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Potential Effect of Biochar Application on Nutrient Content and Uptake of Wheat (*Triticum aestivum* L.) under Water Stress Condition

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ABSTRACT

A field experiment was conducted at Instructional Agronomy Farm, Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan) during *rabi*, 2021–2022 to assess the effect of water stress and biochar on nutrient content and uptake of wheat (*Triticum aestivum* L.). The experiment consists of four levels of water stress (Control, water stress at tillering, water stress at flowering and water stress at grain filling) as main-plot and four levels of biochar (Control, 2, 3 and 4 t ha^{-1}) as sub-plot conducted in split plot design (SPD) replicated thrice. The experiment results revealed that with no water stress (Control) wheat crop content highest quantum of nutrients i.e., nitrogen, phosphorus and potassium by grain (1.849, 0.350 and 0.476 %) and straw (0.443, 0.1368 and 1.774 %). Biochar application at 4 t ha^{-1} recorded significantly higher quantum of nitrogen, phosphorus and potassium uptake by grain (101.22, 19.08 and 26.22 kg ha^{-1}), straw (31.15, 9.47 and 126.27 kg ha^{-1}) and total (132.37, 28.55 and 152.49 kg ha^{-1}). It is statistically on par with biochar 3 t ha^{-1} application.

Keywords Biochar, Wheat, Water stress, Nutrient uptake, Content.

INTRODUCTION

Wheat belongs to family "*Graminae*" and genus "Triticum". "It is primarily grown in temperate region and at higher altitude under tropical climatic areas in winter season. It requires relatively low temperature for satisfactory growth and development. Wheat is the most important staple food crop of the world and emerged as the backbone of India's food security. Wheat grain contains 10-12% protein, which is more than other cereals. Dry and cool weather is most suitable for this crop. The optimum temperature required for ideal germination of the wheat crop ranges from 20 to 25 ºC. It is an important winter cereal contributing about 38% of the total food grain production in India. In the world, wheat was cultivated in an area of about 221.41 million hectares with a total production of 780.29 million tonnes of grains with productivity of 3.52 t/ha during the year 2021-22. In India, total area was 31.13 million hectares with annual production

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was 109.59 million tonnes of grains during the year 2021-22 with the average productivity of 3.52 t/ha (Anonymous 2023).

Biochar is a carbon-rich solid produced by heating biomass with minimal to no oxygen. It has an aromatic surface, a functional group, and a porous carbonaceous structure. (Tan *et al.* 2016). Biochar made from biomass pyrolysis can change the physicochemical properties of the soil, lower gaseous N emissions, alter soil nutrient availability, reduce nutrient leaching and increase crop yield (Major *et al.* 2010, Zheng *et al.* 2013). Because of its varied composition, the surface of biochar can have hydrophilic, hydrophobic, acidic, or basic characteristics. These traits all impact the biochar's capacity to adsorb soil solution materials, which in turn affects fertilizer retention. By means of the adsorption process, biochar has the potential to enhance nutrient retention (Morales *et al.* 2013, Kumar *et al.* 2024).

MATERIALS AND METHODS

The experiment was conducted during *rabi* season of the year 2021-22 at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, which is situated at 74° 42' E longitude and 24° 35' N latitude with an altitude of 581.13 m above mean sea level. The region falls under NARP agro-climatic zone IVa of Rajasthan, i.e., Sub- Humid Southern Plains and Aravalli Hills. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH 8.1), low in available nitrogen (261.24 kg ha^{-1}) and medium in available phosphorus (17.48 kg ha^{-1}) while high in available potassium status (296.45 kg ha^{-1}). The experiment was conducted in a split-plot design (SPD) with sixteen treatments comprising four levels of water stress viz., control (no water stress), water stress at tillering, water stress at flowering and water stress at grain filling stages and four doses of biochar viz., control, 2, 3 and 4 t ha^{-1} and replicated thrice. Wheat crop variety RAJ-4079 was sown on 30^{th} November 2021 at a seed rate of 125 kg ha^{-1}. Recommended doses of Nitrogen, Phosphorus and potassium i.e., 90, 60 and 40 kg ha^{-1} were supplied through Urea, DAP and MOP. Full dose of phosphorous, potash and half dose of nitrogen were applied as basal. Remaining nitrogen was applied at first irrigation. Six irrigations were applied at critical growth stages, i.e., at crown root initiation, tillering, late jointing, flowering, milking and dough stages in no water stress treatment. Irrigation was skipped at tillering in treatment water stress at tillering, at flowering in treatment water stress at flowering and at grain filling in treatment water stress at grain filling. Biochar was applied before sowing of the crop and mixed in soil as per treatments.

Table 1. Methods for determination of plant nutrients content.

Sl. No.	Nutrient	Method of analysis
1	Nitrogen	Nesseler's reagent colorimeter method (Snell and Snell 1949)
2	Phosphorus	Ammonium vanadomolybdate yellow color method (Richards 1968)
3	Potassium	Flame photometer method (Jackson 1973)

Plant analysis

Nutrient content

For estimation of N, P and K contents, the plant samples were collected at the time of harvest of crop. Plant samples were oven dried at 70 oC for 72 hours to obtain constant weight. Fully dried samples were grinded to fine powder and nutrient contents in grain and straw were estimated as per the method mentioned in Table 1 and expressed as percent.

Nutrient uptake

The total uptake of nitrogen, phosphorus and potassium by grain and straw at harvest was calculated by using the following formula:

$$\text{Nutrient uptake by (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content grain/straw (\%) x Grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

RESULTS AND DISCUSSION

Effect of water stress

Nutrient contents in grain and straw as well as their uptake by the grain, straw and total were significantly reduced under water stress at tillering, flowering and grain filling stages of crop as compared to control

Table 2. Effect of water stress and biochar on nutrient content in wheat.

Treatments	Nutrient content (%)					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
Water stress						
Control (no water stress)	1.849	0.442	0.350	0.1368	0.476	1.774
Water stress at tillering	1.737	0.422	0.332	0.1314	0.454	1.677
Water stress at flowering	1.792	0.433	0.340	0.1308	0.465	1.742
Water stress at grain filling	1.840	0.443	0.346	0.1294	0.465	1.721
SEm±	0.019	0.003	0.003	0.0011	0.003	0.010
CD (P=0.05)	0.064	0.010	0.010	0.0037	0.009	0.033
Biochar application						
Control	1.738	0.419	0.332	0.1270	0.442	1.602
2 t ha^{-1}	1.790	0.432	0.339	0.1317	0.464	1.720
3 t ha^{-1}	1.839	0.443	0.348	0.1348	0.475	1.792
4 t ha^{-1}	1.850	0.445	0.349	0.1350	0.479	1.801
SEm±	0.016	0.003	0.003	0.0009	0.003	0.006
CD (P=0.05)	0.046	0.009	0.008	0.0027	0.008	0.016

(No water stress) Effect of water stress bring about a significant variation in nitrogen, phosphorus and potassium content in grain and straw of wheat but the crop accumulated the highest quantum of nutrients i.e., nitrogen, phosphorus and potassium by grain (1.849, 0.350 and 0.476 %), Straw (0.443, 0.1368 and 1.774 %) and total uptake (137.35, 29.99 and 158.81 kg ha^{-1}) by crop with the application of control (No water stress) as compare to other water stress treatments (Table 2 & 3).

Table 3. Effect of water stress and biochar on nutrient uptake of wheat.

Treatments	Nutrient uptake (kg ha^{-1})								
	Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Water stress									
Control (no water stress)	104.53	32.82	137.35	19.82	10.17	29.99	26.94	131.87	158.81
Water stress at tillering	84.33	26.73	111.06	16.10	8.33	24.43	22.04	106.39	128.43
Water stress at flowering	91.62	28.27	119.89	17.39	8.54	25.93	23.79	113.96	137.76
Water stress at grain filling	94.89	29.20	124.09	17.85	8.53	26.38	24.02	113.64	137.66
SEm±	2.19	0.48	1.96	0.44	0.20	0.42	0.56	2.30	2.26
CD (P=0.05)	7.57	1.65	6.79	1.53	0.70	1.45	1.95	7.95	7.82
Biochar application									
Control	84.04	26.25	110.29	16.05	7.93	23.99	21.38	100.20	121.58
2 t ha^{-1}	90.12	28.79	118.91	17.09	8.78	25.87	23.38	114.69	138.07
3 t ha^{-1}	99.98	30.84	130.82	18.95	9.38	28.33	25.81	124.70	150.51
4 t ha^{-1}	101.22	31.15	132.37	19.08	9.47	28.55	26.22	126.27	152.49
SEm±	1.17	0.34	1.11	0.25	0.13	0.24	0.24	1.54	1.46
CD (P=0.05)	3.41	0.99	3.25	0.73	0.39	0.69	0.69	4.49	4.27

Water stress imposed at various growth phases also reduced relative water content in plant. The plant water relation parameters i.e., RWC shows that due to shortage of moisture these might be reduction in nutrient uptake by the stressed plant. Zhao *et al.* (2009) also reported the same result in respect of nutrient concentrations in wheat. Thus, enhanced uptake of nitrogen, phosphorus and potassium in grain, straw and total uptake by the crop under no water stress seems to be in accordance with overall important in growth, productivity and increase in nutrient concentration in plant under no water stress condition. The results are in close agreement with these of kumar and pannu (2012) and shah *et al.* (2017).

Effect of biochar

The results (Tables 2 and 3) showed that biochar application significantly improved the nitrogen status of both grain and straw. This improvement can be attributed to the efficient extraction and translocation of nutrients, resulting from increased root activity and ramification, as biochar plays a crucial role in maintaining the physico-chemical and biological properties of soils. The application of biochar at rates up to 4 t ha^{-1} significantly increased the uptake of nitrogen, phosphorus, and potassium by the grain (1.850%, 0.349%, and 0.479%, respectively), the straw (0.445%, 0.1350%, and 1.801%, respectively), and the total uptake by the crop (132.37, 28.55, and 152.49 kg ha^{-1}, respectively) compared to the control.

Biochar application caused significant improvement in organic carbon and available nutrient contents (Nitrogen, Phosphorus and Potassium) in soil after harvest of crop over control. Biochar improved soil chemical properties because of its ability to absorb soluble organic matter and inorganic nutrients (Thies and Rillig 2009). Lehmann and Rondon (2006) reported that biochar can adsorb both NH4+ and NH3- from the soil solution. Biochar is very efficient at adsorbing dissolved solute nutrients such as ammonium (Lehmann *et al.* 2002), nitrate (Mizuta *et al.* 2004), phosphate, and other ionic solutes (Radovic *et al*. 2001). Biochar as reported by (Xu *et al.* 2014, Jia *et al.* 2015) can absorb leachate which can help to absorb organic matter, total soluble N, plant available P, and K, thereby increasing the nutrient retention capacity of the soil.

CONCLUSION

Based on the above summarized results, it can be concluded that water stress at critical growth stages like tillering, flowering, and grain filling significantly reduces the nutrient content and uptake of nitrogen, phosphorus, and potassium in both the grain and straw of wheat compared to crops grown without water stress. However, the application of biochar, particularly at a rate of up to 4 t ha^{-1}, plays a crucial role in improving the nitrogen, phosphorus, and potassium uptake by enhancing root activity and improving soil properties. Thus, biochar can help mitigate the negative effects of water stress and improve nutrient content and uptake.

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