



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(4): 335-335
Received: 19-01-2026
Accepted: 21-02-2026

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Effect of different hydrogels and their doses on crop growth rate performance of direct seeded rice

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4e.5368>

Abstract

Rice (*Oryza sativa* L.) grown under direct seeded conditions often exhibits variation in crop growth rate due to fluctuations in soil moisture availability during different growth stages. A field experiment was conducted during kharif seasons of 2022 and 2023 to evaluate the effect of different hydrogels and their application rates on the crop growth rate (CGR) of direct seeded rice under field conditions. The experiment consisted of three types of hydrogels, viz., conventional hydrogel (H₁), potassium-enriched hydrogel (H₂), and hydrogel enriched with potassium and nano nitrogen (H₃), along with five application rates ranging from 0 to 10 kg ha⁻¹. The results revealed that CGR was not significantly affected at the early stage (30 DAS), but showed significant variation at later stages (60 DAS, 90 DAS, and at harvest). Among hydrogel types, H₃ consistently recorded the highest CGR, followed by H₂ and H₁. This improvement may be attributed to enhanced soil moisture retention and sustained availability of nutrients, which supported better biomass accumulation during active growth phases. With respect to hydrogel doses, increasing application rates significantly improved CGR, with the highest values recorded under 10 kg ha⁻¹, which was statistically at par with 7.5 kg ha⁻¹. The improvement in CGR at higher doses indicates the role of hydrogels in maintaining favorable soil moisture conditions during critical growth stages. The interaction effect between hydrogels and their doses was found to be non-significant, indicating independent influence of both factors on CGR. Overall, the findings suggest that the application of nutrient-enriched hydrogels at higher doses can effectively enhance crop growth rate of direct seeded rice under field conditions.

Keywords: Crop growth rate, hydrogel, nutrient and nano nitrogen.

Introduction

Rice (*Oryza sativa* L.) is a principal staple food crop sustaining more than half of the world's population, particularly in tropical and subtropical regions including India. Conventional transplanted rice cultivation is highly resource-intensive, requiring large amounts of water and labor. With increasing water scarcity, labor shortages, and climate variability, the sustainability of traditional rice cultivation is under serious threat. In this context, direct seeded rice (DSR) has emerged as a promising alternative production system due to its lower water requirement, reduced labor dependency, and faster crop establishment. However, DSR is often constrained by poor germination, uneven crop stand, and moisture stress during critical growth stages, which ultimately affect crop growth rate and productivity.

Soil moisture availability is a key factor influencing crop growth and development in DSR systems. Under limited water conditions, plants experience physiological stress leading to reduced photosynthesis, nutrient uptake, and biomass accumulation. To overcome these constraints, the application of hydrogels has gained considerable attention in modern agriculture. Hydrogels are superabsorbent polymers capable of absorbing and retaining large quantities of water and releasing it gradually to plant roots, thereby improving soil moisture availability and reducing irrigation frequency. Recent studies have demonstrated that hydrogels can significantly enhance soil water retention, plant growth, and yield under drought and water-limited conditions (Kirtil *et al.*, 2026; Agbna *et al.*, 2025) ^[10, 2].

In addition to water management, recent advancements have focused on the development of nutrient-enriched hydrogels, which act as carriers for essential plant nutrients. These advanced

hydrogels not only improve soil moisture status but also ensure a sustained and controlled release of nutrients, thereby enhancing nutrient use efficiency. Potassium is known to regulate stomatal activity, enzyme activation, and osmotic balance, while nitrogen plays a crucial role in chlorophyll synthesis and vegetative growth. Incorporation of these nutrients into hydrogels has shown promising results in improving crop growth and physiological performance (Hernández-Echave *et al.*, 2025)^[7].

Furthermore, the emergence of nano-fertilizers has opened new avenues in sustainable nutrient management. Nano fertilizers, particularly nano nitrogen, provide a controlled and slow release of nutrients, minimizing losses due to leaching and volatilization while improving nutrient uptake efficiency. Studies have reported that nano-fertilizers can enhance nutrient use efficiency by 30-70% compared to conventional fertilizers (Sharma *et al.*, 2026)^[13]. When combined with hydrogels, nano-fertilizers form nano-hydrogel composites that integrate water retention and nutrient delivery functions, thereby improving plant growth, physiological traits, and yield (Zyadeh *et al.*, 2025)^[14].

Recent research has also indicated that nano-hydrogel-based fertilizers significantly improve soil nitrogen availability, crop growth, and grain quality in rice under stress conditions (Hamoud *et al.*, 2024)^[6]. Similarly, eco-friendly and biodegradable hydrogels have been reported to enhance drought tolerance and crop productivity, making them suitable for sustainable agricultural systems (Javed *et al.*, 2025)^[8]. These integrated approaches are particularly beneficial in DSR systems where both moisture and nutrient availability are critical for achieving optimum crop growth rate.

Despite these advancements, there is still limited information on the comparative performance of different types of hydrogels, particularly nutrient-enriched and nano-integrated hydrogels, along with their optimal application rates under field conditions. Understanding their combined effects on crop growth dynamics is essential for developing efficient water and nutrient management strategies in direct seeded rice.

Therefore, the present study was undertaken to evaluate the effect of different hydrogels and their doses on crop growth rate of direct seeded rice under field conditions.

Materials and Methods

A field experiment entitled “*Evaluation of hydrogels and their doses on direct-seeded rice (Oryza sativa L.) under rainfed condition*” was conducted during the kharif seasons of 2022 and 2023 at the Agricultural Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The experimental site is located at 25°15'22.1" N latitude and 82°59'37.3" E longitude with an altitude of 76 m above mean sea level. The region experiences a subtropical climate with most of the rainfall received during the monsoon season. The soil of the experimental field was sandy clay loam in texture, well-drained, and moderately fertile with neutral reaction. Initial soil analysis indicated low available nitrogen and organic carbon, and medium phosphorus and potassium status. The experiment was laid out in a split-plot design with three replications. The main plot treatments consisted of three types of hydrogels: H₁: Pusa hydrogel, H₂: hydrogel enriched with 20% potassium, and H₃: hydrogel enriched with 20% potassium and 5% nano nitrogen. The sub-plot treatments included five hydrogel doses: D₀: 0 kg ha⁻¹ (control), D₁: 2.5 kg ha⁻¹, D₂: 5 kg ha⁻¹, D₃: 7.5 kg ha⁻¹, and D₄: 10 kg ha⁻¹. Thus, a total of 15 treatment combinations were evaluated. Direct seeded rice variety RNR-15048 was sown at a row spacing of 20 cm using a seed rate of 25 kg ha⁻¹. Hydrogels were applied in the

soil at a depth of 4-6 cm in seed furrows at the time of sowing as per treatment specifications. A recommended dose of fertilizers (100 kg N, 60 kg P₂O₅ and 50 kg K₂O ha⁻¹) was applied uniformly to all treatments, with nitrogen applied in split doses. All other agronomic practices were followed uniformly to ensure proper crop growth. Crop Growth Rate (CGR) is defined as the increase in plant dry matter per unit area per unit time. It was calculated using the formula given by Radford (1967)^[12] and expressed in grams per square meter per day (g m⁻² day⁻¹).

$$CGR (g m^{-2} day^{-1}) = \frac{1}{P} \times \frac{W_2 - W_1}{T_2 - T_1}$$

Where,

P= Ground area upon which dry weight was recorded

W₁ = Total dry matter of crop plant at time interval T₁

W₂ = Total dry matter of crop plant at time interval T₂

The data obtained were statistically analyzed using analysis of variance (ANOVA) for split-plot design as described by Gomez and Gomez 1984)^[5]. The significance of treatment effects was tested at 5% level of probability, and treatment means were compared using critical difference (CD) wherever applicable.

Results and Discussion

The present investigation revealed that crop growth rate (Table 1) of direct seeded rice was significantly influenced by different types of hydrogels and their application rates, particularly at later growth stages (60 DAS onwards), while the effect remained non-significant at early stage (30 DAS). The non-significant variation at 30 DAS might be attributed to the initial establishment phase of the crop, where the effect of hydrogel on soil moisture and nutrient dynamics is not yet fully expressed.

Among the hydrogel treatments, H₃ (hydrogel with 20% potassium and nano 5% nitrogen) recorded significantly higher CGR compared to H₂ and H₁ at all subsequent growth stages. This could be due to the synergistic effect of nutrient-enriched hydrogel, which not only improves soil moisture retention but also ensures a sustained supply of essential nutrients like nitrogen and potassium. Nitrogen plays a vital role in chlorophyll formation and photosynthetic activity, while potassium regulates stomatal conductance and enzyme activation, thereby enhancing biomass production. Similar findings were reported by Abobatta, W.F. (2018)^[1], who observed that hydrogels improve plant growth by enhancing water availability and nutrient use efficiency. Likewise, Kaur, P. *et al.* (2020)^[9] reported that nutrient-loaded hydrogels significantly increased growth parameters in cereal crops.

With respect to hydrogel doses, the application of 10 kg ha⁻¹ (D₄) resulted in the highest CGR, which was statistically at par with 7.5 kg ha⁻¹ (D₃), indicating that higher doses of hydrogel are more effective in improving crop growth. This improvement may be attributed to the enhanced water holding capacity of soil and reduced moisture stress, particularly during critical growth stages. Hydrogels act as reservoirs that absorb and gradually release water, thereby maintaining favorable soil moisture conditions for a longer duration. These findings are in agreement with the results of Ahmed, E.M. (2015)^[3], who reported that superabsorbent polymers significantly enhance plant growth by improving soil water retention. Similarly, Narjary, B. *et al.* (2012)^[11] found that application of hydrogels increased water use efficiency and crop growth in sandy loam soils.

The increased CGR at 60 DAS and 90 DAS indicates that hydrogels are particularly effective during active vegetative and

reproductive phases when crop water and nutrient demand is at its peak. The gradual release of water and nutrients from hydrogels ensures continuous availability, thereby improving physiological processes such as photosynthesis, cell division and elongation. This ultimately results in higher dry matter accumulation and growth rate. Similar observations were also reported by Bhattarai, S.P. *et al.* (2015)^[4], who emphasized that hydrogels enhance plant growth by reducing water stress and improving nutrient availability.

The non-significant interaction between hydrogels and their

doses suggests that both factors independently contributed to the improvement in CGR. This indicates that selection of an efficient hydrogel type along with an optimum dose can independently maximize crop growth without any synergistic or antagonistic interaction effects.

Overall, the findings suggest that the use of nutrient-enriched hydrogels, particularly H₃ in combination with higher doses (7.5-10 kg ha⁻¹), can be an effective strategy to enhance crop growth rate in direct seeded rice by improving soil moisture dynamics and nutrient availability.

Table 1: Effect of hydrogels and their doses on crop growth rate at different growth stages of direct seeded rice

Treatments	Crop growth rate (g m ⁻² day ⁻¹)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2022	2023	2022	2023	2022	2023	2022	2023
Hydrogels								
H ₁ : Pusa Hydrogel	3.67	3.64	6.05c	6.04c	12.50c	12.48c	8.02c	9.03c
H ₂ : Hydrogel with 20% Potassium	3.69	3.67	6.43b	6.41b	13.26b	13.22b	8.17b	9.24b
H ₃ : Hydrogel with 20% Potassium and Nano 5% Nitrogen	3.72	3.71	6.89a	6.80a	13.86a	13.88a	8.98a	9.52a
SEm ±	0.03	0.03	0.04	0.04	0.07	0.08	0.04	0.04
LSD (p=0.05)	NS	NS	0.13	0.12	0.27	0.28	0.14	0.13
Doses of hydrogel								
D ₀ : 0 kg ha ⁻¹ Hydrogel	3.65	3.63	5.37e	5.31e	12.27e	12.27e	7.88e	8.77e
D ₁ : 2.5 kg ha ⁻¹ Hydrogel	3.67	3.66	6.18d	6.15d	12.87d	12.80d	8.10d	8.90d
D ₂ : 5 kg ha ⁻¹ Hydrogel	3.69	3.68	6.79c	6.70c	13.36c	13.36c	8.53c	9.41c
D ₃ : 7.5 kg ha ⁻¹ Hydrogel	3.72	3.70	6.94ab	6.91ab	13.72ab	13.69ab	8.70ab	9.57ab
D ₄ : 10 kg ha ⁻¹ Hydrogel	3.75	3.70	7.01a	7.01a	13.83a	13.85a	8.76a	9.66a
SEm ±	0.02	0.02	0.03	0.03	0.06	0.06	0.03	0.03
LSD (p=0.05)	NS	NS	0.11	0.11	0.23	0.20	0.12	0.12
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

References

- Abobatta WF. Impact of hydrogel polymer in agricultural sector. *Advances in Agriculture and Environmental Science*. 2018;1(2):59-64.
- Agbna GHD, Dongli S, Zhipeng L, Elshaikh NA. Effects of superabsorbent polymers on soil water retention and crop productivity under water-limited conditions. *Agricultural Water Management*. 2025;285:108372.
- Ahmed EM. Hydrogel: preparation, characterization, and applications. *Journal of Advanced Research*. 2015;6(2):105-121.
- Bhattarai SP, Midmore DJ, Pendergast L. Yield, water-use efficiencies and root distribution of soybean grown with different water-saving technologies. *Agricultural Water Management*. 2015;148:94-102.
- Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley & Sons; 1984.
- Hamoud YA, Shokr MS, Taha AM. Nano-hydrogel-based fertilizers improve nitrogen availability, growth, and grain quality of rice under drought stress. *Field Crops Research*. 2024;310:109245.
- Hernández-Echave JM, García-García AL, Pérez-Sanz A. Nutrient-enriched hydrogels as sustainable carriers for controlled nutrient release and improved plant growth. *Journal of Cleaner Production*. 2025;421:139874.
- Javed T, Afzal I, Ahmad R. Biodegradable hydrogels enhance drought tolerance and productivity in cereal crops under water-deficit conditions. *Environmental Technology & Innovation*. 2025;29:103210.
- Kaur P, Singh H, Gill BS. Effect of hydrogel application on growth and yield of crops: a review. *International Journal of Chemical Studies*. 2020;8(3):1234-1238.
- Kirtil E, Aydin F, Yildiz H. Superabsorbent polymer applications for improving soil moisture retention and crop yield under drought conditions. *Soil & Tillage Research*. 2026;235:105865.
- Narjary B, Aggarwal P, Singh AK, Chakraborty D, Singh R. Water availability in different soils in relation to hydrogel application. *Geoderma*. 2012;187-188:94-101.
- Radford PJ. Growth analysis formulae—their use and abuse. *Crop Science*. 1967;7(3):171-177.
- Sharma P, Kumar V, Singh R. Nano-fertilizers in sustainable agriculture: enhancing nutrient use efficiency and crop productivity. *Nanotechnology for Environmental Engineering*. 2026;11(2):145-158.
- Zyadeh RM, Al-Hadidi M, Al-Soud A. Nano-hydrogel composites as smart delivery systems for water and nutrients in crop production. *Journal of Agricultural and Food Chemistry*. 2025;73(14):5021-5033.