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Effect of Biochar Application on Biochemical and Physiological Processes in Wheat (*Triticum aestivum* L.) under Water Stress Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Udaipur (Rajasthan) during rabi season of 2021-22 to evaluate the effect of water stress and biochar application on biochemical and physiological processes in wheat. The experiment consisted of four levels of water stress as main-plot and four

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levels of biochar as sub-plot treatments conducted in split plot design (SPD) replicated thrice. Results revealed that water stress at various growth stages and biochar application had effect on proline, chlorophyll and relative water content (RWC). Water stress at grain filling stages resulted in higher chlorophyll and relative water content as compared to no water stress. Further, water stress at tillering stages resulted in higher proline over no water stress. Application of biochar had no effect on proline and chlorophyll contents Further, application of Biochar @ 4 t/ha in significant relative water content.

Keywords: Biochar; water stress; wheat; physiological and biochemical.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's major cereal crop known as "king of Cereals". It is locally known as Gehun, belongs to the Poaceae family. It contains about 8-15% protein, 1-1.5% fat, 2-2.5% fibre, and 62-71% carbohydrate and supplies 73% of the calories of the average diet. It is consumed in the form of chapatti and its straw is used for feeding the animals [1]. In India wheat is grown in 30.47 M ha area with production of 106.84 MT and productivity 3507 kg ha^{-1}, while in Rajasthan it is cultivated in 2.58 M ha area with production and productivity of 9.48 M T and 3673 $kgha^{-1}$, respectively [2]. Currently water scarcity has become the leading menace to curtail crop productivity around the globe [3]. Water stress is major harmful factor in arid and semi-arid regions worldwide that limits the area under cultivation and yield of crops. Drought is observed in irrigated areas due to insufficient supply of water and canal closure. Recently, biochar is getting importance worldwide to improve the water holding capacity and physiochemical properties of soil [4-7].

Biochar is a carbon-rich co-product resulting from pyrolyzing biomass. When applied to the soil it resists decomposition, effectively sequestering the applied carbon and mitigating anthropogenic CO_2 emissions. Zhang et al. [8] reported that application of biochar to calcareous and infertile dry croplands poor in soil organic carbon enhanced crop productivity and reduced GHGs emissions. Other benefits of biochar application to soil included enhanced plant productivity and reduced nutrient leaching. Biochar soil amendment can affect leaf N status and photosynthesis, but the effect varied with soil type [9]. Biochar is preferred due to its unique properties of low density (providing additional void age and aeration in the soil), significant adsorption and cation exchange capacity, and the ability to promote living microbiology in the soil.

2. MATERIALS AND METHODS

The field experiment was conducted at Rajasthan College of Agriculture, MPUAT, Udaipur during rabi season of 2021-22. Treatments comprised of sixteen treatment combinations consisting of four water stress *viz*., No water stress (W_1), water stress at tillering (W_2), water stress at flowering (W_3) and water stress at grain filling stage (W_4) as main plot and four biochar levels (0, 2, 3 and 4 t/ha) as sub plot were tested in SPD with three replications. In water stress treatments, water stress was imposed at tillering, flowering and grain filling stage of the crop as per treatments, whereas in no water stress six irrigations were provided at critical growth stages of wheat. Biochar was prepared at the Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur from the twigs of trees, weeds and agricultural waste. Biochar was applied as per treatments and mixed well in soil prior to sowing of the crop. Recommended dose of fertilizers *i.e*., 90 kg N, 60 kg P_2O_5 and 40 kg K_2O / ha were applied through commercial fertilizers *viz*., urea, DAP and MOP. Estimation of proline, chlorophyll and relative water content (RWC) in leaves.

Data were analysed statistically for analysis of variance (ANOVA). Treatments were compared by computing the 'F-test'. The significant differences between treatments were compared by critical difference at 5% level of probability [12].

Chart 1. Physiological/Biochemical process

S. No.	Physiological/Biochemical process	References
1.	Proline	Bates et al. [10]
2.	Chlorophyll	SPAD
3.	Relative water content (RWC)	Barrs and Weatherley [11]

3. RESULTS AND DISCUSSION

3.1 Proline Content at 10 Days After Water Stress

A perusal of the data (Table 1) revealed that water stress caused significant variation in proline contents in leaves. At tillering 10 days after water stress, significantly higher proline content was recorded under water stress (8.59µg g^{-1}) over control (7.33µg g^{-1}), water stress at flowering (7.48µg g^{-1}) and grain filling (7.41µg g^{-1}). Whereas, significantly higher proline content was recorded at 10 days after water stress at flowering under treatment water stress at flowering over control (8.48µg g^{-1}), water stress at tillering (8.82µg g^{-1}) and water stress at grain filling (8.62µg g^{-1}). At 10 days after water stress at grain filling, water stress at grain filling treatment (9.39µg g^{-1}) recorded significantly higher proline content over rest of the treatments. These results are conformity with the result obtain by Hafez et al., [13] and Chowdhury et al., [14]. Application of biochar failed to register any significant variation in proline content at all the three stages of proline estimation.

3.2 Chlorophyll Content at 10 Days After Water Stress

Water stress treatments brought about significant variation in chlorophyll content (SPAD) at 10 days after water stress at tillering and flowering stages Whereas, water stress treatments didn't alter SPAD reading for chlorophyll at 10 days after grain filling stage of crop over control. At 10 days after water stress at tillering and flowering, significantly higher SPAD reading was recorded for chlorophyll under water stress treatments over no water stress. All the water stress treatments were at par with each other in respect of SPAD reading for chlorophyll content in leaves at all the three stages. Application of biochar didn't significantly influence chlorophyll content in leaves at 10 days after water stress at tillering, flowering and grain filling over control (Table 1).

Table 1. Effect of Water Stress and Biochar on Proline, Chlorophyll and Relative Water Content (RWC) in Lea

Treatments	Proline content (µg g^{-1})			Chlorophyll content (SPAD)			RWC (%)		
	Water stress at tillering (after 10 days)	Water stress at flowering (after 10 days)	Water stress at grain filling (after 10 days)	Water stress at tillering (after 10 days)	Water stress at flowering (after 10 days)	Water stress at grain filling (after 10 days)	Water stress at tillering (after 10 days)	Water stress at flowering (after 10 days)	Water stress at grain filling (after 10 days)
Water stress									
W_0	7.33	8.48	8.90	53.81	54.03	55.66	54.37	56.91	59.50
W_1	8.59	8.82	8.96	56.16	56.35	54.90	51.76	56.12	58.66
W_2	7.48	9.42	9.00	55.93	56.12	54.67	54.24	53.53	58.96
W_3	7.41	8.62	9.39	56.22	56.42	54.96	54.62	56.93	55.87
SEm±	0.11	0.11	0.05	0.50	0.52	0.50	0.49	0.62	0.60
CD (P=0.05)	0.39	0.38	0.17	1.73	1.81	NS	1.68	2.13	2.07
Biochar application									
Control	7.83	8.96	9.08	55.49	55.69	55.07	52.53	53.96	56.70
2 t ha^{-1}	7.75	8.88	9.08	55.68	55.88	55.18	53.89	56.24	57.84
3 t ha^{-1}	7.69	8.82	9.02	55.46	55.66	54.96	54.11	56.46	59.09
4 t ha^{-1}	7.54	8.67	9.05	55.49	55.69	54.99	54.46	56.84	59.35
SEm±	0.08	0.08	0.04	0.49	0.50	0.49	0.47	0.60	0.58
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.36	1.76	1.69
Interaction (W × B)									
SEm±	0.16	0.16	0.07	0.99	0.99	0.97	0.94	1.21	1.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	3.52	NS

*W_0: Control (no water stress) W_1: Water stress at tillering W_2: Water stress at flowering W_3: Water stress at grain filling

3.3 Relative Water Content at 10 Days after Water Stress

At 10 days after water stress at tillering, relative water content (RWC) in leaves significantly reduced under treatment water stress at tillering over control, water stress at flowering and grain filling. Whereas, at 10 days after water stress at flowering, significant reduction in relative water content was recorded in treatment water stress flowering over no water stress, tillering and grain filling stage. Significant decrease in RWC was recorded under water stress at grain filling at 10 days after water stress at grain filling stage over rest of the treatments. Under the moisture stress condition in soil, less water is available to plant for absorption which reduced both turgidity of cell and relative water content. The relative water content and transpiration intensity of leaves decreased. Similar results were recorded by Gupta and Gupta [15] Nezhedahmedi et al. [16] and Meena [17] in wheat crop. Application of biochar at all three stages significantly increased RWC in leaves at 10 days after water stress at tillering, flowering and grain filling stages over control. Further, application of biochar 2 t ha^{-1}, 3 t ha^{-1} and 4 t ha^{-1} were at par with each other in respect of relative water content at all the three stages (Table 1). The data showed that under no water stress, the addition of biochar at 2 t ha^{-1}, 3 t ha^{-1}, and 4 t ha^{-1} significantly increased relative water content (RWC) at 10 days after flowering compared to no water stress. However, only biochar at 3 t ha^{-1} was superior to the control. Biochar at 2 t ha^{-1} was superior under water stress at tillering. Under water stress at flowering, biochar at 2 t ha^{-1} was significantly superior to the control. Biochar at 4 t ha^{-1} also significantly increased RWC at 10 days after flowering compared to biochar at 3 t ha^{-1} under water stress at grain filling.

4. CONCLUSION

The study concludes that water stress significantly increased proline content in wheat leaves at different growth stages, while biochar application did not alter proline content. Additionally, water stress reduced chlorophyll content and relative water content (RWC), whereas biochar application mitigated these effects, enhancing RWC uniformly across different application rates.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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