the soil health and crop production (Shahbaz Khan *et al.,* 2024).

Plant height (30,60,90 and 120 DAS)

Plant height is measured manually with the help of scale at regular interval 30, 60, 90 and 120 DAS, assess the effects of different treatments on lentil growth. At 30 DAS biochar 4% treatment significantly shows the highest plant height (11.54 cm) (Fig. 1D) which is followed by humic acid 1% with (10.04 cm) (Fig. 1E) and the control at (8.74 cm) (Fig. 1F). At 60 days after sowing (DAS), we observed that the plants treated with biochar 4% had grown to 22.78 cm, while those treated with humic acid 1% reached 19.96 cm and the control treatment measured

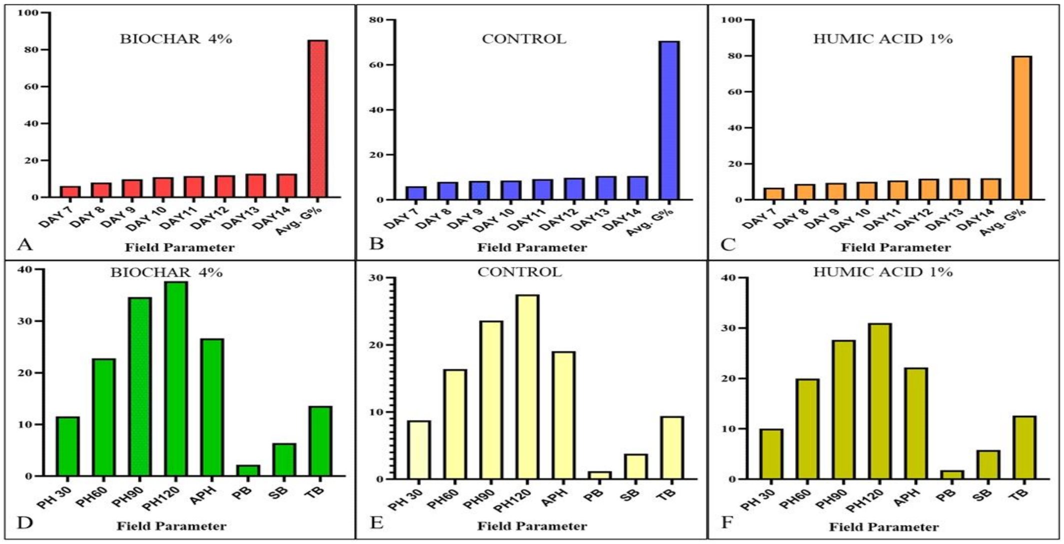

Fig. 1 : Effect of Humic Acid 1% and Biochar 4% on yield Quality attributes; (A) Emergence percentage in B.C 4 %; (B) Emergence percentage in Control; (C) Emergence percentage in H.A 1%; (D) Plant Height and Branches in B.C 4%; (E) Plant Height and Branches in Control; (F) Plant Height and Branches in H.A 1%.

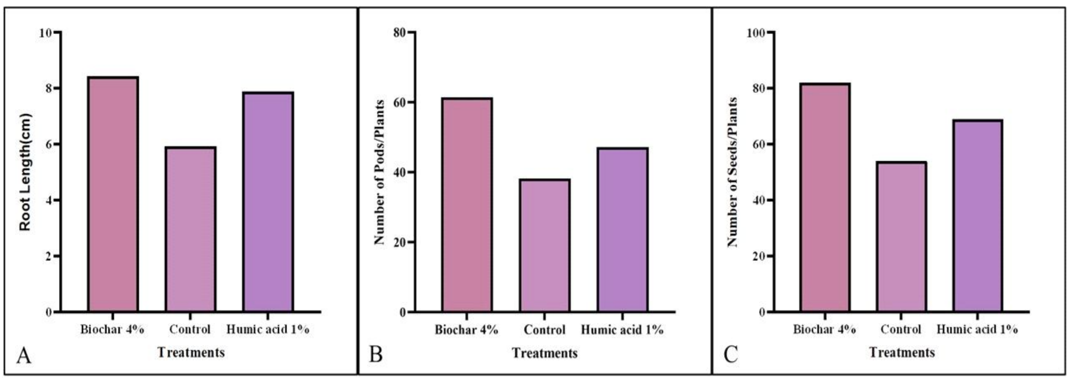

Fig. 2 : Effect of Humic Acid 1% and Biochar 4% on yield Quality attributes; (A) Root Length; (B) Number of Pods / Plant; (C) Number of Seeds / plant.

16.38 cm. At 90 DAS, and the biochar plants were still the tallest at 34.64 cm, followed by humic acid at 27.64 cm and the control at 23.62 cm. By the time we take 120 DAS, the heights were 37.7 cm for biochar 4%, 31.02 cm for humic acid 1% and 27.5 cm for the control. Overall, the average height across all stages was highest for the biochar treatment at 26.65 cm, with humic acid at 22.16 cm, and the control at 19.06 cm. The results of this study align with recent research that showcases biochar's ability to improve soil fertility and support microbial activity (Muhammad Mutasim Billah *et al.*, 2019). Moreover, humic acid has been found to enhance plant vigor during abiotic stress conditions (Poomani *et al*., 2023). It's well-known that organic amendments positively influence vegetative growth, underscoring their significance in sustainable agriculture (Ullah *et al.*, 2021).

Primary, Secondary and Tertiary branches

We observed some notable differences in how branching varied across different treatments, the primary, secondary and tertiary branches count manually in which treatment biochar 4% (T_1) shows developing an average of 2.2 (Fig. 1D) primary branches which is followed by humic acid 1% (T_3) with average 1.8 branches (Fig. 1E) while the control (T_2) treatment recorded lowest 1.2 (Fig 1F). Then secondary branches count where biochar continue shows highest average branches 6.4 followed by humic acid with 5.8 while control with 3.8. Final counting of tertiary branches in which biochar 4% significantly recorded higher with 13.6 and humic acid with 12.6 while control with average of 9.4 branches, clearly showing enhanced vegetative growth (Feng *et al.*, 2021). The effectiveness of biochar can be linked to its ability to improve root development and nutrient uptake, which supports better branching (Liu *et al.*, 2022). Additionally, humic acid contributed positively to growth by influencing hormonal activity. In summary, biochar emerged as the top performer, followed by humic acid, both enhancing plant structure and potential yield.

Root length

The application of biochar has really improved root

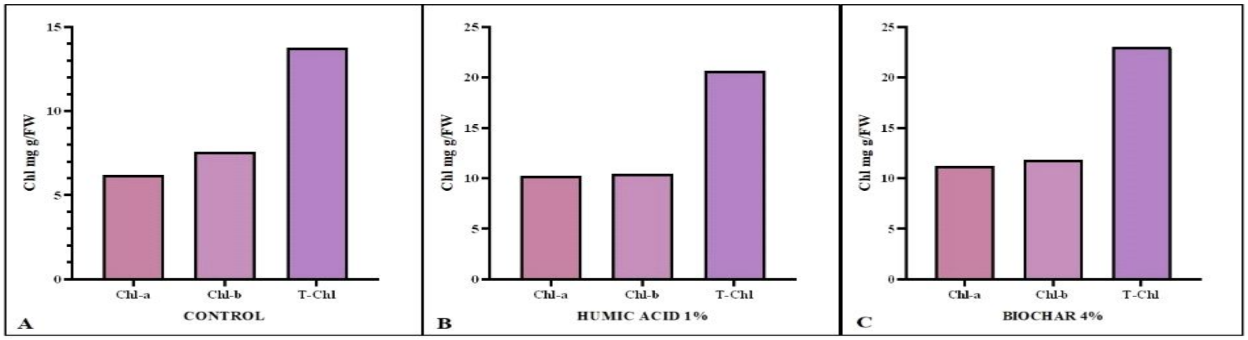

Fig. 3 : Effect of Humic Acid 1% and Biochar 4% on yield Quality attributes; (A) Chl in Control; (B) Chl in Humic Acid 1%; (C) Chl in Biochar 4%.

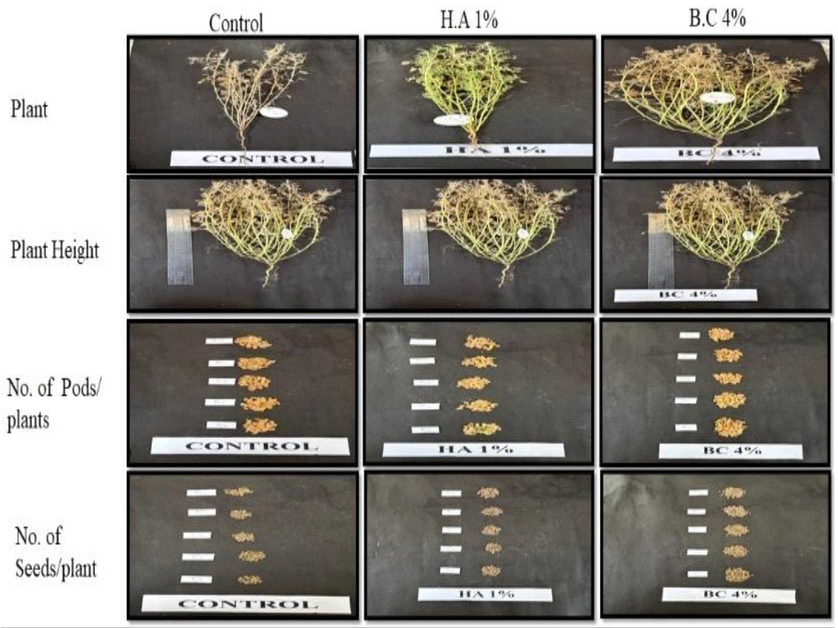

Fig. 4 : Visualization of plant height, Number of pods per plant and Number of seeds per plant.

development in plants. Biochar, in particular, made a significant impact, with roots averaging 8.44 cm, which is much better than the control and humic acid. Humic acid at a 1% concentration also contributed positively, leading to an average root length of 7.88 cm but control with 5.92 cm (Fig. 2A). These findings are consistent with recent studies that highlight how biochar enhances root morphology and helps plants use water more efficiently during stressful times, while also promoting root growth and nutrient absorption (Yangzhou Xiang *et al*., 2017). In lettuce biochar increase root morphological traits (Dilfuza Jabborova *et al*., 2021).

Number of Pods / plant

We observed quite a bit of variation in the number of pods produced by each plant across different soil amendment treatments, which really highlights their effect on lentil productivity. The 4% biochar treatment led to the highest average pod count of 61.4 pods per plant, suggesting that it significantly boosted reproductive performance. The 1% humic acid treatment also contributed positively, with an average of 47.2 pods per plant, especially when compared to the control treatment, which only had an average of 38.2 pods (Fig. 2B). These improvements are likely due to better soil structure, increased nutrient availability, and healthier plants overall (Gasco *et al.,* 2016). Biochar, in particular, seems to show the most promise for enhancing lentil yields.

Number of Seeds / Plant

The research highlighted some differences in seed production across various treatments applied biochar 4% application, plants achieved an average seed count of 82, the highest among the treatments. The humic acid 1% treatment also made a difference, yielding an average of 69.9 seeds per plant, while the control treatment only produced 54.4 seeds (Fig. 2C). These findings indicate that both amendments have a beneficial effect on reproductive development, with biochar having the most significant influence (Ahmad *et al*., 2023). The improvements are likely linked to better soil structure, increased nutrient retention, and the stimulation of helpful microbial communities, all of which support healthier plants and seed production.

Biochemical parameters

Chlorophyll Content (Chl-a, Chl-b and T-Chl)

In our study, we observed that the biochar 4% treatment had the highest chlorophyll a(Chl-a) content, reaching 11.21%. The humic acid 1% treatment came next at 10.25%, while the control treatment recorded a lower level of 6.21%. The highest chlorophyll-b content was observed in the biochar 4% treatment at 11.83%, followed closely by the 1% humic acid treatment at 10.43% and then the control group at 7.57%. The highest total chlorophyll content was found in the biochar (BC) treatment, reaching 23.04%. Following that, the humic acid at 1% showed a content of 20.68% and the control treatment had the lowest at 13.77% (Fig. 4). The increase in chlorophyll content under biochar treatment might be linked to improved nutrient retention and a rise in photosynthetic efficiency.

Conclusion

In this study, use of organic amendments biochar 4% and humic acid 1% in field they enhanced the yield quality attributes as well improve biochemical parameters in open environment. These organic compounds increase the emergence percentage, growth of seedling, also improve the enzymatic activity, improve nutrient uptake. The use of biochar 4% and humic acid 1% application increased overall performance in field condition. Further investigation is needed to understand the biochemical mechanisms involved. Molecular studies under standard conditions could clarify these interactions. Overall, biochar and humic acid offer a sustainable method to improve crop growth across diverse environments.

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