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Role of Rice Husk Biochar for Alleviation against Drought in Wheat Plant

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ABSTRACT

Climate change is causing the world to experience drought stress, which makes the planet water-stressed and unable to supply the demand for water for agriculture. Wheat, the queen of cereal crops, is the second most widely grown crop in the world, and one-third of all people eat it. It serves as a mainstay diet as well. The globe should have to adjust to new crop-cultivation techniques since the high temperatures cause plants to evapotranspirate at a faster rate. Biochar can improve nitrogen uptake and bring out the chemical characteristics of the soil. In the nursery, a controlled pot experiment was carried out wherein wheat seedlings were sown in pots, and biochar (derived from rice husk) was applied in varying percentages (3% and 6%) to assess the growth and water use efficiency of the plants under varying water stress conditions (75% and 50% field capacity). In addition to speeding up wheat plant development, the addition of biochar greatly lessened the impacts of drought. After 90 days of the experiment, the wheat plant reached a height of 41 cm and a maximum root length of 13 cm. The relative water content was 79.76% of 75% FC and 6% biochar-treated plants. The results of the energy disperse spectroscopy (EDS), Fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) tests further indicated the most hydrophilicity on the surface of rice husk biochar, likely due to the abundance of oxygen- and carbon-containing functional groups in the biochar samples. This study concluded that biochar played a beneficial impact in reducing the drought conditions experienced by wheat plants growing in water-deficient environments, which would aid in the achievement of sustainable irrigation.

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INTRODUCTION

Around the world, the effects of climate change are disrupting food supply networks through pandemics and droughts. There have been numerous natural and man-made disasters in the twenty-first century. Approximately 75% of the total harvested land area experienced production losses due to drought on 454 million hectares of harvested land worldwide between 1983 and 2009, with an estimated cost of $166 billion (Kim *et al.*, 2019). The world's drought stress is exacerbated by environmental problems such as global warming and climate change (Mishra *et al.*, 2021).

In developing countries, such as Pakistan, freshwater scarcity is a major issue in agriculture. Pakistan is on the edge of a terrible water disaster, with severe water scarcity nearing alarming levels. Pakistan is one of the world's driest countries, with a mean annual precipitation of less than 240 millimeters (Krebs, 2019). Climate change will increase in the coming days, with increases in air temperatures of 1 to 2 degrees Celsius projected during the next 40 years. As a result, water will be scarce for agricultural productivity. Changes in rainfall timings and patterns will result in a scarcity of excellent-quality water as well as more frequent and prolonged droughts during agricultural production. Water scarcity has a significantly greater impact on normal plant developmental processes, primarily by lowering its turgor and hydration potentials (Irshad *et al*., 2021).

Wheat is the most important nutritional crop. In Pakistan, wheat has a chief role in food and plays a central role in the agricultural department. Wheat is grown in Pakistan on an area of 9.062 million hectares, and the average production rate is 23.4 million tons. With time, the water level is decreasing due to changes in climatic conditions, and the yield of the wheat crop is also decreasing due to limited irrigation water (Nawaz *et al*., 2012). A hundred grams of wheat grains have 69 to 75 grams of carbohydrates, 1.2 to 2.5 grams of fat, and 9.4 to 13.9 grams of proteins (Haider *et al*., 2020).

Biochar is a pyrolyzed natural material that is intended to be used as a soil amendment to practically sequester carbon, enhancing soil qualities and functions while avoiding any negative effects (both short- and long-term). The greater part of Pakistan is a dryland country, with less than 250 mm of annual rainfall falling on 75% of the land. In Pakistan, almost 30 million people live in drylands and rely on agriculture for a living. There is insufficient water for agriculture throughout the year and no reliable water supply to reduce crop failure risk (Rasul *et al*., 2017). Biochar's ability to retain water is mostly determined by its pore structure and hydrophilic functional groups on the surface. Biochar with high porosity and hydrophilic functional groups can enhance soil water retention. Biochar improves soil water retention for three reasons: its high porosity and the presence of OH and COOH groups (Li & Tan, 2021). Similar improvements in plant growth, relative water contents of leaves, transpiration rate, osmotic potential, and photosynthesis in maize plants with limited water availability have been reported (Haider *et al*., 2015). The objectives of the research are to assess the potential of biochar in assisting wheat to grow in water-stress conditions and estimate the effect of biochar addition on the growth parameters of wheat in applied conditions.

MATERIAL AND METHODS

Experimental design

A pot experiment was conducted by sowing wheat plants in pots with the application of biochar (obtained from rice husk) in different percentages (3% and 6%). The experiment was initiated by sowing six wheat seeds in each pot, which were filled with 2.5 kg of biochar-mixed soil (air-dried soil was used). Water stress treatments were applied on day 30 after the germination of seeds. Treatments were applied in 36 pots, with three replicates and three additional replicates for the destructive parameter of relative water content. Wheat plants were analyzed for growth parameters (plant height, leaf area, root length, biomass, and relative water content).

Characterization of soil

The soil was air-dried, sieved with a 2 mm sieve, and prepared by adding different treatments of biochar. The soil used in the pots was also characterized before and after the experiment for the parameters of pH, electrical conductivity, organic matter, soil texture, and moisture content. This study focused on the response of wheat plants grown in biochar amendment soil. pH of soil was measured by the glass electrode method; soil EC was measured by using a multimeter (Alam *et al*., 2020). The Walkley-Black method was used for the measurement of organic matter in soil (Nelson & Sommers 1996). The gravity method is used to measure the moisture content of soil (Rowe, 2018). The hydrometric method was used to measure the texture of the soil (Beretta *et al*., 2014).

Preparation and characterization of biochar

The biomass of rice husk taken in a China dish was pyrolyzed at 450 ^{o}C for 20 minutes (Batool *et al*., 2015). The prepared biochar was characterized by parameters like pH, electrical conductivity, moisture content, bulk density, ash content, FTIR, SEM, and EDS following standard protocols.

Fourier transform infrared spectroscopy (FTIR)

Fourier transform infrared spectroscopy was performed by an equipment spectrometer through a ceramic source of light, a KBr beam splitter, and a deuterated triglycine sulfate doped with L-alanine (DLATGS) detector. Entire samples remained crushed into powders before the spectral gain (Armynah *et al*., 2018).

Scanning electron microscope (SEM)

Scanning electron microscopy (SEM) imaging analysis was performed using MIRA3 TESCON scanning microscope in order to detect the morphology of the Oryza stiva biochar.

Energy disperse spectroscopy (EDS)

Energy disperse spectroscopy is a technique used for the analysis of the elemental composition of the investigated volume on a micro- or nanoscale by using X-rays that are released from the sample during irradiation by the electron beam.

Water stress and biochar treatments

The details of the applied treatments are given in Table 1. After the application of water stresses, the pots were covered with polythene bags to prevent evaporation from the soil. By using the field balance, pots were weighed daily, and moisture was maintained up to 50% and 75% of the field capacity. We chose these two field capacities based on soil texture; the texture of the soil measured before the application of biochar treatment was sand, silt, and clay, respectively, at 34%, 18%, and 48%.

Table 1. The treatments of water stress and percentages of biochar for pot experiment.

Treatments	Water Level%	Biochar%
T_1	75%FC	0%
T_2	50%FC	0%
T_3	75%FC	3%
T_4	50%FC	3%
T_5	75%FC	6%
T_6	50%FC	6%

FC = “field capacity”

Plant parameters

Wheat plants were analyzed for plant height, leaf area, root length, biomass, and relative water content. After 30 days of seed germination, plant parameters were measured first. The three replicates of each pot treatment were specified for the destructive parameter, and the relative water content was measured.

RESULTS

Soil physicochemical characterization

The physiochemical parameters of the soil were analyzed before and after the wheat experiment. The results are shown in Table 2.

Table 2. Physicochemical Characterization of soil (Loamy in texture) after application of treatments.

Treatments	pH	EC	Moisture content	Organic matter
		μS/cm	*%*	*%*
Control	7.43	4.02	0.93	0.67
75%FC+0%B	7.32	4.56	0.88	0.69
50%FC+0%B	7.42	6.23	22	0.87
75%FC+3%B	7.76	108.25	16	2.01
50%FC+3%B	8.23	107.88	32	1.2
75%FC+6%B	9.06	124.34	42	3.7
50%FC+6%B	9.82	112.45	39	4.00

Physicochemical analysis of biochar

Table3. Physical properties of *Oryza sativa* biochar.

Biochar parameters	Values
pH	8.7
EC(μS/cm)	109.4
Moisture Content (%)	9.98
Bulk Density(gm/cm^3)	0.8
Ash Content (%)	30.13

Fourier transform infrared spectroscopy (FTIR) analysis

The FTIR spectra were obtained by scanning with a wave number range of 500-4000 cm^{-1}. The peak at 3376-3342cm^{-1} was assigned to the presence of adsorbed water and hydrogen-bonded biochar O-H groups. The bond between the C-H was 2929-2818cm^{-1}. Carbon-carbon stretching was 2260-2238 cm^{-1}. The C-N stretch of tertiary amine was 1212-1178 cm^{-1}. Pyrolysis transforms the cellulose in raw materials into fatty carbon and aromatic carbon in biochar, which is advantageous for creating the biochar structure (Figure 1).

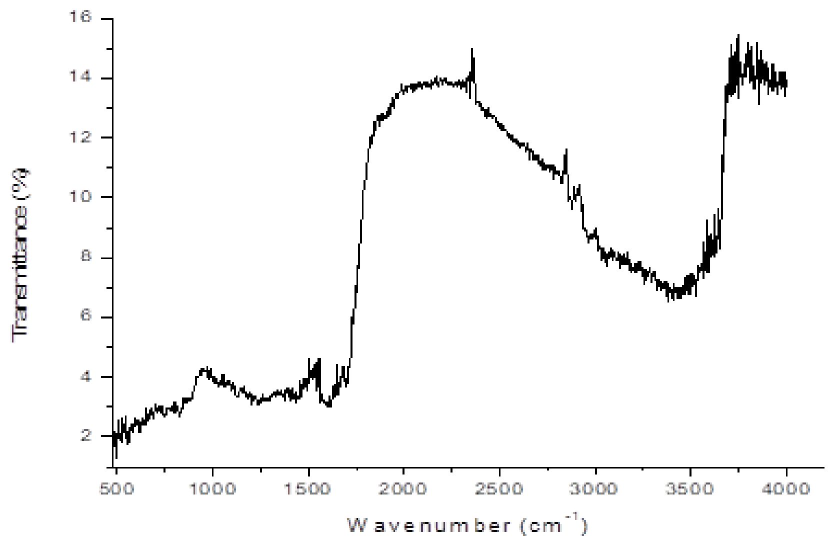
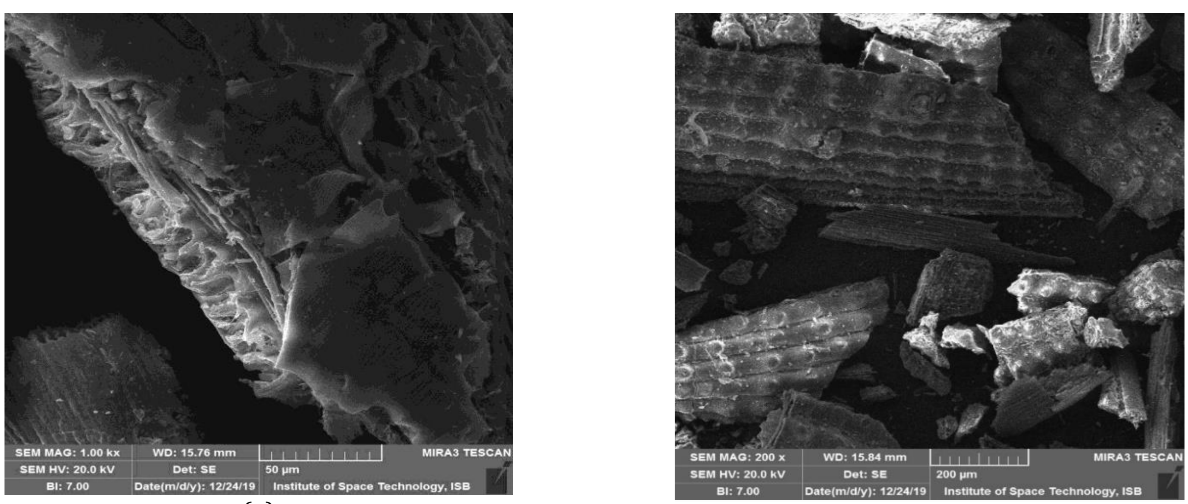


Figure 1. The organic functional groups existing in biochar sample peaks.

Scanning electron microscope (SEM) analysis

It involves how cellular structure is formed of rice husk biochar. When high temperatures are applied during pyrolysis, the biochar's internal cellular structure is fractured. Its porous surface structure helps in holding water and helps the soil retain water for a long time, especially during periods of water stress (Figure 2).



(a) (b)

Figure 2. Scanning Electron Microscope (SEM) images of rice husk biochar at different magnifications (a) SEM magnification 1.00kx (b) SEM magnification 200x.

Energy disperse spectroscopy (EDS)

EDS shows the presence of carbon (C), oxygen (O), silicon (Si), potassium (K), and calcium (Ca) in biochar sample. Accordingly, the appropriate contributions to the elemental composition weights were 58.54% of carbon, 33.40% of oxygen, 7.45% of silicon, 0.47% of potassium, and 0.14% of calcium. The atomic percentages of the rice husk biochar were carbon (67.30%), oxygen (28.82%), silicon (3.66%), potassium (0.17%), and calcium (0.05%). The most significant peak is assigned to the presence of carbon in the rice husk biochar.

Plant growth parameters

Plant height

Plant height was noted at a 30-day interval in the experiment. A one-month reading of plant heights was noticed before the application of stress, and the values were different because of different percentages of biochar and water levels in the soil. The 6% biochar showed the highest length of plants. The different values of pants are shown in the table according to percentages of biochar reactions on plants in one month (Figure 3).

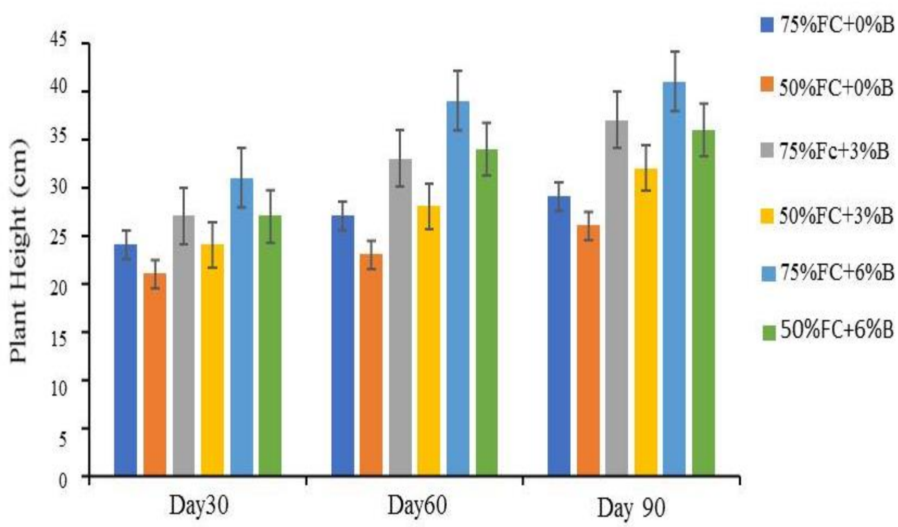


Figure 3. Height comparison of plants kept at 75% FC and 50% FC at 30 days interval with 0.3% and 6% biochar treatments.

Root length

With varying percentages of biochar and water use efficiency, the wheat plant's roots also varied in length. Up to 14 centimeters of length are shown by 6% biochar, 8 centimeters of acceptable root length are shown by 3% biochar, and negligible root length is shown by 0% biochar. At the conclusion of the experiment, root lengths were measured (Figure 4).

Leaf area

The foliar spectral reflectance of wheat plants with an area of m^2 was measured, and the leaf area of those plants that took a large amount of biochar (6%) was good. The plants with small leaf areas were those without biochar or in control plant pots. The bar graph compares the leaf area of treated plants that were stressed vs those that were not. (Figure 5).

Biomass

Biochar was helpful in the improvement of the biomass of wheat plants. Biochar increases plant height, tiller count, and dry biomass. Organic soil amendment applications improved the characteristics of the soil and improved wheat development. The biomass of different treatments and their comparisons are shown in the bar graph (Figure 6).

Relative water content

The relative water content of the wheat plants was measured by using leaf discs. Discs were collected from the leaves of each pot of the treatments: 75% FC and 0%B, 75% FC and 3%B, 75% FC and 6%B, 50% FC and 0%B, 50% FC and 3%B, and 50% FC and 6%B. The highest relative water content of the wheat plants treated with 6% biochar was 79.76%. In the case of wheat, mostly the relative water content of the wheat plants was 60% to 70%, and RWC mostly depends on the varieties of wheat. Different species show different ranges of relative water contents.

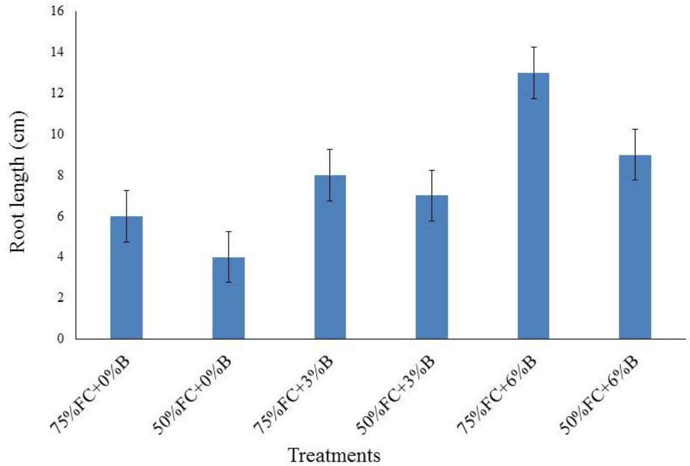


Figure 4. Root length measurements at the end of experiment.

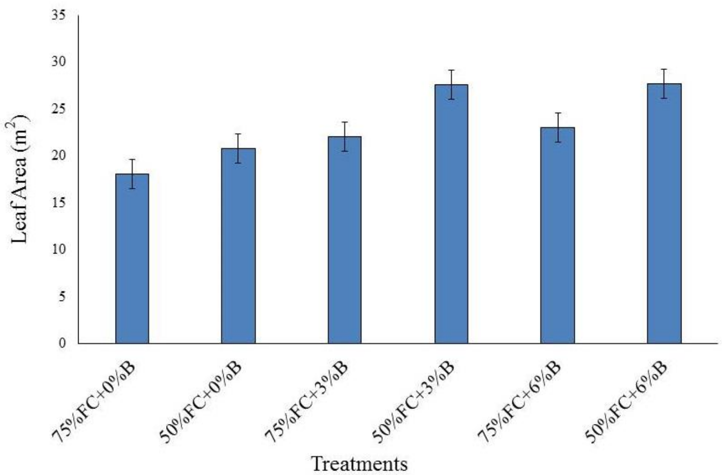


Figure 5. Leaf area (m2) measurements of the treated plants at the end of experiment.

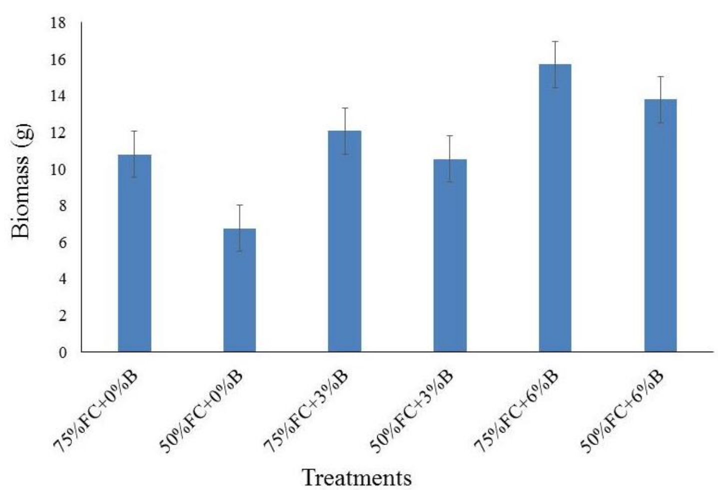


Figure 6. Biomass of plants at the end of the experiment.

DISCUSSION

Wheat is one of the world's three most important food crops. Research studies have concluded that drought stress could considerably reduce plant growth and output. Biochar is considered a possible soil improvement source that affects the physical and hydrological characteristics of the soil. It has the potential to aid in the rehabilitation of degraded land. The effect of biochar was measured by testing the physiological parameters of the wheat plant, and biochar application helped reduce the drought effect and increase the number of tillers, length of spikes, weight, and number of grains in the wheat crop. After the application of biochar and water stress treatments, the growth parameters improved.

Water scarcity is now a significant barrier to socioeconomic progress and even a risk to survival in many regions of the world. Research on water scarcity has received a lot of political and public interest since the late 1980s. The lack of freshwater is increasingly seen as a global systemic problem. Due to a failure to account for seasonal variations in water availability and consumption, previous global water scarcity assessments, which generally measure water shortages annually, have overestimated actual water scarcity. Four billion people, or two-thirds of the world's population, experience acute water scarcity for at least one month out of the year (Mekonnen & Hoekstra, 2016). To adequately represent the complex nature of water scarcity, integrated techniques are needed (Liu *et al*., 2017).

The growing water shortage in a changing climate and the frequent droughts have made water use efficiency (WUE) a key topic of discussion in biochar trials. The results of the investigations demonstrate that WUE reacted favorably to the application of biochar; a significant mean improvement in leaf water use efficiency of 20.0% was observed. Thus, using biochar might be regarded as an effective strategy to increase WUE. The effectiveness of applying biochar on water use efficiency was impacted by variations in soil, biochar, and management traits, though (Gao *et al*., 2020).

The tested soil had an EC of 4.02µS/cm, little organic matter, a 7.43 pH, and was normal water, loamy soil from arid subtropical climates. It has been noted that biochar responded well to an increase in all the analyzed soil characteristics. According to Van *et al*., (2010), the highest increase was seen when biochar was applied to acidic red ferrosol that had been seeded with wheat; this treatment resulted in a nearly 2.5-fold increase in plant biomass production.

For many agricultural soils, biochar addition offers a powerful and exceptional chance to enhance soil fertility and nitrogen usage efficiency. More research has been done on the value of biochar for production systems in dry areas, and some biochar's properties may make them problematic to employ in those soils. An improvement in soil pH, EC, and nutrient usage efficiency are among the soil chemical characteristics changed by biochar (Diatta *et al*., 2020).

Depending on the type of soil, species of plants, and biomass utilized to make the biochar, different plants responded differently to it. Interactions between biochar and additional nitrogen could cause a significant reaction in the soil and crops (Khan *et al*., 2021). Agronomic advantages in soil carbon sequestration and nutrient cycling, as well as increases in water use efficiency, crop development, and yield, make biochar frequently employed as a promising environment-friendly and economically advantageous alternative for soil amendment.

Different results have been observed across soil types and management techniques in studies of the effects of biochar on soil health and crop productivity. Plant growth responses ranged from 29% to 324% when biochar was applied at rates of 0.5 to 135 t ha^{-1}. Biochar application increased soil organic matter (SOM), soil pH, phosphorus (P), potassium (K), sulfur (S) contents, and the shoot and root biomass of wheat (Bista *et al*., 2019).

Osmotic compensation sustained turgor in all the plants; however, some of the high-saline plants' leaf RWC sharply declined despite full maintenance. This happened because of the samples' ability to absorb extra water while floating on water during the RWC measurement (Arjenaki *et al*., 2016). In this study, the relative water content of the wheat plants was higher than that grown in 6% biochar, and the RWC was 76.79%. Biochar applications of 2.5% seem to promote plant development; additions of 5% seem to have the opposite effect (Devereux *et al*., 2012). Compared to the control (1.3 g/pot), shoot biomass increased by 39 and 45% without the addition of fertilizer and by 19% and 24% with the use of fertilizer at a rate of 11.2 and the application of biochar at 22.4 Mg ha1 (Bista *et al*., 2019). Biochar can also significantly increase crop growth and productivity (Spokas *et al*., 2010).

Sigua *et al.* (2015) stated that when sorghum biochar was added to the wheat plants, their total biomass rose by roughly 31% in comparison with the control plants. To meet the long-term environmental risk assessment and to better understand the usage of pyrolyzed crop residues in agriculture, their work has contributed significant information on the contrasting effects of sorghum residues and sorghum biochar.

CONCLUSION

Pakistan is on the edge of a terrible water disaster, with severe water scarcity nearing alarming levels. Pakistan is one of the world's driest countries, with a mean annual precipitation of less than 240 millimeters. Climate change will increase in the coming days, with increases in air temperatures of 1 to 2 degrees Celsius projected during the next 40 years. As a result, water will be scarce for agricultural productivity. Changes in rainfall timings and patterns will result in a scarcity of excellent-quality water as well as more frequent and prolonged droughts during agricultural production. The rice husk-based biochar may be a great material for use in various applications in water conservation, wastewater treatment, and soil amendment based on the physicochemical features identified. This study assisted wheat plants to grow in water-deficient conditions, which would thus help in achieving sustainable irrigation. Highly significant results were found for plants in both treatments (3% B and 6% B). This study shows how to improve soil health, water holding capacity, and water use efficiency. The growth parameters (biomass, plant height, and root length) of wheat plants showed a positive effect when treated with 6% biochar at 75% FC. There are no significant changes in the leaf area in both treatments (3% and 6% biochar at 50% FC). The highest relative water content was observed (79.76%) at 75% FC+6% biochar-treated plants.

COMPETING INTEREST

There are no conflict and competing interest among the authors and none with any organization. The research is self-funded.

AVAILABILITY OF DATA AND MATERIALS

The Data and Materials used are available and will be presented when requested.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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