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Effect of irrigation and hydrogel levels on yield and economics of wheat (*Triticum aestivum* L.)

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Abstract
The present study was aimed to evaluate the influence of irrigation and hydrogel levels on the yield and economics of wheat (*Triticum aestivum* L.) during *rabi*, 2024-25 at the instructional farm of Dr. Sharadchandra Pawar College of Agriculture, Baramati, Maharashtra, India. Experiment was laid out in split plot design with 4 irrigation levels (CRI, tillering, flowering and milking stage) and 4 hydrogel levels (control, hydrogel application at 2.5, 5 and 7.5 kg ha-1). Results revealed that among irrigation levels three irrigations at CRI, tillering and flowering stage to wheat crop recorded significantly higher number of spike m-2 (327.62), length of spike (9.23 cm), weight of grains spike-1 (1.73 g), grain yield (36.03), straw yield (48.07), biological yield (84.09) and harvest index (43.90) with significantly highest gross monetary returns (₹135700.50 ha^{-1}), net monetary returns (₹49323.50 ha^{-1}) and B: C ratio (1.57) as compared to all other treatments. Among hydrogel levels, hydrogel application @ 5 kg ha-1 recorded significantly higher number of spike m-2 (327.62), weight of grains spike-1 (1.73 g), grain yield (36.03), straw yield (48.07), biological yield (84.09) and harvest index (43.90) with significantly highest gross monetary returns (₹136067 ha^{-1}), net monetary returns (₹47914.50 ha^{-1}) and B: C ratio (1.54).

Keywords: Wheat, irrigation levels, hydrogel, yield, economics and B: C ratio

Introduction
Wheat (*Triticum aestivum* L.), a member of the Poaceae family, is a globally important cereal crop, contributing about 19% of the total calorie intake and serving as a staple food for nearly one-third of the world's population (Tyagi *et al.,* 2015) [14]. In India, it ranks second after rice, with demand projected to reach 140 million tonnes by 2050 (Tripathi *et al.,* 2023) [13]. The crop covered 341.57 lakh hectares in 2023-24, yet significant yield gaps persist among states, highlighting the need for improved productivity through efficient resource management. Water scarcity is an increasing challenge for wheat cultivation in India, making irrigation scheduling crucial for enhancing water use efficiency. Applying irrigation at critical growth stages like crown root initiation (CRI), tillering, flowering, and milking maximizes yield and grain quality (Awasthi *et al.,* 2021; Kaur *et al.,* 2018) [3, 5]. Wheat is particularly sensitive to water stress during critical phases such as stem elongation to booting, anthesis, and grain-filling stages (Zhang and Oweis, 1999) [16]. Hydrogels offer an additional strategy by improving soil moisture retention and availability, particularly under moisture stress (Tyagi *et al.,* 2015) [14]. Its integration with proper irrigation scheduling may provide a sustainable and profitable approach to wheat production under limited water availability.

Materials and Methods
The experiment was conducted during the *rabi* season of 2024-25 at the instructional farm of Dr. Sharadchandra Pawar College of Agriculture, Baramati, Maharashtra, India. Geographically, the experimental site is situated at 18º144' N latitude and 74º527' E longitude and the climatic conditions are characterized by a semi-arid tropical climate and field had clay textural soil.
The field experiment was conducted using a split plot design with 3 replications. It consisted of 16 treatment combinations, involving four irrigation levels i.e. I_1: one irrigation at CRI stage, I_2: two irrigations at CRI and tillering stages, I_3: three irrigations at CRI, tillering, and flowering

stages, and I_4: four irrigations at CRI, tillering, flowering, and milking stages as main plot treatments. The subplots comprised four hydrogel levels i.e. H_1: hydrogel application @ 0 kg ha^{-1}, H_2: hydrogel application @ 2.5 kg ha^{-1}, H_3: hydrogel application @ 5 kg ha^{-1}, and H_4: hydrogel application @ 7.5 kg ha^{-1}. Pusa hydrogel was used in the experiment.

Results and Discussion Yield attributes and yield Effect of irrigation levels

Yield attributes and yield was significantly influenced by irrigation levels. The maximum number of spikes m-2 (327.62), length of spike (9.23 cm), weight of grains spike-1 (1.73 g), grain yield (36.03 q ha^{-1}), straw yield (48.07 q ha^{-1}), biological yield (84.09 q ha^{-1}) and harvest index (43.90%) were obtained with three irrigations applied at CRI, tillering and flowering stages, which was statistically comparable to four irrigations given at CRI, tillering, flowering, and milking stages. In contrast, a single irrigation at the CRI stage produced the lowest number of spikes m-2 (271.77), length of spike (7.45 cm), weight of grains spike-1 (1.20 g), grain yield (25.93 q ha^{-1}), straw yield (36.87 q ha^{-1}), biological yield (62.80 q ha^{-1}) and harvest index (42.69%) (Table. 1 and 2, Fig. 1 and 2).

The improvement in yield and yield attributes with increased irrigation frequency up to three applications can be attributed to better water availability during critical growth stages, which promoted efficient grain filling, vigorous vegetative growth, and higher overall productivity. Similar trends have been reported by Ram and Gupta (2016) [12], Ali *et al.,* (2018) [2], Verma *et al.,* (2022) [15], Kumar *et al.*, (2019) [6] and Ali and Amin (2004) [1].

Effect of hydrogel levels

Among the hydrogel treatments, application of hydrogel at 5 kg ha^{-1} recorded the highest number of spikes m-2 (346.99), weight of grains spike-1 (1.72 g), grain yield (36.24 q ha^{-1}), straw yield (46.14 q ha^{-1}), and biological yield (82.12 q ha^{-1}), along with the maximum harvest index (47.83%). These results were statistically similar with the application of hydrogel at 7.5 kg ha^{-1}, which produced 34.92 q ha^{-1} grain yield, 45.76 q ha^{-1} straw yield, 80.68 q ha^{-1}, biological yield and harvest index of 46.30%. In contrast, the control treatment (0 kg ha^{-1} hydrogel) registered the lowest values for grain yield (25.18 q ha^{-1}), straw yield (38.12 q ha^{-1}), biological yield (63.29 q ha^{-1}) and harvest index (39.78%). Length of spike (cm) was not significantly affected by different irrigation levels (Table. 1 and 2, Fig. 1 and 2).

The improvement in yield attributes with higher hydrogel levels can be attributed to better soil moisture conservation, which enhanced nutrient uptake, photosynthetic efficiency, and plant-water relationships. This, in turn, supported vigorous vegetative and reproductive growth, resulting in higher yield attributes and yield. However, excessive hydrogel may not proportionally increase water-use efficiency, possibly due to saturation effects or impaired soil aeration. These results are consistent with the findings of Kumar *et al.*, (2016) [7], Mane *et al.*, (2017) [9], Patel *et al.,* (2021) [11] and Meena *et al.,* (2022) [10].

Interaction effect

The interaction effect between irrigation and hydrogel levels observed significantly highest number of spike m-2 and weight of grains spike^{-1} (384.46 m^{-2} and 2.07 g) under the combination of three irrigations applied at CRI, tillering and flowering stages with the application of hydrogel at 5 kg ha^{-1} along with grain yield (40.44 q ha^{-1}), straw yield (51.05 q ha^{-1}) and biological yield (91.49 q ha^{-1}). The lowest number of spikes m^{-2} and weight of grains spike^{-1}, grain, straw and biological yield (236.50 m^{-2}, 1.01 g, 19.53 q ha^{-1}, 31.84 q ha^{-1} and 51.37 q ha^{-1}) was recorded with a single irrigation at the crown root initiation stage without hydrogel application. However, length of spike (cm) recorded non-significant interaction effect.

Economics

Effect of irrigation levels

Among the irrigation levels, three irrigations at crown root initiation, tillering, and flowering stages resulted in the highest gross monetary returns (₹1,35,700.50 ha^{-1}), net monetary returns (₹49,323.50 ha^{-1}), and benefit-cost ratio (1.57). This was closely followed by four irrigations at crown root initiation, tillering, flowering, and milking stages. The lowest economic returns and B:C ratio were observed with a single irrigation at the CRI stage (I_1) recorded gross and net returns of ₹ 98112 ha^{-1} and ₹15551 ha^{-1}, respectively, with a B:C ratio of 1.19 (Table. 3, Fig. 3).

This pattern can be attributed to higher grain yield and improved water productivity achieved through adequate water supply during critical growth periods. The yield gains from more frequent irrigations substantially enhanced economic returns, making the practice more profitable. Similar observations were reported by Mahla and Wanjari (2017) [8], who also found that timely and adequate irrigation leads to better productivity and profitability in wheat.

Effect of hydrogel levels

Application of hydrogel @ 5 kg ha^{-1} (H_3) resulted in the highest gross monetary returns (₹1,36,067.00 ha^{-1}), net monetary returns (₹47,914.50 ha^{-1}), and benefit-cost ratio (1.54). The control treatment (H_1), without hydrogel application, registered the lowest economic returns recorded gross returns of ₹ 95753 ha^{-1}, net returns of ₹ 18518.50 ha^{-1}, and a B:C ratio of 1.24. While lowest cost of cultivation obtained from control treatment (Table. 3, Fig. 3).

The positive economic impact of hydrogel application can be attributed to its ability to conserve soil moisture, which supports better crop growth and higher yields. By reducing water stress during dry periods, hydrogel application improves productivity and profitability. These findings are in agreement with the observations of Jat *et al.,* (2005) [4] and Kumar *et al.,* (2019) [6], who also reported that hydrogel use enhances yield and economic returns by improving soil moisture availability.

Interaction effect

Interaction effect between irrigation and hydrogel levels had no statistically significant impact on economics of wheat cultivation.

Table 1: Effect of irrigation and hydrogel levels on No. of spike m-2, length of spike (cm), weight of grains spike-1 (g) of wheat

Sr. No.	Treatments	No. of spike m-2	Length of spike (cm)	Weight of grains spike -1 (g)
A. Main plot (Irrigation levels)				
I1	One irrigation at crown root initiation stage (18-21 DAS)	271.77	7.45	1.20
I2	Two irrigations at crown root initiation and tillering stage (18-21 and 45-50 DAS)	308.15	8.69	1.40
I3	Three irrigations at crown root initiation, tillering and flowering stage (18-21, 45-50 and 60-65 DAS)	327.62	9.23	1.73
I4	Four irrigations at crown root initiation, tillering, flowering and milking stage (18-21, 45-50, 60-65 and 80-85 DAS)	326.25	9.10	1.73
	S.Em. +	3.73	0.51	0.04
	C.D. at 5%	12.89	1.52	0.14
B. Sub plot (Hydrogel levels)				
H1	Hydrogel @ 0 Kg ha-1 (control)	244.61	8.14	1.29
H2	Hydrogel @ 2.5 Kg ha-1 at basal application	297.54	8.32	1.40
H3	Hydrogel @ 5 Kg ha-1 at basal application	346.99	10.97	1.72
H4	Hydrogel @ 7.5 Kg ha-1 at basal application	344.66	9.76	1.66
	S.Em. +	4.13	0.90	0.03
	C.D. at 5%	12.05	NS	0.08
C. Interaction effect				
	S.Em. +	8.25	2.11	0.05
	C.D. at 5%	24.09	NS	0.15

Table 2: Effect of irrigation and hydrogel levels on grain, straw and biological yield and harvest index of wheat

Sr. No.	Treatments	Grain yield (q ha-1)	Straw yield (q ha-1)	Biological yield (q ha-1)	Harvest index (%)
A. Main plot (Irrigation levels)					
I1	One irrigation at crown root initiation stage (18-21 DAS)	25.93	36.87	62.80	42.69
I2	Two irrigations at crown root initiation and tillering stage (18-21 and 45-50 DAS)	29.95	41.34	71.28	43.25
I3	Three irrigations at crown root initiation, tillering and flowering stage (18-21, 45-50 and 60-65 DAS)	36.03	48.07	84.09	43.90
I4	Four irrigations at crown root initiation, tillering, flowering and milking stage (18-21, 45-50, 60-65 and 80-85 DAS)	34.66	46.32	80.73	43.72
	S.Em. +	1.14	1.53	2.67	-
	C.D. at 5%	3.96	5.30	9.22	-
B. Sub plot (Hydrogel levels)					
H1	Hydrogel @ 0 Kg ha-1 (control)	25.18	38.12	63.29	39.78
H2	Hydrogel @ 2.5 Kg ha-1 at basal application	30.21	42.58	72.79	41.50
H3	Hydrogel @ 5 Kg ha-1 at basal application	36.24	46.14	82.12	47.83
H4	Hydrogel @ 7.5 Kg ha-1 at basal application	34.92	45.76	80.68	46.30
	S.Em. +	1.02	1.37	2.38	-
	C.D. at 5%	2.97	3.99	6.94	-
C. Interaction effect					
	S.Em. +	2.03	2.63	4.76	-
	C.D. at 5%	5.94	7.88	13.62	-

Table 3: Effect of irrigation and hydrogel levels on economics of wheat cultivation

Sr. No.	Treatments	Cost of Cultivation (₹ ha-1)	Gross monetary returns (₹ ha-1)	Net monetary returns (₹ ha-1)	B:C ratio
A. Main plot (Irrigation levels)					
I1	One irrigation at crown root initiation stage (18-21 DAS)	82561.00	98112.00	15551.00	1.19
I2	Two irrigations at crown root initiation and tillering stage (18-21and 45-50 DAS)	84469.00	113074.50	28605.50	1.34
I3	Three irrigations at crown root initiation, tillering and flowering stage (18-21, 45-50 and 60-65 DAS)	86377.00	135700.50	49323.50	1.57
I4	Four irrigations at crown root initiation, tillering, flowering and milking stage (18-21, 45-50, 0-65 and 80-85 DAS)	88285.00	130555.50	42270.50	1.48
	S.Em. +	-	4308.39	4308.39	-
	C.D. at 5%	-	14908.98	14908.98	-
B. Sub plot (Hydrogel levels)					
H1	Hydrogel @ 0 Kg ha-1 (control)	77234.50	95753.00	18518.50	1.24
H2	Hydrogel @ 2.5 Kg ha-1 at basal application	82852.50	114250.50	31398.00	1.38
H3	Hydrogel @ 5 Kg ha-1 at basal application	88152.50	136067.00	47914.50	1.54
H4	Hydrogel @ 7.5 Kg ha-1 at basal application	93452.50	131372.00	37919.50	1.41
	S.Em. +	-	3833.45	3833.45	-
	C.D. at 5%	-	11189.04	11189.04	-
C. Interaction effect					
	S.Em. +	-	7666.89	2534.33	-
	C.D. at 5%	-	NS	NS	-

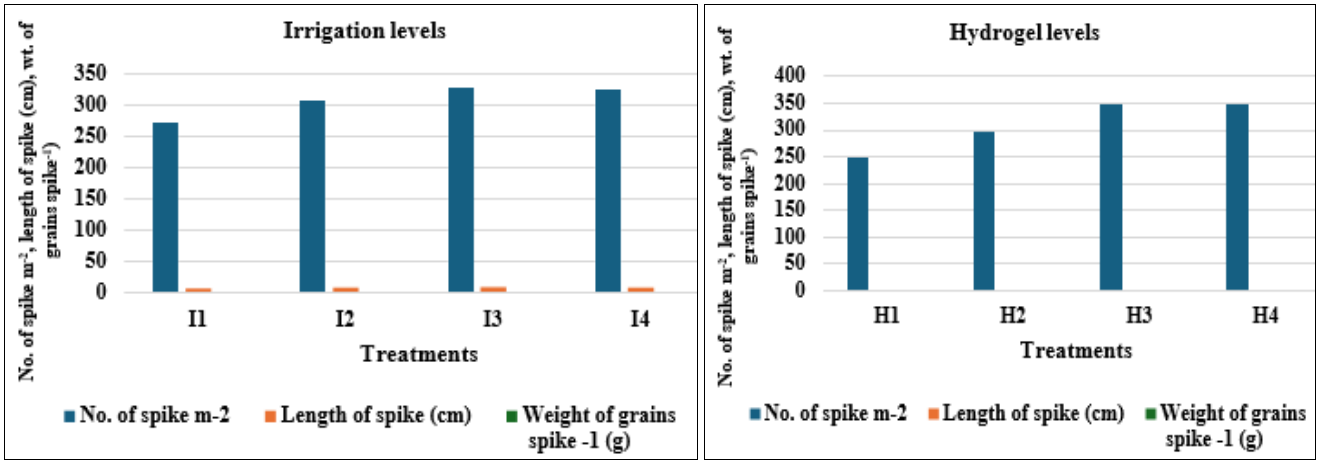

Fig 1: Effect of irrigation and hydrogel levels on No. of spike m-2, length of spike (cm), weight of grains spike-1 (g) of wheat

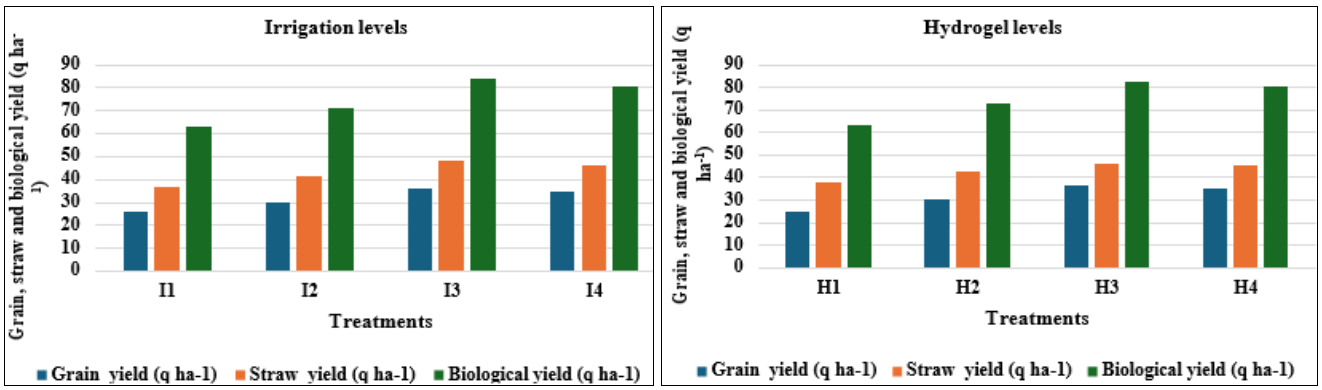

Fig 2: Effect of irrigation and hydrogel levels on grain, straw and biological yield (q ha-1) of wheat

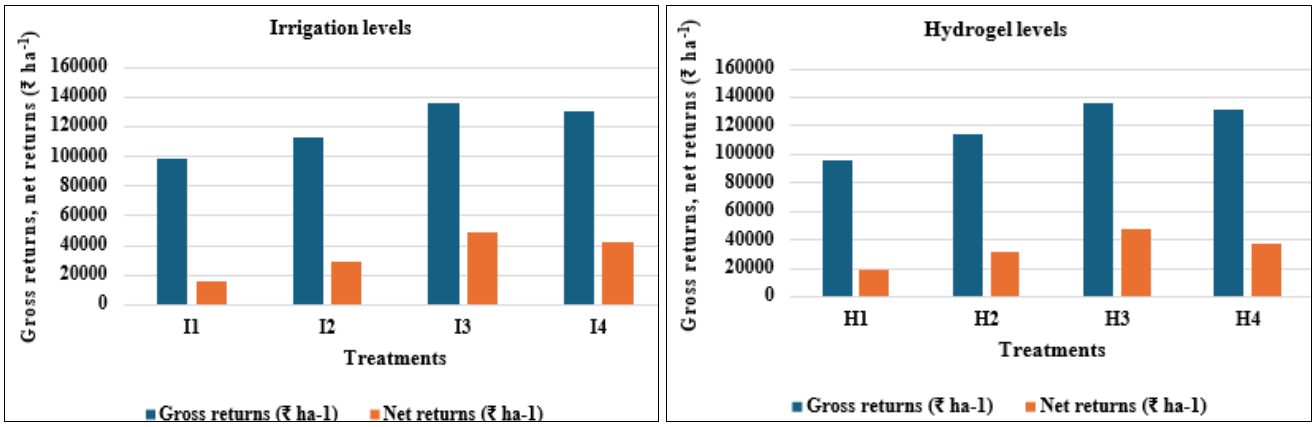

Fig 3: Effect of irrigation and hydrogel levels on economics of wheat cultivation

Conclusion

It is concluded that three irrigations at CRI, tillering and flowering stages with hydrogel application of @ 5 kg ha^{-1} gives significantly best yield attributes and yield as compared to one irrigation at CRI with no hydrogel applied treatment.

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