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Enhancing *Triticum aestivum* Growth ParamSeedeters and Alleviating Cadmium Toxicity through Biochar Priming

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Abstract: Heavy metal contamination, particularly from cadmium, poses serious risks to food security and human health. This study explores the use of biochar, a carbon-rich material from plant waste, as a strategy to mitigate cadmium toxicity in wheat seedlings. By treating seeds with various concentrations of biochar before exposure to cadmium, the research assessed growth, photosynthesis, and antioxidant activity. Findings indicate that biochar priming significantly alleviated cadmium's negative effects, enhancing germination, seedling growth, and photosynthetic efficiency. Additionally, biochar increased the activity of guaiacol peroxidase, an enzyme crucial for detoxifying reactive oxygen species. Overall, biochar priming shows promise for sustainable agriculture by reducing heavy metal toxicity in crops.

Introduction: The 10% sodium hypochlorite solution was used to clean the surface of the healthy seeds of wheat for 10 min followed by a continuous washing with double distilled water. This research was conducted in 2023 at Razi University based on completely randomized designs. Wheat seeds were primed with varying concentrations of biochar (0, 0.5, 1, and 2 g/L) before being exposed to different cadmium concentrations (0, 100, and 200 mg/L). Each treatment was replicated three times, and the number of germinated seeds was counted daily. The study assessed various parameters, including germination rate, seedling growth, photosynthetic pigment levels (Chl a, b and carotenoids), antioxidant enzyme activities (guaiacol peroxidase and catalase), and hydrogen peroxide levels. The analysis of data was conducted through SPSS software, and mean values were compared utilizing Duncan's test, with the findings detailed in Table 1.

Results and Discussion: Results showed that biochar priming significantly improved germination percentage, seedling dry and fresh weight, chlorophyll content, and antioxidant enzyme activities, particularly at 0.5 and 1 g/L biochar concentrations. This suggests biochar mitigated cadmium toxicity, promoting healthier seedling development. Cadmium stress significantly reduced germination, seedling growth, and photosynthetic pigments (Table 2). However, biochar priming counteracted these negative effects, likely due to its porous structure and functional groups, which may bind cadmium and reduce its bioavailability (muhammad, 2020). The study found that biochar priming, especially at 2 g/L, significantly increased guaiacol peroxidase enzyme activity, leading to enhanced scavenging of hydrogen peroxide radicals. The porous structure and functional groups present in biochar likely contribute to reducing cadmium toxicity and significantly enhancing the aforementioned parameters. This suggests biochar promotes antioxidant defence mechanisms, further mitigating cadmium's damaging effects.

Table 1. F-value of ANOVA for germination, growth vigor, root structure, chlorophyll content, antioxidants enzyme. *$p < 0.05$, **$p < 0.01$, ns = not significant ($p \geq 0.05$).

Parameters	Biochar × cadmium	cadmium	Biochar
Germination Rate (%)	1.7ns	17.41**	69.47 **
Root Fresh Weight (gr)	21.42**	39.05**	18.88**
Leaf Fresh Weight (gr)	11.91**	221.29**	19.52**
Root Length (cm)	9.48**	270.62**	25ns
Leaf Height (cm)	2.81*	157.48**	7.54**
Root Dry Weight (gr)	11.52**	19.01**	8.78**
Leaf Dry Weight (gr)	1.91**	23.99**	19.02**
Chl-a (mg g-1 F.W.)	1.81*	63.64**	6.07**
Chl-b (mg g-1 F.W.)	1.47ns	21.41**	2.145ns
Carotenoids (mg g-1 F.W.)	1.32ns	21.12**	5.39**
Total protein (mg/g -1FW)	8.47**	123.34**	4.77*
Catalase (u/g FW)	1.32ns	1.32ns	1.32ns
Guaiacol peroxidase (u/g FW)	0.13ns	8.54**	0.78ns
Hydrogen peroxide (mol gr-1µ)	4.12*	59.92**	6.11**

Materials and methods: The 10% sodium hypochlorite solution was used to clean the surface of the healthy seeds of wheat for 10 min followed by a continuous washing with double distilled water. This research was conducted in 2023 at Razi University based on completely randomized designs. Wheat seeds were primed with varying concentrations of biochar (0, 0.5, 1, and 2 g/L) before being exposed to different cadmium concentrations (0, 100, and 200 mg/L). Each treatment was replicated three times, and the number of germinated seeds was counted daily. The study assessed various parameters, including germination rate, seedling growth, photosynthetic pigment levels (Chl a, b and carotenoids), antioxidant enzyme activities (guaiacol peroxidase and catalase), and hydrogen peroxide levels. The analysis of data was conducted through SPSS software, and mean values were compared utilizing Duncan's test, with the findings detailed in Table 1..

ConclusionL: Biochar priming effectively alleviated cadmium toxicity in wheat seedlings, promoting germination, growth, and physiological parameters. This research highlights the potential of biochar as a sustainable strategy for reducing heavy metal contamination and improving crop productivity.

Keywords: *Seed priming, Biochar, cadmium toxicity, Plant resistance*

Table2. The effect of seed Priming on germination parametr, photosynthetic pigments, and antioxidant enzyme levels.

Parameters	Cadmium 200				Cadmium 200				Cadmium 0			
	BC 2	BC 1	BC 0.5	BC 0	BC 2	BC 1	BC 0.5	BC 0	BC 2	BC 1	BC 0.5	BC 0
Germination Rate (%)	56b	53b	46b	30c	76ab	80ab	80ab	50c	80ab	86ab	90a	73b
Root Fresh Weight (gr)	0.35cde	0.26bc	0.19ab	0.14a	0.36def	0.41de	0.35cde	0.3cd	0.55f	0.75g	0.96h	0.42e
Leaf Fresh Weight (gr)	0.59fg	0.39gh	0.29h5	0.25i	o.66de	0.71d	0.56dde	0.57ef	0.92c	1.12b	1.29a	0.7de
Root Length (cm)	4.46fg	3.86gh	2.66hi	1.67i	8d	8d	7de	5.66ef	10c	12b	14a	14a
Leaf Height (cm)	5.63fg	4.66gh	3.66hi	2.36i	8e	8e	7ef	5.86fg	10e	12d	12d	10.33de
Root Dry Weight (gr)	0.034cde	0.02fg	0.013gh	0.019h	0.032dcd	0.04de	0.037def	0.03ce	0.051e	0.075f	0.094a	0.046d
Leaf Dry Weight (gr)	0.054cf	0.03bg	0.024hi	0.023i	o.063de	0.077d	0.051dde	0.053ef	0.098c	0.14b	1.023a	0.07ed
Chl-a (mg g-1 F.W.)	5.06bcd	4.31f	4.43ef	3.17a	5.59dc	5.98cd	6.23ef	4.07fg	7.67a	7.11ab	8.06a	5.42ccd
Chl-b (mg g-1 F.W.)	3.55cd	2.44de	2.72cde	1.46e	3.84bcd	3.58cd	2.65abc	2.69cde	4.31abc	5.75a	5.41ab	4.45abc
Carotenoids (mg g-1 F.W.)	1.66bbc	2.31ab	1.73bcd	2.55a	1.51cd	1.6bbc	2.11cab	1.97cab	0.76a	1.13de	1.15de	1.46cd
Total protein (mg/g -1FW)	41.32de	27.3ef	18.99f	21.1a	43.05d	44.52d	37.32de	32.3def	60.03c	83.41b	103.2a	68.25c
Catalase (u/g FW)	43.32ab	48.3ab	50.29ab	45.59ab	43.15ab	46.6ab	47.17ab	47.66ab	43.7ab	41.7ab	35.44bc	28.76c
Guaiacol peroxidase (u/g FW)	30.41a	31.97a	29.01ab	26.3aab	24.89ab	26.9ab	27.21ab	22.32ab	20.51ab	20.5ab	18.52b	18.26b
Hydrogen peroxide (mol gr-1µ)	19.78ccd	23.7bc	25.73ab	28.16a	16.76efg	18.4fg	19.71cde	21.7cd	14.97fg	14.02g	14.34fg	1.19fg

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