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Response of Wheat (*Triticum Aestivum* L.) to Different Irrigation Frequencies for Improved Growth and Grain Yield

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ABSTRACT

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A field experiment was conducted during Rabi 2024-25 at the Agronomy Research Farm, Department of Agronomy, Sindh Agriculture University, Tandojam, to evaluate the effect of irrigation frequency on growth and yield of wheat (*Triticum aestivum* L.) cv. Imdad-2005. The experiment was arranged in a randomized complete block design (RCBD) with three replications and five irrigation regimes: I_0 = control (soaking irrigation only), I_1 = two irrigations, I_2 = three irrigations, I_3 = four irrigations and I_4 = five irrigations. Five irrigations produced the highest plant height (90.65 cm), spike length (11.08 cm), grains spike⁻¹ (39.69), grain weight spike⁻¹ (1.909 g), seed index (48.11 g), biological yield (17,956.05 kg ha⁻¹), and grain yield (7,182.42 kg ha⁻¹). Four irrigations resulted in 78.45 cm plant height and 5,985.50 kg ha⁻¹ grain yield, while three and two irrigations produced 5,200.84 and 4,053.49 kg ha⁻¹ grain yield, respectively. The control treatment recorded the lowest values, including 56.46 cm plant height and 1,646.59 kg ha⁻¹ grain yield. Overall, increasing irrigation frequency progressively enhanced wheat growth and productivity. The five-irrigation regime consistently produced the highest values for all measured traits and was therefore identified as the most effective treatment for maximizing growth and grain yield of wheat cv. Imdad-2005 under the conditions of the study.

Introduction

Wheat (*Triticum aestivum* L.) is a globally important staple cereal crop that contributes significantly to food security. It provides essential calories, protein, and micronutrients for human nutrition and livestock feed, particularly in developing countries (Singh et al., 2021; Singh & Sandhu, 2021b; Kaleri et al., 2023). Wheat is valued for its proteins, dietary fiber, vitamins, micronutrients, and antioxidants, which contribute to human health. Increasing wheat production is associated with expanded cultivation and improved agricultural technologies (Sadeghi et al., 2021a; Baloch et al., 2023). In 2023, wheat production increased to 27.634 million tons from 26.208 million tones, reflecting growing demand and improved productivity (GoP, 2023). Wheat productivity is strongly influenced by water availability. Adequate irrigation supports photosynthesis, nutrient uptake, and plant development, whereas water stress during critical stages such as flowering and grain filling can reduce growth and yield. Excessive irrigation may cause water logging, impairing root aeration and nutrient uptake (Rehman et al., 2019; Kumar, 2020). Therefore, proper irrigation timing and frequency are essential for maintaining crop performance, improving water-use efficiency, and conserving water under increasing scarcity. Efficient irrigation is essential for increasing wheat productivity under growing water scarcity. Soil moisture deficits during critical stages such as tillering, booting, heading, and grain filling can reduce grain number, kernel weight, and overall yield (Kanwal et al., 2020; Liu et al., 2020). Appropriate irrigation scheduling can improve water-use efficiency, reduce irrigation requirements and production costs, and sustain crop productivity (Khan et al., 2021). Therefore, optimizing irrigation frequency according to crop water requirements is essential for achieving higher wheat yield and efficient water use (Araya et al., 2019; Zulfiqar et al., 2023). Irrigation is essential for sustaining wheat production, particularly in regions with inadequate or variable rainfall. Timely irrigation supplies water during critical stages such as germination, flowering, and grain filling, thereby improving growth, yield components, and grain production (Bhatta et al., 2020; Ahmed et al., 2023). Effective irrigation also reduces drought stress and supports nutrient uptake and photosynthesis. Moreover, efficient irrigation management can improve water-use efficiency and strengthen wheat production under increasing climate variability and water scarcity (Oweis et al., 2021; Lobell et al., 2021). Irrigation frequency is important for maintaining soil moisture, improving water-use efficiency, and enhancing wheat growth and yield (Khan et al., 2021; Javed et al., 2023). Adequate water supply during critical stages, particularly tillering, flowering, and grain filling, supports physiological processes and yield formation, whereas insufficient irrigation can cause water stress and reduce productivity (Moussa et al., 2023; Payero et al., 2024). Timely irrigation improves yield components and grain production, although excessive irrigation may increase water use and production costs (Sadeghi et al., 2021b; Khan et al., 2020). Therefore, the present study was conducted to evaluate the effect of different irrigation frequencies on wheat growth and yield.

Materials and Methods

The experiment was conducted during the Rabi season of 2024-25 at Agronomy Research Farm, Department of Agronomy, Sindh Agriculture University Tandojam, during 2024-25. The Experimental description is as under:

- Experimental design=Randomized Complete Block
- Replications =03
- Net plot size =6m × 5m (30m²)
- Variety= Imdad-2005

Irrigations frequencies = 05

- I₀ = Control (Soaking dose only)
- I₁= 2 irrigations
- I₂ = 3 irrigations
- I₃= 4 irrigations
- I₄= 5 irrigations

Observations were recorded

1. Plant height (cm)
2. Spike length (cm)

3. Grains spike⁻¹
4. Weight of grain spike⁻¹ (g)
5. Seed index (1000-grain weight, g)
6. Biological yield (kg ha⁻¹)
7. Grain yield (kg ha⁻¹)

Statistical analysis

The collected data was subject to Analysis of variance technique using computer software Statistix Ver. 8.1 (Statistix, 2006). The LSD test was applied to compare treatments superiority, where necessary.

Results

The experiment was conducted during Rabi 2023–24 at the Students' Experimental Farm, Department of Agronomy, Sindh Agriculture University, Tandojam, to evaluate the effect of irrigation frequency on wheat growth and yield. The experiment was arranged in a three-replicated Randomized Complete Block Design (RCBD) with five irrigation treatments: I₀ = control (soaking dose only), I₁ = two irrigations, I₂ = three irrigations, I₃ = four irrigations and I₄ = five irrigations. Data were recorded for plant height, spike length, grains spike⁻¹, grain weight spike⁻¹, seed index, biological yield, and grain yield.

Table 01: Response of Wheat to Different Irrigation Frequencies for Improved Growth and Grain Yield

Irrigations frequencis	Plant height (cm)	Spike length (cm)	Grains spike ⁻¹
I ₀ = control (soaking dose only)	56.46 E	3.83 E	14.67 E
I ₁ = 2 irrigations	61.79 D	6.38 D	23.33 D
I ₂ = 3 irrigations	71.43 C	7.63 C	30.14 C
I ₃ = 4 irrigations	78.45 B	9.43 B	36.15 B
I ₄ = 5 irrigations	90.65 A	11.08 A	39.69 A
P-value	0.0000	0.0000	0.0000
SE±	0.4492	0.0734	0.7818
LSD 0.05	1.0358	0.1693	1.8029

Plant height (cm)

The results were recorded that the plant height (cm) of wheat as affected by different irrigation frequencies are presented in Table .01 and its analysis of variance as Appendix 1. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on plant height (cm). The maximum plant height (90.65 cm) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average plant height 78.45 cm, respectively. Significant decreases in plant height were observed in irrigation that included 3 irrigations (71.43 cm). The plant height was further decreased to (61.79 cm) when wheat was treated with 2 irrigations. Finally, the minimum plant height 56.46 cm was observed with control (soaking dose only).

Spike length (cm)

The results were recorded that the spike length (cm) of wheat as affected by different irrigation frequencies are presented in Table .01 and its analysis of variance as Appendix 2. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on spike length (cm). The maximum spike length (11.08 cm) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average spike length 9.43 cm, respectively. Significant decreases in spike length were observed in irrigation that included 3 irrigations (7.63 cm). The spike length was further decreased to (6.38 cm) when wheat was treated with 2 irrigations. Finally, the minimum spike length 3.83 cm was observed with control plot.

Grains spike⁻¹

The results were recorded that the grains spike⁻¹ of wheat as affected by different irrigation frequencies are presented in Table .01 and its analysis of variance as Appendix 3. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on grains spike⁻¹. The maximum grains spike⁻¹ (39.69) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average grains spike⁻¹ 36.15, respectively. Significant decreases in

grains spike⁻¹ were observed in irrigation that included 3 irrigations (30.14). The grains spike⁻¹ was further decreased to (23.33) when wheat was treated with 2 irrigations. Finally, the minimum grains spike⁻¹ 14.67 was observed with control plot.

Weight of grain spike⁻¹ (g)

The results were recorded that the weight of grain spike⁻¹ (g) of wheat as affected by different irrigation frequencies are presented in Figure .01 and its analysis of variance as Appendix 4. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on weight of grain spike⁻¹ (g). The maximum weight of grain spike⁻¹ (1.909 g) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average weight of grain spike⁻¹ (1.546 g), respectively. Significant decreases in weight of grain spike⁻¹ were observed in irrigation that included 3 irrigations (1.196 g). The weight of grain spike⁻¹ was further decreased to (0.857 g) when wheat was treated with 2 irrigations. Finally, the minimum weight of grain spike⁻¹ (0.463 g) was observed with control plot.

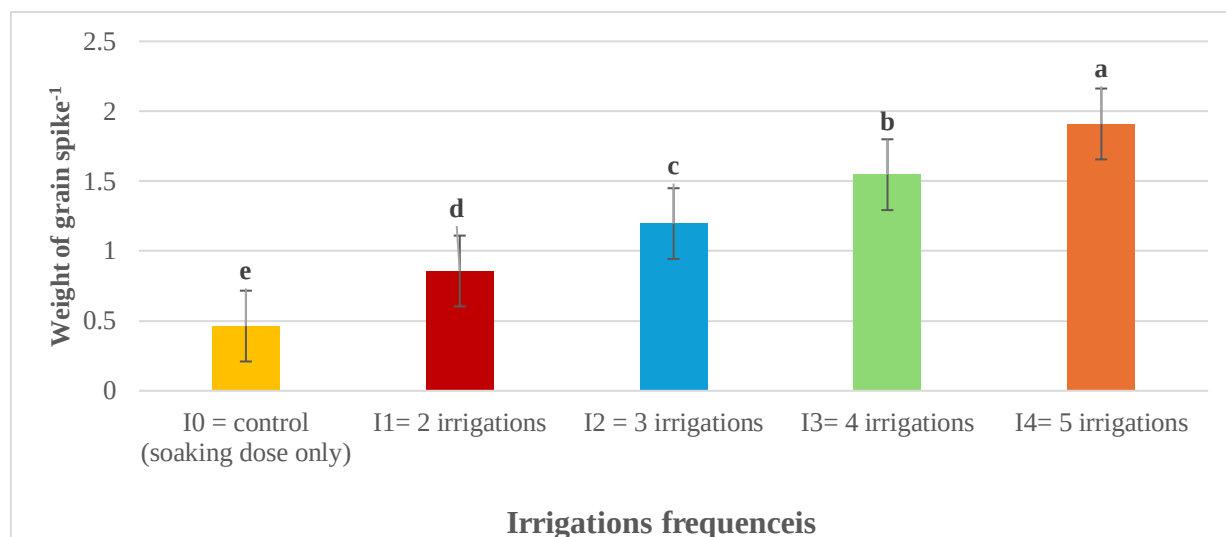


Figure 01: Effect of irrigation frequencies on Weight of grain spike-1 (g) of wheat

Seed index (1000-grain weight g)

The results were recorded that the seed index (g) of wheat as affected by different irrigation frequencies are presented in Figure .02 and its analysis of variance as Appendix 5. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on seed index (g). The maximum seed index (48.11 g) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average seed index 42.77 g, respectively. Significant decreases in seed index were observed in irrigation that included 3 irrigations (39.67 g). The seed index was further decreased to (36.71g) when wheat was treated with 2 irrigations. Finally, the minimum seed index 31.53 g was observed with control plot.

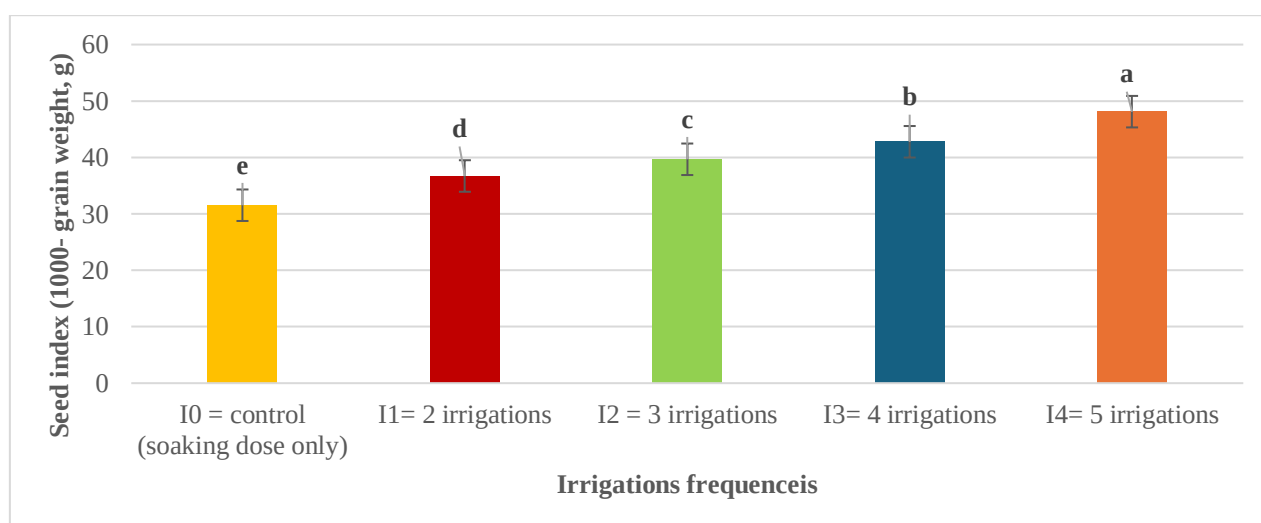


Figure 02: Effect of irrigation frequencies on Seed index (1000-grain weight g) of wheat

Biological yield (kg ha⁻¹)

The results were recorded that the biological yield (kg ha⁻¹) of wheat as affected by different irrigation frequencies are presented in Figure .03 and its analysis of variance as Appendix 6. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on biological yield (kg ha⁻¹). The maximum biological yield (17956.05 kg ha⁻¹) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average biological yield 14964.63 kg ha⁻¹, respectively. Significant decreases in biological yield were observed in irrigation that included 3 irrigations (13002.10 kg ha⁻¹). The biological yield was further decreased to (10133.73 kg ha⁻¹) when wheat was treated with 2 irrigations. Finally, the minimum biological yield 4116 kg ha⁻¹ was observed with control plot.

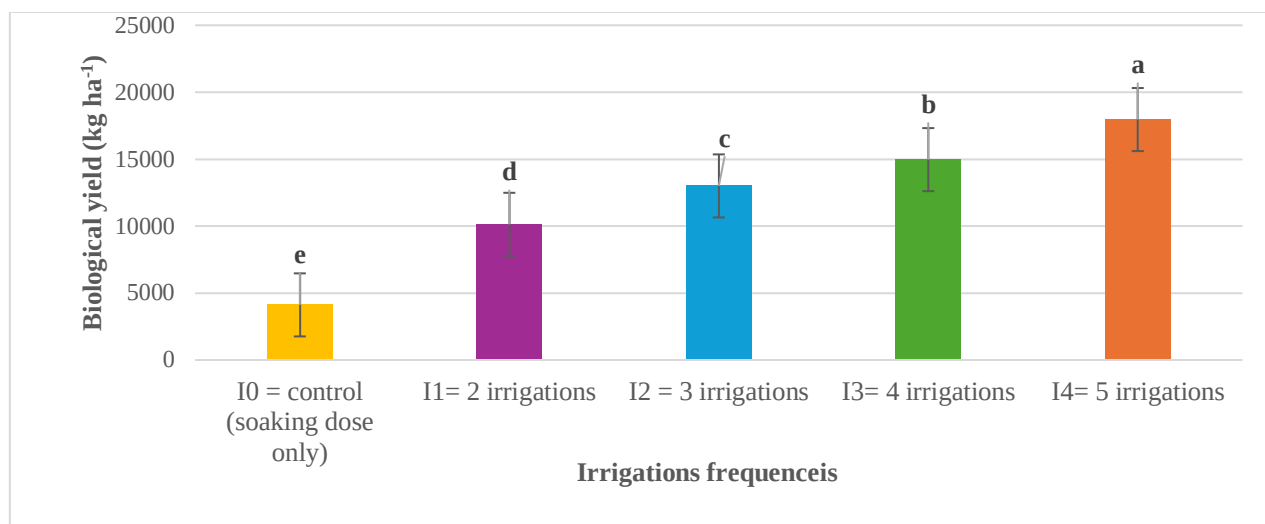


Figure 03: Effect of irrigation frequencies on biological yield (kg ha⁻¹) of wheat

Grain yield (kg ha⁻¹)

The results were recorded that the grain yield (kg ha⁻¹) of wheat as affected by different irrigation frequencies are presented in Table 04 and its analysis of variance as Appendix 7. The analysis of variance showed that there was significant ($P < 0.05$) impact of various irrigation frequencies on grain yield (kg ha⁻¹). The maximum grain yield (7182.42 kg ha⁻¹) was observed with 5 irrigations. Following this, the 4 irrigations resulted in average grain yield 5985.85 kg ha⁻¹, respectively. Significant decreases in grain yield were observed in irrigation that included 3 irrigations (5200.84 kg ha⁻¹). The grain yield was further decreased to (4053.49 kg ha⁻¹) when wheat was treated with 2 irrigations. Finally, the minimum grain yield 1646.59 kg ha⁻¹ was observed with control plot.

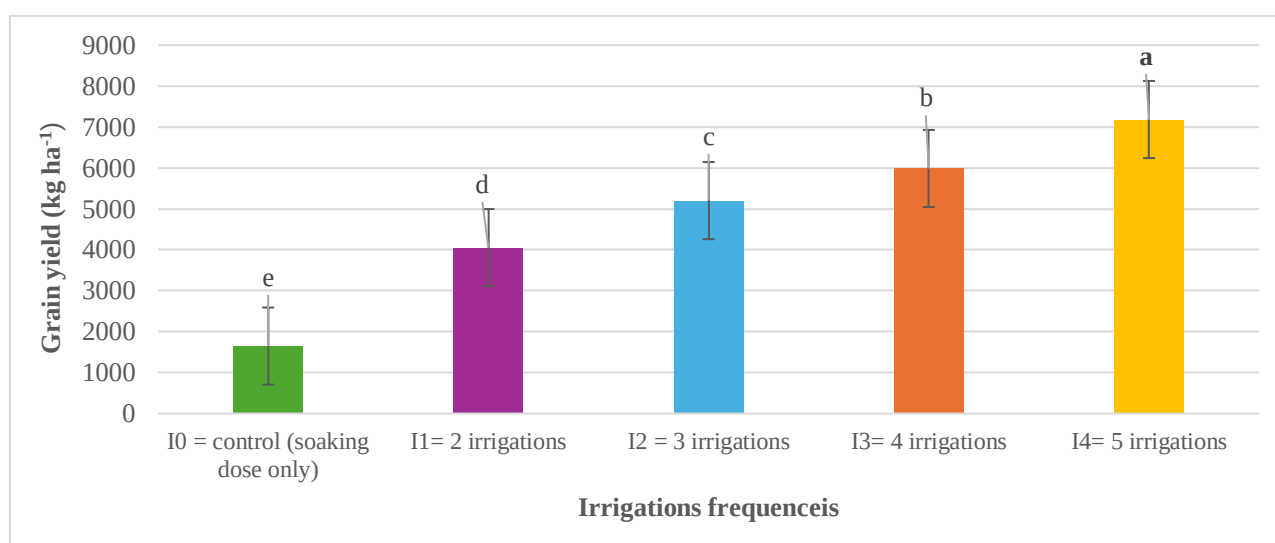


Figure 04: Effect of irrigation frequencies on grain yield (kg ha⁻¹) of wheat

Discussion

Irrigation is essential for wheat productivity, particularly in water-limited regions. Water availability influences key processes including germination, nutrient uptake, photosynthesis, growth, and yield. Different irrigation levels create varying soil-moisture conditions that affect crop development from establishment to maturity. Therefore, optimizing irrigation management is important for maximizing wheat productivity and improving water-use efficiency, especially in arid and semi-arid regions. The present study evaluated the effects of different irrigation levels on wheat growth, yield components, and productivity to support efficient and sustainable water management. The highest plant height, spike length, grains spike⁻¹, and yield under five irrigations were consistent with (Iqbal et al., 2022; Rehmani et al., 2024 and Khan et al., 2023), who reported that adequate irrigation improves nutrient uptake, photosynthesis, tillering, and yield formation. The progressive decline in growth and biological yield with less irrigation agreed with (Ashraf et al., 2020; Kaleri et al., 2024), who associated water stress during heading and grain filling with reduced cell elongation, spikelet development, and grain weight. Adequate moisture during tillering, jointing, heading, and grain filling supports leaf turgor, photosynthesis, assimilate production, and kernel development (Ali et al., 2023; Farooq et al., 2021b). Conversely, water deficit reduces photosynthesis and disturbs hormonal regulation, limiting tillering and grain development (Jalota et al., 2023). The lowest growth and yield under the control and limited irrigation treatments were consistent with Khan et al. (2021), who reported shorter grain-filling duration and reduced assimilate translocation under water stress. Ahmad et al., (2022) also indicated that four to five irrigations can support maximum wheat yield under suitable conditions. Overall, appropriate irrigation scheduling is essential for maintaining wheat productivity while improving water-use efficiency. Reduced irrigation significantly decreased grain weight and yield, particularly under water stress during grain filling. The highest grain weight (3.10 g) under five irrigations compared with 1.60 g under two irrigations and 0.80 g in the control indicates that adequate moisture supports photosynthate production and carbohydrate translocation to developing grains (Fang et al., 2018; Memon et al., 2020). Water stress also reduces stomatal conductance and photosynthesis, resulting in shorter plants and lower biomass production (Zhang et al., 2018; Turner et al., 2020). Accordingly, plant height declined from 90.65 cm with five irrigations to 56.46 cm in the control, while spike length decreased from 11.08 to 3.83 cm. Limited water during vegetative and reproductive stages restricts spike development and grain formation (Ahmad et al., 2023). Adequate irrigation during jointing, booting, anthesis, and grain filling promotes tillering, spike development, and grain yield (Singh & Pal, 2022). Overall, the superior performance under five irrigations was associated with better water availability throughout critical growth stages, whereas less irrigation reduced growth, yield components, and final productivity. Optimum irrigation scheduling can improve wheat yield while avoiding unnecessary water use. In the present study, four irrigations produced 4,756 kg ha⁻¹ compared with 5,071 kg ha⁻¹ under five irrigations, indicating that four well-timed irrigations may provide near-maximum yield with less water. Similar findings were reported by Tahir et al. (2022), and Qureshi et al. (2020), who emphasized efficient irrigation timing and diminishing yield gains from additional irrigation. Biological yield was highest under five irrigations (11,272 kg ha⁻¹), reflecting improved vegetative growth and biomass accumulation under adequate moisture (Gowda et al., 2022). In contrast, biological yield decreased to 9,288 kg ha⁻¹ with two irrigations and 8,628 kg ha⁻¹ in the control, likely due to restricted root growth and reduced water and nutrient uptake under water stress (Shao et al., 2019). Overall, well-timed irrigation is essential for balancing wheat productivity and water conservation..

Conclusion

After going through the findings of the present research, it was concluded that the 4, 3 and 2 irrigations also showed increasing results, while the control plot (soaking dose only) exhibited the lowest growth and yield across all parameters. Based on these findings, it can be concluded that the optimal irrigation regime for maximizing both growth and yield of the wheat variety Imdad-2005 is 5 irrigations, with diminishing returns observed as the number of irrigations decreases. The data clearly indicates that wheat crops subjected to 5 irrigations exhibited the maximum growth and yield.

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