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Research Article

Effect of Water Stress Levels and Hydrogel Application on Nutrient Content and Uptake of Wheat (*Triticum aestivum* L.)

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Abstract

A field experiment entitled was conducted during rabi 2025–26 at the Research Farm, Vivekananda Global University, Jaipur, Rajasthan, to evaluate the effect of different levels of water stress and hydrogel application on nutrient content and nutrient uptake of wheat. The experiment was laid out in a factorial randomized block design with three replications comprising four water stress levels and four hydrogel levels. The results revealed that water stress significantly influenced nutrient concentration and nutrient uptake in wheat. The highest nitrogen (1.82 and 0.43%), phosphorus (0.343 and 0.143%) and potassium content (0.58 and 1.75%) in grain and straw, respectively, were recorded under W1, whereas the lowest values were observed under W2. Hydrogel application caused a slight increase in nutrient content; however, the effect was statistically non-significant. Nutrient uptake by grain and straw was significantly affected by both water stress and hydrogel levels. Among water stress treatments, W1 recorded the highest total nitrogen (129.63 kg ha^{-1}), phosphorus (28.45 kg ha^{-1}) and potassium uptake (144.79 kg ha^{-1}). Among hydrogel treatments, H4 recorded maximum total nitrogen (124.51 kg ha^{-1}), phosphorus (26.98 kg ha^{-1}) and potassium uptake (136.69 kg ha^{-1}). The study indicated that hydrogel application improved nutrient uptake and helped mitigate the adverse effects of moisture stress by enhancing soil moisture availability.

Keywords: Moisture stress, Super absorbent polymer, Nutrient uptake, Water retention

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops and serves as a staple food for nearly one-third of the world's population. In India, wheat occupies about 31.23 million ha with a production of 112.92 million tonnes and an average productivity of 3615 kg ha^{-1} (Hindustan Times, 2024). In Rajasthan, it is cultivated over 3.12 million ha with a productivity of 3938 kg ha^{-1} (CEIC Data, 2024). Owing to its high nutritional value and excellent processing quality, wheat plays a vital role in food and nutritional security. Water scarcity is one of the major constraints limiting wheat productivity, particularly in arid and semi-arid regions. Drought stress adversely affects physiological and biochemical processes, resulting in poor growth and reduced grain yield (Farooq *et al*., 2014). Under limited irrigation conditions, moisture deficit at critical growth stages significantly decreases yield and nutrient uptake (Prasad et al., 2017; Hussain et al., 2017). Therefore, efficient management practices are essential to improve water-use efficiency and sustain wheat production under water-stress conditions.

Hydrogel, a hydrophilic polymer capable of absorbing and retaining large quantities of water, has emerged as an effective soil amendment for moisture conservation (Schacht, 2004). Hydrogel improves soil physical properties, increases water availability, and enhances crop growth under limited water supply (El-Hady and Abo-Sedera, 2006). Application of hydrogel at 5 kg ha^{-1} significantly improved soil moisture characteristics and plant available water (Narjary and Aggarwal, 2014). Studies have reported that hydrogel application enhances root growth, relative water content, grain yield, nutrient uptake and water-use efficiency in wheat under moisture stress conditions (Dorraji et al., 2010; Ekebafe et al., 2011; Tyagi et al., 2015). Moreover, eco-friendly hydrogels contribute to sustainable agriculture by improving soil health and reducing irrigation requirements (Sivapalan, 2006). Information on the interaction between water stress levels and hydrogel application on nutrient uptake of wheat under semi-arid conditions of Rajasthan is limited. Therefore, the present investigation was undertaken to evaluate the effect of water stress and hydrogel application on nutrient content and nutrient uptake of wheat.

Material and Methods

A field experiment entitled was conducted during the rabi season of 2025–26 at the Research Farm, Vivekananda Global University, Jaipur, Rajasthan, India. The experimental site is situated in the semi-arid region of Rajasthan and experiences subtropical climatic conditions characterized by low rainfall and high evaporative demand. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications comprising sixteen treatment combinations involving four levels of water stress (W1, W2, W3 and W4) and four levels of hydrogel application (H1, H2, H3 and H4). Recommended agronomic practices and plant protection measures were adopted uniformly for all treatments. Hydrogel was applied in the soil according to the treatment schedule at the time of sowing. Irrigation treatments were imposed at different critical growth stages to create varying levels of water stress. The recommended dose of fertilizers (120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}) was applied through suitable fertilizer sources. Half of the nitrogen and the full dose of phosphorus and potassium were applied as basal, while the remaining nitrogen was top-dressed in two equal splits at the crown root initiation and first node stages.

Observations on growth and yield parameters were recorded periodically. After harvest, grain and straw samples were analyzed for nitrogen, phosphorus and potassium contents following standard procedures. Nitrogen content was determined by the Kjeldahl method, phosphorus by the vanadomolybdate yellow colour method and potassium by flame photometry. Nutrient uptake by grain and straw was calculated by multiplying nutrient concentration with their respective dry matter yields. The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for Factorial Randomized Block Design as described by Gomez and Gomez (1984). The significance of treatment effects was tested at the 5 per cent level of probability, and critical difference (CD) values were calculated wherever the F-test was found significant.

Table 1 Effect of water stress and hydrogel on nutrient Content and uptake by wheat

Treatment	Nutrient Content (%)						Nutrient uptake (Kg ha^{-1})								
	Nitrogen		Phosphorus		Potassium		Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Water Stress															
W_1	1.82	0.43	0.343	0.143	0.58	1.75	102.04	27.58	129.63	19.29	9.16	28.45	32.55	112.24	144.79
W_2	1.70	0.41	0.325	0.135	0.55	1.67	82.15	22.48	104.64	15.64	7.42	23.06	26.56	91.29	117.85
W_3	1.76	0.42	0.333	0.139	0.57	1.71	89.35	23.81	113.17	16.92	7.85	24.76	28.72	96.72	125.45
W_4	1.81	0.43	0.339	0.141	0.57	1.71	92.69	24.58	117.26	17.37	8.03	25.40	28.98	97.27	126.25
SEm±	0.022	0.003	0.003	0.001	0.004	0.012	2.23	0.57	2.08	0.42	0.18	0.39	0.60	2.08	1.72
CD (P=0.05)	0.098	0.014	0.013	0.005	0.018	0.055	10.03	2.57	9.36	1.88	0.81	1.75	2.69	9.38	7.73
Hydrogel															
H_1	1.74	0.42	0.332	0.138	0.56	1.68	81.97	22.26	104.23	15.64	7.34	22.98	26.24	89.27	115.50
H_2	1.76	0.42	0.335	0.140	0.57	1.71	89.71	24.57	114.28	17.10	8.14	25.24	28.80	99.44	128.25
H_3	1.79	0.43	0.336	0.140	0.57	1.72	96.08	25.60	121.68	18.05	8.43	26.48	30.55	103.35	133.90
H_4	1.80	0.43	0.337	0.140	0.57	1.73	98.48	26.03	124.51	18.42	8.56	26.98	31.23	105.46	136.69
SEm±	0.016	0.003	0.003	0.001	0.004	0.012	1.81	0.51	1.84	0.29	0.18	0.34	0.50	2.07	2.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	8.15	2.30	8.29	1.32	0.80	1.54	2.27	9.33	9.52

Result and Discussion

Water stress significantly influenced the nutrient content of wheat grain and straw (**Table 1**). Among different water regimes, W1 recorded the highest nitrogen content in grain (1.82%) and straw (0.43%), phosphorus content in grain (0.343%) and straw (0.143%), and potassium content in grain (0.58%) and straw (1.75%). The lowest nutrient content was observed under W2, which recorded 1.70 and 0.41% nitrogen, 0.325 and 0.135% phosphorus, and 0.55 and 1.67% potassium in grain and straw, respectively. The reduction in nutrient concentration under severe moisture stress may be attributed to restricted nutrient absorption and translocation due to lower soil moisture availability. Hydrogel application exhibited a marginal increase in nutrient concentration; however, the differences among hydrogel levels were statistically non-significant. Nevertheless, application of H4 recorded relatively higher nitrogen content (1.80 and 0.43%), phosphorus content (0.337 and 0.140%) and potassium content (0.57 and 1.73%) in grain and straw, respectively. The improved moisture availability due to hydrogel might have facilitated better nutrient absorption and utilization. Similar findings were reported by Tyagi et al. (2015) and Ekebafe et al. (2011), who observed enhanced nutrient availability and improved crop performance under hydrogel application.

Water stress levels exerted a significant effect on nutrient uptake by wheat (**Table 2**). Among the irrigation treatments, W1 recorded the highest nitrogen uptake in grain (102.04 kg ha^{-1}), straw (27.58 kg ha^{-1}) and total uptake (129.63 kg ha^{-1}). Similarly, phosphorus uptake was maximum under W1 with values of 19.29, 9.16 and 28.45 kg ha^{-1} in grain, straw and total uptake, respectively. Potassium uptake also followed the same trend, recording the highest total uptake (144.79 kg ha^{-1}) under W1. The lowest nutrient uptake was observed under W2. Higher nutrient uptake under favourable moisture conditions might be due to improved root growth, greater dry matter production and enhanced nutrient mobility in soil. Hydrogel application significantly increased nutrient uptake by wheat. Application of H4 recorded the maximum nitrogen uptake in grain (98.48 kg ha^{-1}), straw (26.03 kg ha^{-1}) and total uptake (124.51 kg ha^{-1}), followed closely by H3. Similarly, H4 resulted in maximum phosphorus uptake (18.42, 8.56 and 26.98 kg ha^{-1}) and potassium uptake (31.23, 105.46 and 136.69 kg ha^{-1}) in grain, straw and total, respectively. The increase in nutrient uptake with hydrogel application could be attributed to improved soil moisture retention, enhanced root proliferation and greater nutrient availability throughout the crop growth period. These findings are in agreement with the reports of Dorraji et al. (2010), Tyagi et al. (2015) and Narjary and Aggarwal (2014), who observed increased nutrient uptake and improved water-use efficiency in wheat with hydrogel application.

Conclusion

Water stress significantly affected nutrient content and uptake in wheat. Adequate moisture availability (W1) resulted in higher nitrogen, phosphorus and potassium content and uptake, while moisture stress reduced nutrient absorption. Hydrogel application improved nutrient uptake, although its effect on nutrient concentration was non-significant. The highest hydrogel level (H4) recorded maximum nutrient uptake, indicating enhanced soil moisture retention and nutrient availability. Thus, hydrogel application can mitigate the adverse effects of water stress and may be an effective and sustainable strategy for improving wheat productivity under limited irrigation conditions in arid and semi-arid regions.

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