Development and Testing of Biochar-Based Foliar Fertilizer

Submitted by:

Aleeza Arshad

00000357126

Supervisor:

Dr. Ghulam Haider

Atta-Ur-Rahman School of Applied Biosciences (ASAB) National University of Sciences and Technology Islamabad, Pakistan

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Signature: ____________________

Name of Supervisor: **Dr. Ghulam Haider**

Date: 15-05-2024

Signature (HOD): ____________________

Dr. Hussain Mustatab Wahedi
Head of Department (HoD)
Dept. of Biomedicine
ASAB, NUST, H-12, Islamabad

HOD Healthcare Biotechnology: **Dr. Mustatab Wahedi**

Date: 15-05-2024

Signature (Dean/Principal): ____________________

Prof. Dr. Muhammad Asghar
Principal & Dean
Atta-ur-Rahman School of Applied Biosciences (ASAB), NUST, Islamabad

Principal ASAB: **Dr. M. Asghar**

Date: 15-05-2024

DECLARATION

We certify that this research work titled **"Development and Testing of Biochar-Based Foliar Fertilizer"** is our own work. The work has not been presented elsewhere for assessment. The work here in was carried out while we were an undergraduate student at Atta-ur-Rahman School of Applied Biosciences (ASAB), National University of Sciences and Technology (NUST) under the supervision of **Dr. Ghulam Haider.** The material that has been used from other sources has been properly acknowledged / referred.

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Aleeza Arshad

Reg No. 357126

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Signature of Supervisor
Dr. Ghulam Haider
Associate Professor
Atta-ur-Rahman School of Applied Biosciences (ASAB)
National University of Sciences and Technology (NUST)
Islamabad, Pakistan.

“And ˹surely˺ your Lord will give so much to you that you will be pleased.”
Quran 93: 5

DEDICATION

"This work is dedicated to our beloved parents and teachers. Their continuous love and support have been our motivation to strive and move forward.

To our honored Supervisor for his immense guidance, support, and inspiration.

To our friends and siblings who motivated and cheered us during these years"

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ABSTRACT

Nitrogen fertilizers are essential to improve the crop yield and meet the food demand of the growing global population. Half the world population is dependent on nitrogen fertilizers hence, they play an important role in ensuring food security. However, Nitrogen Use Efficiency is constantly declining and has been reduced to 33% globally and 23-25% in Pakistan. This is due to ineffective fertilizer application methods and management practices which cause excessive nitrogen losses to the environment such as ammonia volatilization, leaching of nitrates. Thus, this necessitates the development of innovative strategies to cope with the declining NUE by reducing nitrogen losses to prevent environmental pollution associated with fertilizer use. Foliar fertilizers are being developed and used to achieve high fertilizer use efficiency and improve agricultural yield due to their enhanced nutrient uptake efficiency. They are sprayed directly on leaves which fulfills the micronutrient deficiencies of plants and prevents excess fertilizer waste. Biochar which is a carbon rich residue has been proved beneficial for the crops and improving their productivity. It improves the soil structure, nutrient retention process, reduces greenhouse gas emissions and leaching of nitrates to prevent contamination of air and water. This study aims to explore the benefits of biochar based foliar fertilizer to test the effectiveness of foliar applied nutrients focusing on their potential to enhance yield quality and nitrogen use efficiency.

CHAPTER 1

INTRODUCTION

The world population is increasing strikingly with the food demand increasing proportionally and this is not just the quantity of food but also the quality of food. Today, there is about 8.1 billion world population and is expected to increase in the next few years. The world is facing the challenge of meeting the requirement of the food supply to feed the growing number of people. Developing countries like Pakistan, which do not have enough resources is more susceptible to such challenges like food security, climate change etc. (Ahmad, 2014).

It is necessary to produce nutrient-rich food to meet the health requirements of the population. Our crops require essential nutrients like nitrogen (N), phosphorus (P), potassium (K) to promote healthy growth and development. Nitrogen is an essential nutrient for the growth and development of plants and its vital functions. Thus, nitrogen is incorporated into the crops through the application of fertilizers. Nitrogen fertilizers include urea fertilizers, ammonium sulphate, ammonium phosphate and others. The most commonly used fertilizers in Pakistan are urea fertilizers which contain nitrogen in considerable amount. These fertilizers are applied to increase the yield and quality of the crops. With the effective application of fertilizer, we can get enough yield of crop to fulfil the need of growing population and to enhance food security for our developing nation (Wang, 2022).

Around the world, the application of fertilizers is not effective enough to achieve productivity and profitability with agriculture. Due to the ineffective fertilizer application, the desired benefits are not achieved by the crops. Nitrogen is applied in excessive amounts but is not available for the plant to utilize it. This is because of low Nitrogen Use Efficiency (NUE) when there is surplus amount of nitrogen applied but the desired output is not obtained. The current NUE in Pakistan has declined to 23% while the desired NUE is 60-70%. This is due to the lack of knowledge and limited training among the illiterate farmers who do not follow the good management practices to utilize their land efficiently and improve productivity (Kumar, 2021).

Inefficient use of nitrogen fertilizers leads to excessive nitrogen loss in the atmosphere leading to environmental problems like air pollution, water contamination, and reduction in biodiversity. There are different forms of nitrogen but only nitrate and ammonium ion are the plant available forms. Other forms of nitrogen are lost in the atmosphere causing damage to the environment. Nitogen losses include denitrification, volatilization, and leaching. In this way, the harmful nitrogen gas which is released into the atmosphere through denitrification is posing serious threats to the air quality. As a result of volatilization, harmful ammonia gas also combines with other particles in the air. Leaching of nitrogen causes contamination of water sources (Yu, 2017).

Consequently, there is high nitrogen input in the form of urea fertilizers with comparison to little or no potassium and phosphorus. So instead of providing benefit, it creates an imbalance of nutrients in the soil. Our farmers do not have enough knowledge of farming that impacts economic sustainability. The atmosphere is facing more challenges over the years due to the surplus nitrogen input intended to improve nitrogen use efficiency, however, it is constantly declining. Thus, there is a need to devise some strategies to protect the environment from further damage.

The researchers are focused on developing strategies to reduce nitrogen losses from the environment. Thus, development and testing of biochar based foliar fertilizer will be an effective solution to control the loss and negative impacts of nitrogen and improve agricultural productivity. Biochar, a carbon rich residue which is obtained from biomass can be used for beneficial purposes in agriculture. Its benefits include improvement in the fertility of soil, enhanced water holding capacity of soil and improved soil structure. Thus, it is a sustainable alternative to improve nitrogen use efficiency reducing reliance on nitrogen fertilizers. Biochar prevents leaching of fertilizers, particularly nitrogen because its runoff can contaminate groundwater. This innovative fertilization technique also prevents greenhouse gas emissions. Thus, biochar is more sustainable option in terms of optimizing nitrogen use efficiency and reducing nitrogen losses to the atmosphere (Wang, 2022).

By replacing conventional fertilization technique with foliar fertilizer sprays, we can address the harmful effects of soil fertilization. There is not enough research done, so the potential of foliar fertilizer sprays is yet underexplored. Foliar fertilizers are directly sprayed on the plant leaves to improve their uptake efficiency and reduction of waste. In this way, the essential nutrients are directly delivered to plants without losses associated with denitrification, volatilization, and leaching of nitrogen. The background information makes it a critical need to do more research and explore the foliar fertilization strategy for optimizing the nitrogen use and effectiveness in agricultural production (Niu, 2020).

CHAPTER 2

REVIEW OF LITERATURE

Nitrogen (N) is a vital component for agricultural growth, but when present in excessive amounts, it can contribute to water pollution and eutrophication. In plain regions, the primary method by which nitrogen (N) is transported from cropland to bodies of water is through surface runoffs, which occur when natural precipitation occurs. The runoff of nitrogen (N) from farmlands as a result of fertilization is affected by factors such as precipitation, type of fertiliser, and application technique. Sustainable agriculture requires the careful management of economic viability, environmental well-being, and ethical concerns. The rapid growth in population exerts additional strain on both land and water resources, emphasizing the urgent necessity for the implementation of sustainable agriculture methods. Conventional nitrogen management strategies frequently result in environmental damage and contamination. Enhancing nitrogen usage efficiency (NUE) is vital for minimizing environmental consequences and promoting sustainable agriculture. The utilisation of synthetic nitrogen fertilizers is extensive, but it also leads to environmental contamination and health concerns. Implementing precision agriculture techniques and adopting initiatives to increase soil health can significantly enhance nutrient use efficiency (NUE). The adoption of effective management methods is impeded by a range of reasons, such as a lack of expertise and policy assistance. Developing nations, such as Pakistan, encounter difficulties in enhancing NUE (nitrogen use efficiency) and mitigating nitrogen pollution.

The global rate of N generation by human activities has increased from around 15 $TgNyr^{-1}$ to 140 $TgNyr^{-1}$ between 1890 and 1990. In contrast, the N produced via biological nitrogen fixation (BNF) has declined from around 100 $TgNyr^{-1}$ to approximately 89 $TgNyr^{-1}$ (Raza et al., 2018). Human activities, namely the release of nitrogen compounds, contribute to the formation of smog, atmospheric haze, acidification of the atmosphere, loss of biodiversity, pollution of groundwater with nitrate, and depletion of the ozone layer in the stratosphere. Urea is commonly utilised as a nitrogen (N) source, often in combination with insufficient phosphorus (P) and minimal or no potassium (K). This is a significant factor contributing to low nitrogen usage efficiency (NUE). From 1981 to 2013, urea constituted around 85% of the total nitrogen (N) utilised in Pakistan. However, its efficiency is rather low compared to other nitrogenous fertilizers (Bhardwaj et al., 2021).

Biochar has demonstrated potential in mitigating nitrogen losses and enhancing soil fertility. Biochar-based foliar fertilisers provide distinct benefits such as enhanced nutrient retention, increased absorption, and greater stress tolerance in plants.

2.2. Food Security and Agricultural Nitrogen Demand

Rapid population growth imposes a further burden on land and water resources, thereby requiring the implementation of sustainable farming practices. Global agriculture sustains a population of almost 6.4 billion people and provides other supplementary benefits, including rural employment, bioenergy, and biodiversity. The global population is growing at a rate of approximately 1 billion individuals every 12 years. By the year 2050, it is estimated that the global population will reach approximately 9 billion. Sustainability is founded on the notion of satisfying the current demands while safeguarding future needs. Sustainable agriculture integrates economic viability, environmental well-being, and ethical integrity. Insufficient nitrogen use efficiency (NUE) in intensive agriculture systems results in environmental damage. The rise in nitrogen fertiliser utilisation has led to environmental concerns such as soil deterioration and contamination. Ensuring a proper balance between the availability of nitrogen and the needs of crops is essential for the long-term viability of agriculture. Developing nations, such as Pakistan, encounter challenges in enhancing nitrogen use efficiency (NUE) and mitigating nitrogen pollution (Jones et al., 2013).

Nitrogen is essential for crop productivity in food crop systems, and historically, it has been obtained from manure, biological fixation, and soil organic matter. Since the 1960s, there has been a significant increase in the usage of nitrogen fertiliser, which has multiplied by seven. However, between 30% and 80% of this fertiliser is lost through water and air. By 1990, the amount of nitrogen from fertiliser made up 60% of the total amount of plant growth worldwide, which is more than what crops were able to absorb since 1980. Excessive use of reactive nitrogen, which leads to environmental and economic advantages, is responsible for 60% of the global nitrogen load. The impact of nitrogen extends beyond crop output, influencing ecosystems and human well-being. This emphasises the importance of using nitrogen in a balanced manner that takes into account both economic benefits and environmental sustainability (Spiertz, 2009).

Clearly, there is a requirement to shift the existing agricultural systems towards more efficient utilisation of resources and to examine possibilities for enhancing nitrogen-use efficiency in cropping and farming systems. High-input systems prioritise maximising yields while minimising nitrogen (N) usage, whereas low-input systems may necessitate more nitrogen for enhanced yield and stability.

2.3. Availability of Nitrogen Fertilizer and Their Use Efficiency

Modern agriculture extensively utilizes synthetic nitrogen fertilizers. The NUE (Nitrogen Use Efficiency) is influenced by various factors such as application methods, soil fertility, and choice of crops. Implementing precision agriculture techniques and adopting soil health improvement methods can significantly raise nutrient use efficiency (NUE). Inadequate implementation of effective management strategies is a significant factor in the occurrence of nitrogen pollution in agriculture. Developing nations encounter obstacles in enhancing nitrogen use efficiency (NUE) and mitigating The predominant nitrogen fertilizers utilized in modern agriculture are synthetic in nature, with urea, ammonium sulphate, and ammonium nitrate being the most commonly employed. These fertilisers are easily accessible and frequently utilised in the agricultural industry. Nevertheless, the use of these substances has resulted in substantial environmental concerns, such as the contamination of air and water, the decline of biodiversity, and the occurrence of health difficulties in humans. It is worth noting that agriculture is responsible for almost half of the whole world volatilization of NH3. In Pakistan, the utilisation rate of nitrogen fertiliser is low, with crops only utilising 23% of the nitrogen. This means that a significant 77% of nitrogen is lost to the environment, amounting to an excess of 3581 Gg of nitrogen. In Pakistan, urea is the primary nitrogen fertiliser used, representing 72% and 85% of nitrogen fertiliser use during the periods of 1981-1985 and 2009-2013, respectively. There has been a significant 50-fold rise in nitrogen fertiliser usage over the previous five decades (Sanaullah et al., 2022). Nevertheless, the utilisation of urea has resulted in unbalanced fertilisation, exhaustion of other vital elements, and ineffective fertiliser usage, resulting in 30-40% of Pakistan's soils lacking potassium. In order to enhance nitrogen, use efficiency (NUE), it is necessary to implement improved management practices. This involves applying synthetic nitrogen fertilisers based on the specific needs of the crops and the nutritional condition of the soil. Additionally, alternate fertilisers like NH4NO3 or NH4SO4, as well as controlled-release or slow-release fertilisers, can be utilised to decrease NH3 volatilization losses by 35-40%. Furthermore, the usage of nitrogen fertiliser in Pakistan has grown by a factor of 50 over the last 50 years. This growth is mostly due to the greater use of synthetic nitrogen fertiliser in developing nations, including Pakistan, which contributed to 2274% of the overall increase between 1961 and 2013. Moreover, the use of nitrogen fertiliser is associated with the release of N2O, as the amount of nitrogen directly influences the processes of nitrification and denitrification. It is expected that there would be a rise in nitrogen loss from developing countries between 1995 and 2030.

2.4. Biochar and Its Role in Economy

Biochar, a promising soil enhancer, is produced by heating biomass without oxygen. It holds potential for improving soil health by reducing nitrogen loss and enhancing fertility. Recycling organic waste into biochar provides an eco-friendly waste management solution. Biochar's special properties, like its high carbon content and ability to bind metals, make it useful for soil remediation. Furthermore, it can help plants withstand environmental stress (Agarwal, 2022).

Biochar possesses remarkable attributes such as a large surface area, porous microstructure, graphitic composition, and abundant surface groups (Ahmad, 2014). These unique characteristics have spurred investigations into various potential applications including soil improvement, adsorption, waste management, catalysis, energy storage, and carbon sequestration (Feng, 2020). Among these applications, soil enhancement stands out due to its less stringent requirement for precise molecular structure and morphology. Previous studies have demonstrated that applying biochar to soil can enhance nutrient availability and crop yields, improve soil texture and properties (Yu, 2017), and mitigate greenhouse gas emissions (Wang, 2022).

Biochar plays a significant role in mitigating the impacts of drought induced by climate change, primarily through its water retention capabilities (Allohverdi, 2022), and also contributes to soil health by immobilizing heavy metals and organic contaminants, as well as reducing nutrient loss and extending the efficiency of fertilizers for plant uptake (Wang, 2022).

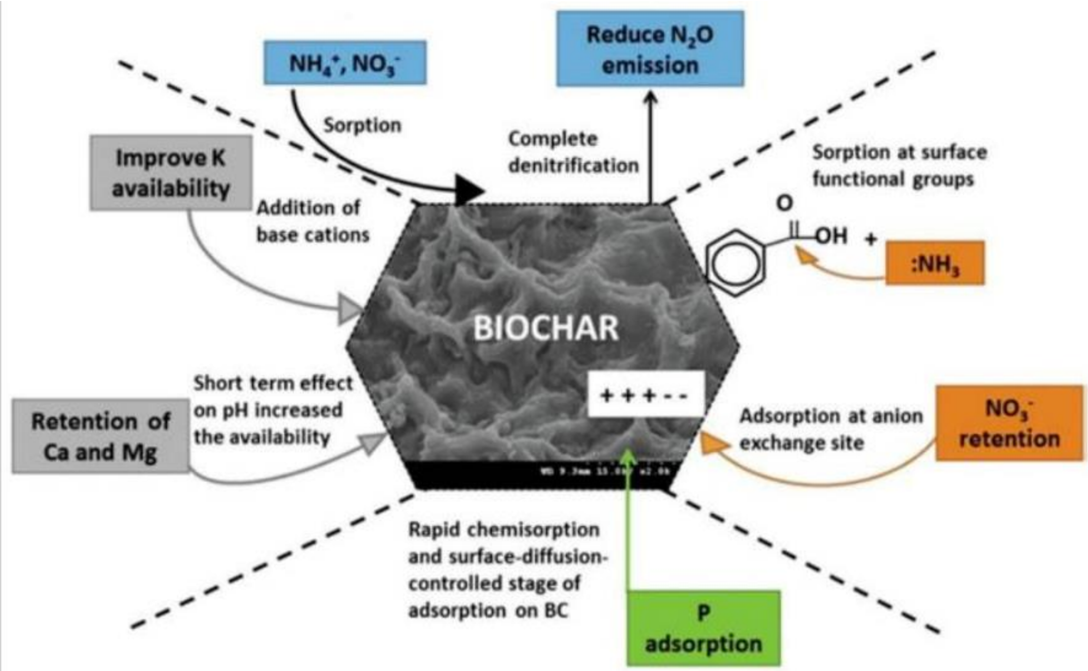

Figure 1: Effects caused by biochar. Adopted from (Allohverdi, 2022)

2.5. Biochar-Based Foliar Fertilizer

Extensive research has demonstrated that utilizing chelated fertilizers through foliar spraying can significantly decrease the overall amount of fertilizer needed while maximizing its effectiveness. Applying foliar fertilizers after soil fertilization proves to be an efficient approach in boosting crop yield, enhancing the concentration of trace elements in crops, and ameliorating the soil environment (Niu, 2020).

Biochar extracts show promising potential as highly effective foliar nanofertilizers for enhancing plant growth. Studies utilizing electron microscopy and spectroscopy indicate that organomineral nanoparticle complexes and carbon nanomaterials from these biochar extracts play a significant role in improving plant growth and performance. These porous nanofertilizers have the capability to gradually release minerals in line with the requirements of plants over time, contributing to sustained growth and development (Kumar, 2021).

Biochar-based foliar fertilizers present distinct benefits such as enhanced nutrient retention, improved uptake, and heightened stress tolerance in plants. They signify a cutting-edge field of study within agriculture, holding promise for minimizing environmental footprint. By utilizing aqueous extracts of biochar as foliar sprays, crop yields can be increased, providing an alternative avenue for decreasing biochar application rates while maximizing agricultural productivity.

CHAPTER 3

MATERIALS AND METHODS

3.1. Materials

- Compost was utilized as a potting material for plants.
- The test crop for this study was brinjal, a commonly cultivated vegetable with significant agricultural value.
- The fertilizer solution was made using a certain concentration of Nitrogen, Phosphorus, Potassium, and biochar.

3.2. Preparation of Biochar Fertilizer

The biochar used was obtained from cotton stock pyrolysis which was then further processed through ball milling to increase its surface area and improve its nutrient-holding capacity. Then, A fertilizer solution was prepared by dissolving precise concentrations of Nitrogen (N), Phosphorus (P), Potassium (K), and biochar into water. Biochar was added to the solution at a specific concentration. This preparation ensured a balanced supply of essential nutrients and enhanced the properties of the biochar for effective application. This biochar fertilizer was used in two forms: as a soil additive and as a foliar spray, to investigate its efficacy in different application methods.

3.3. Pot Experiment

Brinjal plants were obtained from the nursery. Standard thinning practices were employed to ensure that each plant had sufficient space to grow, which involved removing weaker plants to avoid overcrowding. The plants were potted in containers filled with compost and were kept in natural environmental conditions.

The experiment was conducted over 26 days, during which the plants were watered daily to maintain consistent moisture levels. Both soil and foliar applications of the biochar fertilizer were performed three times during the experiment

Figure 2: Day 1 plants after thinning.

3.3. Experimental Design

The experimental design followed a Completely Randomized Design (CRD) to minimize bias and ensure the reliability of the results. The study included three distinct treatment groups, each with five replicates, resulting in a total of 15 experimental units. The treatment groups were defined as follows:

- Control Group (T1): No fertilizer was applied to this group. Plants relied solely on the nutrients available in the compost.
- Soil Fertilizer Group (T2): The biochar fertilizer solution was incorporated into the soil
- Foliar Fertilizer Group (T3): The biochar-based fertilizer solution was sprayed directly onto the foliage of the plants.

3.4. Plant Analysis

3.4.1. Harvesting and sample preparation

On the 26th day, the plants were carefully harvested. The shoots and roots were separated using scissors. Each part was labeled and prepared for further analysis to measure the morphological and physiological parameters.

Figure 3: At the harvest day 26.

3.4.2. Morphological Parameters

Four morphological parameters were measured to assess the growth and development of the plants:

- **Leaf Count:** The number of leaves on each plant was manually counted and recorded.
- **Shoot and Root Length:** The lengths of the shoots and roots were measured using a standard metric scale. Measurements were taken from the base to the tip of the shoot and root, respectively.
- **Fresh Weight:** The fresh weights of the shoots and roots were measured using a precision digital balance. Each part was weighed immediately after separation to prevent dehydration.

Figure 4: Measurement of fresh weight of plant shoots.

- **Dry Weight:** The shoots and roots were placed in a drying oven set at 70°C for 24 hours. After drying, the dry weights were measured using the same precision balance. This step helped to determine the biomass accumulation in the plant parts.

Figure 5: Measurement of dry weight of plant shoots and roots.

3.4.3. Physiological Parameters

Two key physiological parameters were measured to evaluate the photosynthetic performance and stress response of the plants:

SPAD Index: The SPAD index, which provides an estimate of chlorophyll content, was measured using a SPAD-502 Meter. Measurements were taken on days 1, 13, and 26 of the experiment from the fully expanded leaf of each plant.

Non-Photochemical Quenching (NPQ) and Photosynthetic Yield: These parameters were assessed using the PhotoSynQ device. NPQ provides insights into the plant's ability to dissipate excess light energy as heat, while photosynthetic yield indicates the efficiency of photosynthesis. Measurements were taken under standardized light conditions to ensure comparability.

3.5. Statistical Analysis

The experimental data were subjected to statistical analysis using GraphPad Prism software. One-way ANOVA was performed to identify significant differences among the treatment groups. Following ANOVA, Tukey's post hoc test was conducted to make pairwise comparisons between the groups. A significance level of $p \leq 0.05$ was used to determine statistical significance, ensuring the robustness of the findings.

CHAPTER 4

RESULTS

4.1. Number of Leaves

The impact of soil fertilizer and foliar fertilizer on the number of leaves was assessed at the time of harvest. The number of leaves for each treatment group—control, soil-applied fertilizer, and foliar fertilizer were counted and compared. As shown in the graph, there was no significant difference in the number of leaves among the three treatment groups. This indicates that neither the soil nor foliar application of the biochar-based fertilizer had a significant effect on leaf count under the conditions of this experiment.

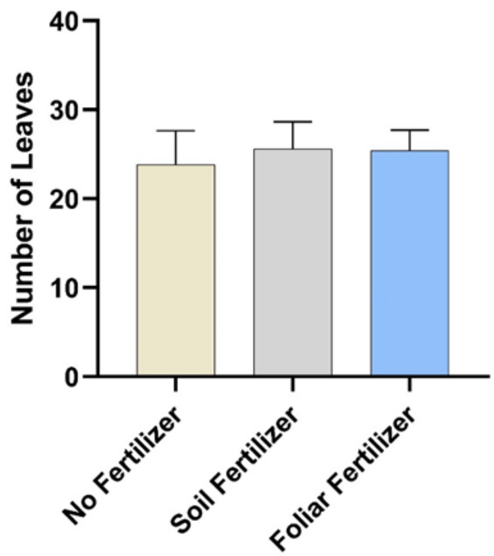

Figure 6: Effect of foliar fertilizer in comparison with soil fertilizer on number of plant leaves.

4.2. SPAD Index

The chlorophyll content of the brinjal plants, indicated by the SPAD index, was measured using a SPAD meter at three time points: day 1, day 13, and day 26. The results are illustrated in three separate graphs: Graph A for day 1, Graph B for day 13, and Graph C for day 26.

Day 1 (Graph A)

No significant difference in SPAD values was observed among the control, soil-applied fertilizer, and foliar fertilizer groups. This suggests that the initial chlorophyll content was similar across all treatments.

Day 13 (Graph B)

Like day 1, no significant difference was found in the SPAD values between the three treatment groups. This indicates that the chlorophyll content remained unaffected by the treatments up to the midpoint of the experiment.

Day 26 (Graph C)

A significant decline in the SPAD index was observed in plants treated with foliar fertilizer compared to those treated with soil-applied fertilizer. This suggests that by day 26, the foliar application of the biochar-based fertilizer might have negatively impacted the chlorophyll content, whereas the soil-applied fertilizer maintained or possibly improved chlorophyll levels.

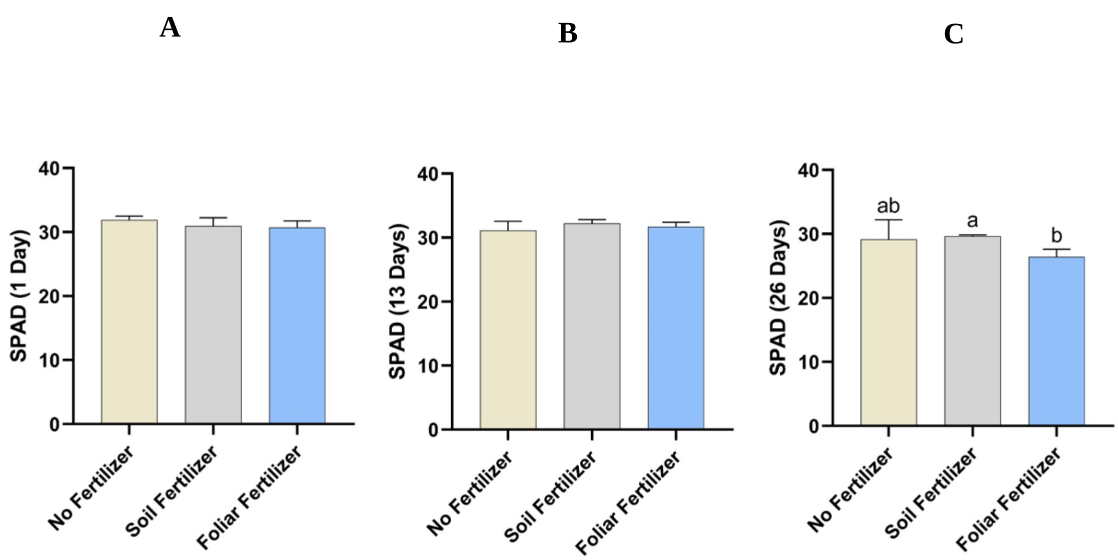

Figure 7: Effect of foliar fertilizer in comparison with soil fertilizer on SPAD values at, A: Day 0, B: Day 13, C: Day 26

4.3. Non-Photochemical Quenching

Non-photochemical quenching (NPQ), measured using PhotoSynQ, reflects the plant's ability to dissipate excess light as heat. The NPQ values were significantly higher in the soil-applied fertilizer group compared to the control group, indicating enhanced protective dissipation of excess light in plants receiving soil-applied biochar fertilizer.

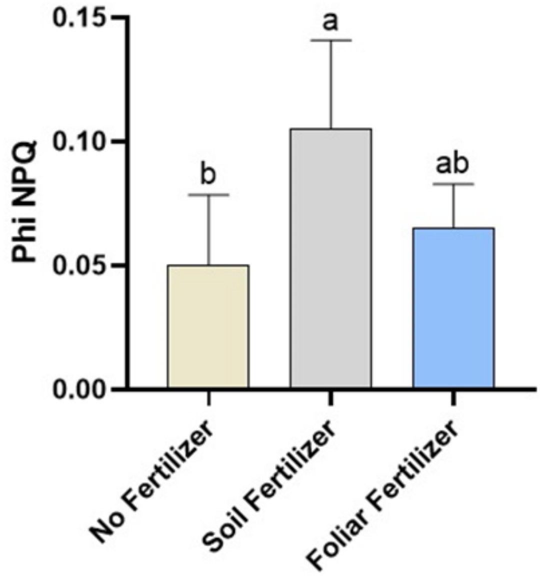

Figure 8: Non-photochemical quenching.

4.3.1. Non-Photochemical Quenching Efficiency

The graph showing non-photochemical quenching efficiency explains the NPQ results. The soil-applied fertilizer group exhibited significantly higher NPQ efficiency than the control group, further suggesting that soil application of biochar fertilizer improves the plant's capacity to handle excess light energy.

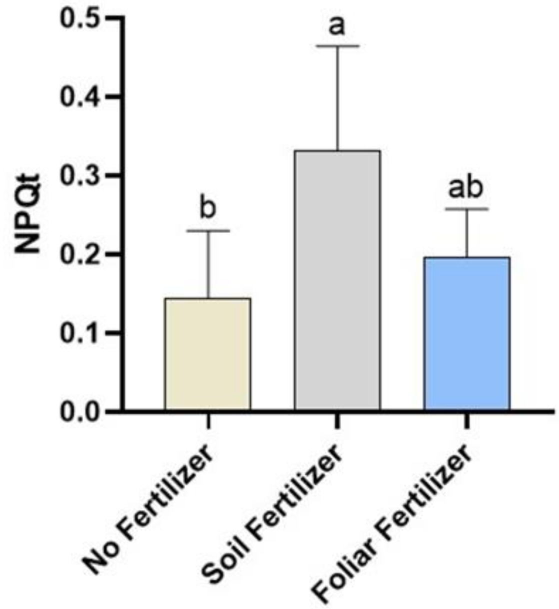

Figure 9: Non-photochemical quenching efficiency.

4.4. Non-Regulated Energy Dissipation

No significant differences were observed in non-regulated energy dissipation among the three treatment groups, indicating that this parameter was not notably affected by the type of fertilizer application.

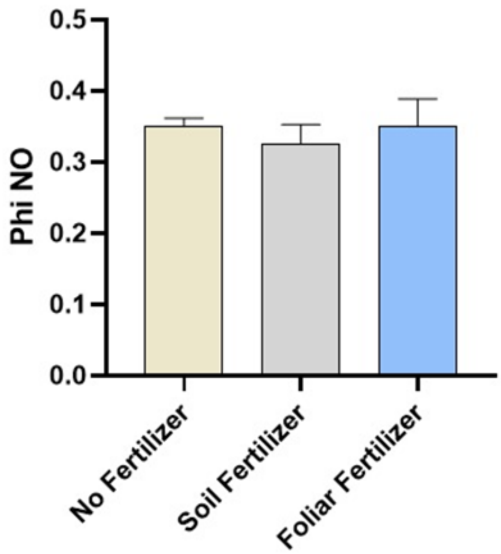

Figure 10: Non-regulated energy dissipation process.

4.5. Photosynthetic Yield

Photosynthetic yield, another crucial parameter measured using PhotoSynQ, was significantly lower in the soil-applied fertilizer group compared to both the foliar fertilizer and control groups. This suggests that while soil-applied fertilizer enhanced NPQ, it may have negatively affected the overall photosynthetic efficiency.

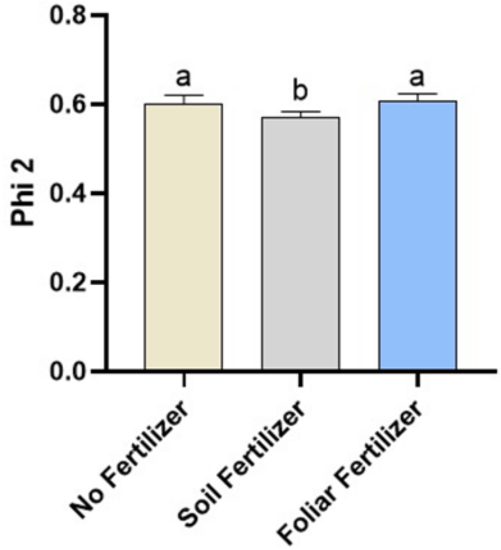

Figure 11: The effect of foliar fertilizer in comparison with soil fertilizer on the photosynthetic yield.

4.6. Shoot And Root Length:

The shoot and root lengths were measured, with results presented in two graphs.

Shoot Length

Foliar fertilizer-treated plants exhibited significantly shorter shoot lengths compared to the control and soil-applied fertilizer groups.

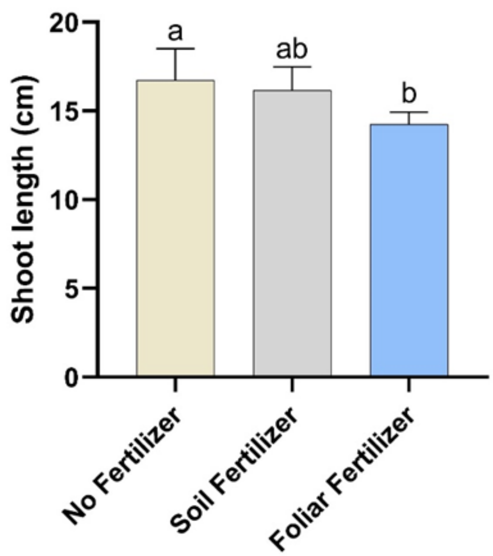

Figure 12: The effect of foliar fertilizer in comparison with soil fertilizer on the shoot length.

Root Length

No significant differences were observed in root lengths across the three treatment groups, suggesting that root growth was unaffected by the different fertilizer applications.

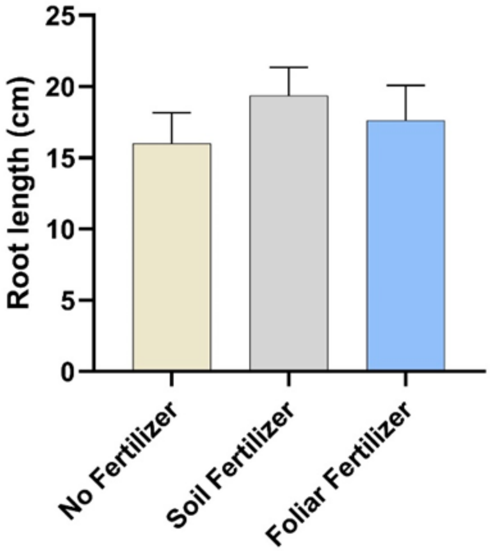

Figure 13: The effect of foliar fertilizer in comparison with soil fertilizer on the root length.

4.7. Shoot And Root Fresh Weight:

The fresh weights of shoots and roots were measured to assess biomass accumulation.

Shoot Fresh Weight

There were no significant differences in shoot fresh weight among the control, foliar fertilizer, and soil-applied fertilizer groups.

Root Fresh Weight

The root fresh weight was significantly lower in the foliar fertilizer group compared to the soil-applied fertilizer and control groups. Plants treated with soil-applied fertilizer exhibited a significant increase in root fresh weight, indicating better root biomass accumulation with soil application of biochar fertilizer.

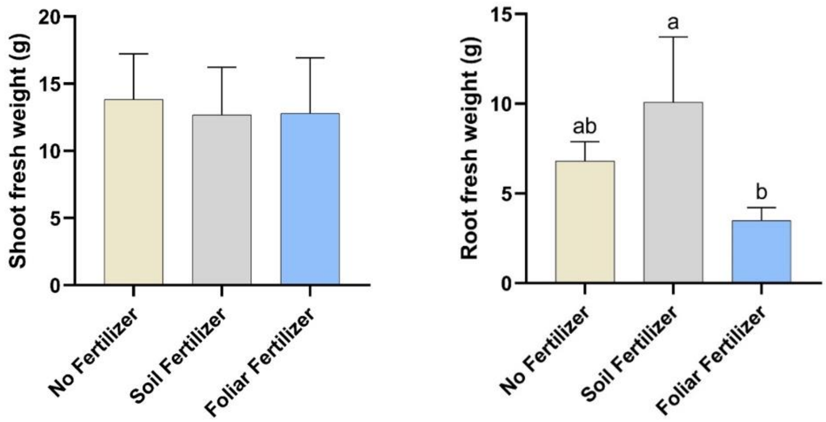

Figure 14: The effect of foliar fertilizer in comparison with soil fertilizer on the shoot and root fresh weight.

4.8. Shoot And Root Dry Weight:

The dry weights of shoots and roots were also measured after drying in an oven.

Shoot Dry Weight

No significant differences were observed in shoot dry weight across the three treatment groups.

Root Dry Weight

The root dry weight was significantly higher in plants treated with soil-applied fertilizer compared to both the control and foliar fertilizer groups. Plants treated with foliar fertilizer had the lowest root dry weight, indicating that soil application of biochar fertilizer most effectively enhanced root biomass.

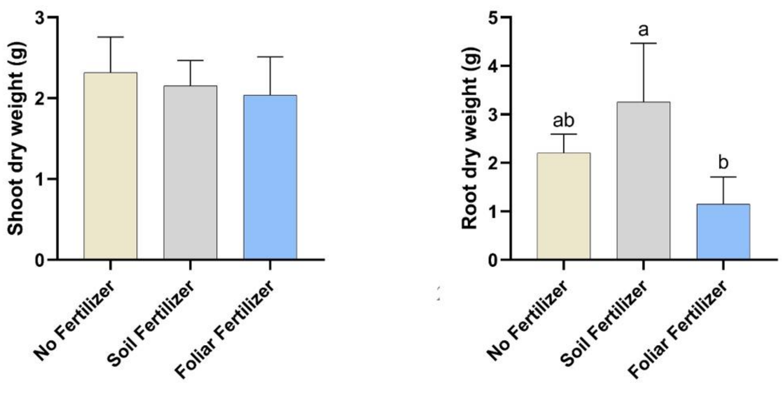

Figure 15: The effect of foliar fertilizer in comparison with soil fertilizer on the shoot and root dry weight.

CHAPTER 5

DISCUSSION

The obtained results from the experiment provide valuable insights into the differential impacts of soil and foliar fertilizers on various physiological and growth parameters in plants.

Firstly, regarding leaf production, it is noteworthy that there were no significant differences observed in the number of leaves among the control group, soil-applied fertilizer group, and foliar fertilizer group. This suggests that neither soil nor foliar fertilization exerted a discernible effect on leaf proliferation in the studied plants.

Moving on to chlorophyll content, as assessed by the SPAD index, temporal dynamics reveal intriguing patterns. While no significant differences were evident in SPAD values between the control group and the foliar fertilizer group on days 1 and 13, a notable decline in chlorophyll content was observed in plants treated with foliar fertilizer compared to those treated with soil-applied fertilizer by day 26. This temporal discrepancy suggests a nuanced interaction between fertilizer application methods and chlorophyll maintenance over time.

Regarding non-photochemical quenching (NPQ), a vital mechanism for photoprotection, the results demonstrate significant differences. The soil-applied fertilizer group exhibited markedly higher NPQ values compared to the control group, indicative of a potentially enhanced capacity to dissipate excess light energy and mitigate photodamage.

Additionally, non-photochemical quenching efficiency was notably elevated in plants treated with soil-applied fertilizer compared to the control group, further corroborating the beneficial effects of soil fertilization on the plant's ability to regulate light energy absorption and dissipate it efficiently.

Examining photosynthetic yield, a pivotal parameter for assessing plant productivity, a significant reduction was observed in plants treated with soil-applied fertilizer compared to both the foliar fertilizer and control groups. This reduction suggests a potential negative impact of soil application on photosynthetic efficiency.

Regarding shoot and root growth parameters, fertilizer application method emerged as a critical determinant. While shoot length was significantly diminished in plants treated with foliar fertilizer compared to the other groups, root length remained unaffected across all treatments. However, both root fresh and dry weights were significantly augmented in plants treated with root fertilizer, underscoring the importance of targeted nutrient delivery to the root system for fostering robust root development and overall plant vigor.

In conclusion, the findings elucidate the nuanced effects of soil and foliar fertilizers on various physiological and growth parameters in plants. While soil application appears to confer advantages in terms of chlorophyll content, non-photochemical quenching, and root development, foliar application may offer benefits in shoot length enhancement. These results underscore the necessity of tailored fertilizer application strategies to optimize plant growth and productivity, with implications for agricultural practices aimed at sustainable crop production and yield maximization. Further mechanistic investigations are warranted to elucidate the underlying physiological processes driving these observed effects and inform targeted agricultural intervention.

CHAPTER 6

CONCLUSION AND FUTURE PROSPECTS

6.1. Conclusion

The findings of this study suggest that the biochar-based fertilizer can influence crop growth and physiology. The application of biochar fertiliser to the soil greatly improves non-photochemical quenching and root biomass in brinjal plants enhancing photoprotective mechanisms and promoting root growth. However, it could potentially decrease the overall efficiency of photosynthesis.

Foliar application, although it had little impact on improving photoprotective mechanisms and root biomass, did not have a significant negative influence on most growth parameters, except for shoot length. The results emphasise the possibility of using biochar-based fertilisers in sustainable agriculture and emphasise the importance of using specific application strategies to maximize their advantages. Additional research is required to determine the optimal rates and timing of application in order to achieve a balance between both effects.

6.2. Prospects

Further studies are required for extensive investigations. An experiment to understand the cumulative effects of foliar fertilizer application for different crops over multiple growing seasons can be performed. Additionally, an investigation of the impact of foliar fertilizer on specific crops to identify the plants that benefit by its application can also be conducted. Lastly, experiments involving the utilization of different concentrations other than the ones used in this study can further allow for optimized results.

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