



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(5): 872-877
Received: 02-02-2026
Accepted: 08-03-2026

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Influence of irrigation regimes and sowing methods on growth and yield of bread wheat

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5l.5632>

Abstract

An investigation was carried out during the *rabi* season of the year 2024-25 at Anand Agricultural University, Anand, in order to evaluate the influence of irrigation regimes and sowing methods on bread wheat. The experiment was laid out in split plot design with fifteen treatment combinations and the treatments were replicated thrice. Five irrigation levels were assigned to the main plot and three sowing methods were assigned to the subplot. The results reported that irrigation scheduled at CRI+ 10 days interval recorded significantly higher plant height at harvest (95.22 cm), as well as yield attributes viz., total tillers (560.7 m²), effective tillers (546.5 m²), spike length (9.81 cm), grains per spike (55.51). It recorded significantly higher grain yield (5992 kg/ha), straw yield (6272 kg/ha) and harvest index (48.96%). It was also at par with the irrigation scheduling at CRI, tillering, jointing, flag leaf, pre-anthesis, milking and dough stages. Among the sowing methods significantly higher plant population (130.3 m⁻²), leaf area index at harvest (2.37), total tillers (548.4 m²), effective tillers (528.7 m²), grain yield (5043 kg/ha) and straw yield (6155 kg/ha) was recorded in criss-cross sowing. This study provides valuable insights into best practices for resource management in wheat cultivation.

Keywords: Wheat, irrigation, sowing methods, CRI

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple food grain crops of human race. It is an annual crop which belongs to the family *Gramineae* and genus "*Triticum*". In the context of Indian economy wheat has emerged as a backbone by contributing more than 14.5 percent of the country's cropped area. It is economically very important crop as wheat grain flour is used in the form of chapati, puri, bread, cake, halwa etc. It provides 20% of total calories for humans (Shewry and Hey, 2015) ^[14]. The growth and yield of wheat is significantly affected by rising temperatures and forced maturity specially in the central Indian conditions. The moisture content in the soil gradually decreases with time in dry season and simultaneously soil moisture tension increases. Excessive irrigation increases evapo-transpiration and decreases water use efficiency and may also reduce grain yield. The water scarcity also affects the growth and yield of the crop. Wheat yield might be lowered by 50-60% on an average when there is drought stress. Wheat cultivated under drought stress circumstances can only yield 1.5-2.5 tons per hectare, however wheat grown under irrigation can yield 3-5 tons per hectare (Sharma *et al.*, 2010) ^[12]. The moisture content in the soil gradually decreases with time in dry season, si multaneously soil-moisture tension increases and diminishes water-use proficiency and may likewise decrease the yield (Yadav *et al.*, 2018) ^[17]. Irrigation scheduling at critical stages can also be used to maximize the crop growth and yield (Dhaliwal *et al.*, 2020) ^[3]. Along with increased irrigation efficiency, it is also important for the good establishment of crops. Among various cultural practices, adoption of proper sowing method is also important factor and it is a low-cost input, that helps in maximization of crop yield. Adoption of proper sowing methods helps in performing secondary agricultural operations like weeding, hoeing, and harvesting at ease. These factors influence root growth, light interception, nutrient absorption, and soil moisture utilization (Yadav *et al.*, 2017) ^[18]. Sowing methods also affect soil moisture conservation and nutrient use efficiency. Line and criss cross sowing promote better infiltration, reduce runoff losses, and allow precise placement of fertilizers near the root zone, improving

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fertilizer use efficiency (Kumari *et al.*, 2021) [8]. Both irrigation scheduling at critical growth stages and choice of appropriate sowing method are essential for improving crop productivity, resource-use efficiency, and sustainability in modern agriculture. In view of this, the experiment was planned to consider the impact of irrigation scheduling and sowing methods on development of wheat, so that viable management strategies could be identified to improve wheat growth and yield. This paper explores the interplay between irrigation scheduling and sowing methods.

2. Materials and Methods

The field experiment was conducted during the winter season of 2024-25 at Agronomy Farm of the Anand Agricultural University, Anand, Gujarat situated (22.56° North latitude and 72.94° E longitude and 45.1 m above mean sea-level) in the middle Gujarat agro-climatic zone (AES-III) of Gujarat. The soil is loamy sand with pH 8.19, organic carbon (OC) (0.53%), medium in available phosphorus (36.2 kg/ha), potassium (208.69 kg/ha). The experiment was laid out in split-plot design, replicated three times, having 15 treatment combinations. Treatments consisted of 5 irrigation schedules, viz. I₁ (irrigation at CRI + tillering + jointing + milking stages); I₂ (irrigation at CRI + tillering + flag leaf + milking + dough stages); I₃ (irrigation at CRI + tillering + jointing + flag leaf + milking + dough stages); I₄ (irrigation at CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages) and I₅ (irrigation at CRI + 10 days interval) were laid out in main plots and sowing methods, viz. S₁- Broadcasting, S₂- Drilling and S₃- Criss-cross were allocated to subplots. Wheat variety 'GW 513' was sown at 22.5 cm spacing using seed rate of 120 kg/ha and 25% extra seed rate was utilised for broadcasting and criss-cross sowing. All the plots were treated alike for inputs and agronomic practices except treatments. The recommended dose of fertilizers for wheat crop is 120, 60 and 00 kg/ha of N, P₂O₅ and K₂O respectively was used. 50% N and 100% P₂O₅ was applied as basal, remaining 50% N applied at CRI stage. The climatic data were obtained from weather station of the university. Just after sowing the first common irrigation was applied to all the plots for the good establishment and germination; after that irrigations were applied as per the treatments. The depth of 50 mm was maintained with the help of parshall flume. Regular biometric observations were recorded at periodic intervals of 30, 60, 90 DAS and at harvest stage. Yield parameters were recorded just before the harvesting of crop. The grain yield of each plot was recorded and converted in hectare. The recorded data were analysed by utilizing investigation of difference procedure in the computer-based statistical program (Gomez and Gomez, 1984) [4]. The data was analyzed at $P \leq 0.05$ by utilizing the LSD test.

3. Results and Discussion

3.1. Effect of irrigation scheduling

3.1.1 Plant height

Irrigation scheduling significantly influenced plant height at periodical stages. Application of irrigation at CRI + 10 days (I₅) interval recorded significantly higher plant height at 30, 60 DAS and at harvest. However, it was statistically at par with irrigation scheduling at CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages (I₄). The significantly lower

plant height was observed under treatment I₁ (CRI + tillering + jointing + milking stages). Increase in plant height is a function of cell expansion and depends upon cell water potential. Significant increase in plant height was brought by I₅ (CRI + 10 days interval) scheduled at each and every critical stage was due to optimum moisture supplied during the vegetative and reproductive phases which maintained good establishment of roots and various metabolic processes and resulted into profuse and vertical growth of the plants. Adequate moisture supply during critical growth stages promotes better physiological activities such as photosynthesis and translocation of assimilates, which ultimately results in taller plants. These findings were in line to those reported by Ramunaidu *et al.* (2022) [11].

3.1.2 Total and effective tillers

It was observed from the experimental results that irrigation scheduling had a significant effect on total tillers per meter square at harvest. Significantly higher number of total tillers was recorded under treatment I₅ (CRI + 10 days interval) which was at par I₄ (CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages) and I₃ (CRI + tillering + jointing + flag leaf + milking + dough stages). However significantly lower number of total tillers was recorded under I₁ (CRI + tillering + jointing + milking stages) which was being at par with treatment I₂. Percentage differences indicated that I₅ (CRI + 10 days interval) produced 16.93% higher total tillers than I₁; 14.99% higher than I₂; 5.99% higher than I₃ and 0.63% higher than I₄. This increase in total tiller production under higher irrigation levels might be attributed to better soil moisture availability during the active vegetative growth stages of wheat, which favoured tiller initiation and development. Along with this the favourable environment available may have increase the nutrition to active growing part of plant, which have the ability to multi-shooting with favourable condition and which ultimately lead to higher shooting of the tillers to the base of the plant. These findings are in line with those reported by Niwas *et al.* (2020) [9].

Effective tillers per meter square at harvest were also found to be significantly influenced by irrigation scheduling. Significantly higher number of effective tillers was recorded under treatment I₅ (CRI + 10 days interval) which remained at par with treatment I₄ and I₃. Significantly lower number of effective tillers was recorded under treatment I₁ (CRI + tillering + jointing + milking stages). Percentage differences indicated that I₅ (CRI + 10 days interval) produced 19.53% higher effective tillers than I₁; 17.12% higher than I₂; 7.43% higher than I₃ and 1.03% higher effective tillers than I₄ respectively. The effective tillers are considered as the most important yield contributing characters varied significantly under different irrigation scheduling as reported by Dar *et al.* (2019) [1] and Dhaliwal *et al.* (2020) [3]. The decrease in number of effective tillers towards maturity is mainly due to competition for limited resources. This increase in effective tillers with higher irrigation levels might be attributed to continuous availability of soil moisture during each and every growth stages, which promotes better tiller survival and reduces tiller mortality, ultimately resulting in higher number of productive tillers. Moreover, under such conditions photosynthesis is also enhanced.

Table 1: Periodical plant height, total and effective tillers of wheat crop as influenced by irrigation scheduling and sowing methods

Treatments	Plant height (cm)				
	30 DAS	60 DAS	At harvest	Total tillers (m²)	Effective tillers (m²)
Main plot: Irrigation Scheduling (I)					
I ₁	31.47	72.24	75.42	479.5	457.2
I ₂	32.08	75.58	79.32	487.6	466.6
I ₃	33.08	79.47	82.14	529.0	508.7
I ₄	31.92	81.50	91.52	557.2	540.9
I ₅	33.87	83.82	95.22	560.7	546.5
S.Em. ±	1.11	2.36	2.88	17.7	16.9
C.D. at 5%	NS	7.71	9.39	57.7	55.3
Sub plot: Sowing Methods (S)					
S ₁	31.98	76.14	83.88	512.1	493.6
S ₂	32.02	78.17	84.74	508.0	489.6
S ₃	33.45	81.25	85.54	548.4	528.7
S.Em. ±	0.70	1.47	1.76	9.6	9.1
C.D. at 5%	NS	NS	NS	28.5	27.1

3.1.3 Yield attributes

Significantly higher spike length was recorded under treatment I₅ (CRI + 10 days interval) which remained at par with treatment I₄. Significantly lower ear length was observed under treatment I₁ (CRI + tillering + jointing + milking stages). percentage differences indicated that I₅ (CRI + 10 days interval) recorded 31.32%, 13.80%, 13.01% and 5.59% higher ear length than treatments I₁ (CRI + T + J + M), I₂ (CRI + T + F + M + D), I₃ (CRI + T + J + F + M + D) and I₄ (CRI + T + J + F + P + M + D), respectively. The increase in ear length with higher irrigation levels might be attributed to adequate soil moisture availability that maintains cell turgidity and water status in the plant tissues; preventing stomatal closure during critical reproductive stages of wheat, which promotes better nutrient uptake and photosynthate translocation towards the developing spike. Adequate moisture conditions enhance cell division and elongation in spike tissues, which ultimately results in longer ears. These findings are in line with those reported by Kumar *et al.* (2015) [5], Dar and Ram (2016) [2] and Dhaliwal *et al.* (2020) [3].

Different irrigation schedules significantly influenced the number of grains per spike of wheat. Significantly higher grains per ear were recorded under treatment I₅ (CRI + 10 days interval) which remained at par with treatment I₄. However significantly lower number of grains per ear was recorded under treatment I₁ (CRI + tillering + jointing + milking stages), which was at par with treatment I₂. Percentage differences indicated that I₅ (CRI + 10 days interval) recorded 49.58, 30.91, 17.60 and 6.25% higher grains per ear than treatments I₁ (CRI + T + J + M); I₂ (CRI + T + F + M + D); I₃ (CRI + T + J + F + M + D) and I₄ (CRI + T + J + F + P + M + D) respectively. These findings suggested that selecting the optimal irrigation scheduling, such as I₅ (CRI + 10 days interval) could enhance the grains per ear. The increase in grains per ear with higher irrigation levels may be attributed to adequate moisture availability during the reproductive and grain formation stages, which favours pollination, higher fertilization and grain development. Sufficient soil moisture during flowering and grain filling stages enhances photosynthesis and assimilate translocation to developing grains, thereby increasing the number of grains per ear. Conversely, inadequate moisture supply may cause floret

sterility and poor grain set, resulting in fewer grains per ear. Along with this during later stages the crop is subjected to a sudden rise in temperature and hot winds and when there is moisture deficit it results in poor grain filling. Kumar *et al.* (2017) [6] and Dhaliwal *et al.* (2020) [3] also suggested the similar findings.

Different irrigation schedules significantly influenced test weight of wheat grains. Significantly higher test weight was recorded under treatment I₄ (CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages) which remained at par with treatment I₅. Significantly lower test weight was recorded under treatment I₁ (CRI + tillering + jointing + milking stages), which was at par with treatments I₂ and I₃. Based on the data presented in Table 2, percentage differences indicated that I₄ (CRI + T + J + F + P + M + D) recorded 11.60% higher test weight than I₁ (CRI + T + J + M); 10.29% higher than I₂ (CRI + T + F + M + D); 5.61% higher than I₃ (CRI + T + J + F + M + D) and higher than 2.80% I₅ (CRI + 10 days interval). The decrease in test weight under I₅ (CRI + 10 days interval) irrigation level may be attributed to disrupting the natural drying process, causing re-wetting of grains, which leads to respiration losses and starch degradation. Adding water causes the grain to absorb moisture, resuming respiration and consuming stored carbohydrate that were supposed to create weight. The unnecessary moisture disrupts the accumulation of dry matter, leading to underdeveloped, shrivelled kernels. Hence availability of optimum moisture at I₄ (CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages) schedule gave the higher test weight resulting in bold and heavier grains. In contrast, moisture stress during grain filling may restrict assimilate accumulation in grains, leading to lower test weight. Late irrigation increases plant and soil moisture, which delays senescence and prolongs grain moisture content without contributing to additional dry matter accumulation. This leads to dilution of assimilates and reduced translocation efficiency, ultimately producing shriveled or lighter grains with lower test weight. Moreover, excess moisture at this stage may enhance respiratory losses and reduce net assimilate availability for grains. These finding resonate with the earlier findings by Sharma and Solanki (2022) [13].

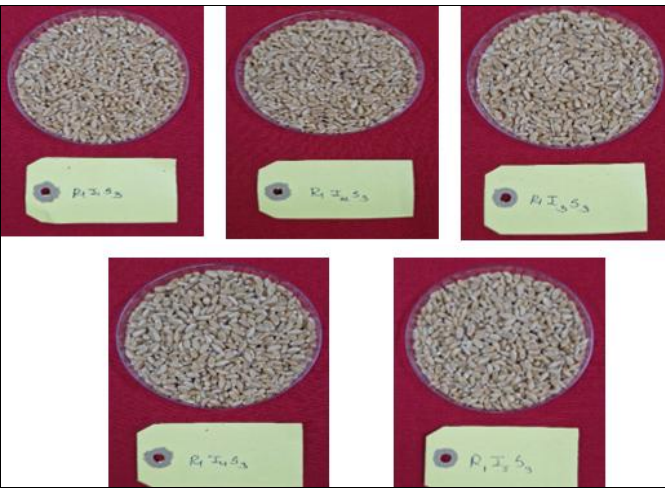


Fig 1: Comparison of grain size as influenced by different irrigation scheduling

3.1.4 Yield and Harvest Index

Various irrigation schedules significantly influenced the grain yield of wheat. Significantly higher grain yield was obtained with irrigation at CRI + 10 days interval and was found to be statistically at par with I₄ (CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages). the yield was found to decrease to the tune of 41.37%, 30.47%, 21.94% and 7.45% under treatments I₁ (CRI + T + J + M); I₂ (CRI + T + F + M + D); I₃ (CRI + T + J + F + M + D) and I₄ (CRI + T + J + F + P + M + D), respectively. Adequate irrigation at flowering stage helps in maintaining pollen viability, fertilization and grain setting, whereas sufficient moisture during grain filling stage enhances translocation of photosynthates from leaves to grains, resulting in well-filled and heavier grains. Moreover, under

favorable moisture conditions, photosynthetic activity, nutrient uptake and enzymatic processes involved in starch synthesis remain optimum, leading to increased yield (Kumar *et al.* 2018 and Tripathi *et al.*, 2023) [7, 16]. Treatment I₅ (CRI + 10 days interval) reported significantly higher straw yield and was found to be statistically at par with I₄, I₃ and I₂. The increase in straw yield is proportional to the vigorous vegetative growth. The higher straw yield under I₅ (CRI + 10 days interval) might be attributed to continuous availability of soil moisture throughout the crop growth period, which promoted vegetative growth. Sufficient moisture availability during vegetative stages leads to increased cell division and elongation, resulting in taller plants and greater biomass accumulation. Moreover, adequate soil moisture improves nutrient uptake and photosynthetic efficiency thereby, enhancing dry matter production and ultimately increasing straw yield. This is in line with as recorded by Sharma and Solanki (2022) [13]. It was observed irrigation scheduling had significant effect on harvest index of wheat crop. Treatment I₅ (CRI + 10 days interval) reported significantly higher harvest index, due to maximum grain yield obtained compare to other irrigation scheduling and which was statistically at par with I₄. Whereas, significantly lower harvest index was observed under treatment I₁ (CRI + tillering + jointing + milking stages). Higher harvest index under I₅ (CRI + 10 days interval) might be attributed to efficient partitioning of assimilates towards economic yield (grain) rather than vegetative biomass. Under adequate soil moisture conditions, photosynthesis remains active for a longer duration, and senescence is delayed, thereby improving assimilate availability for grain filling. This leads to an increase in grain yield without a proportionate increase in straw yield, ultimately enhancing harvest index.

Table 2: Yield attributes and yield of wheat crop as influenced by irrigation scheduling and sowing methods

Treatments	Ear length (cm)	Grains per ear	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Main plot: Irrigation Scheduling (I)						
I ₁	7.47	37.11	37.73	3513	5256	39.96
I ₂	8.62	42.40	38.18	4166	5746	41.92
I ₃	8.68	47.20	39.87	4677	6008	43.81
I ₄	9.29	52.24	42.11	5545	6193	47.14
I ₅	9.81	55.51	40.96	5992	6272	48.96
S.Em. ±	0.30	1.93	0.93	178	184	1.09
C.D. at 5%	0.98	6.31	3.05	581	602	3.55
Sub plot: Sowing Methods (S)						
S ₁	8.78	46.84	39.22	4656	5825	44.05
S ₂	8.85	47.87	40.03	4637	5705	44.43
S ₃	8.69	45.97	40.05	5043	6155	44.60
S.Em. ±	0.18	1.22	0.64	87	116	0.53
C.D. at 5%	NS	NS	NS	257	343	NS

3.2 Effect of sowing methods

3.2.1 Plant height

Plant height of wheat was not significantly influenced by sowing methods at 30, 60 DAS and at harvest.

3.2.2. Total and effective tillers

Total and effective tillers were also significantly influenced by sowing methods. Significantly higher total tillers were observed under criss-cross sowing (S₃) which was superior to broadcasting (S₁) and drilling (S₂). The effective tillers were also recorded significantly higher in criss-cross sowing method. Percentage differences indicated that criss-cross sowing (S₃) produced 7.98% higher than drilling (S₂) and 7.12% higher effective tillers than broadcasting (S₁). Higher number of

effective tillers under criss-cross sowing might be attributed to better plant distribution and denser crop canopy, which improved light interception and resource utilization, thereby enhancing tiller survival and the development of productive tillers. These findings were also suggested by Singh and Chaturvedi (2023) [15].

3.2.3 Yield attributes

The results showed that spike length, grains per spike and test weight were not significantly influenced by sowing methods.

3.2.4 Yield and Harvest index

Sowing methods significantly influenced the yield of wheat crop. Significantly higher grain and straw yield was recorded

under criss-cross sowing (S_3). Improved canopy structure under criss-cross sowing facilitates greater assimilate production and efficient translocation to developing grains, thereby enhancing yield attributes and ultimately grain yield. Similar findings were

reported by Paikra *et al.* (2024) [10]. Criss cross sowing results in higher tiller density and greater biomass, which is a direct contributor to increased straw yield. Different sowing methods did not show their significant effect on harvest index.

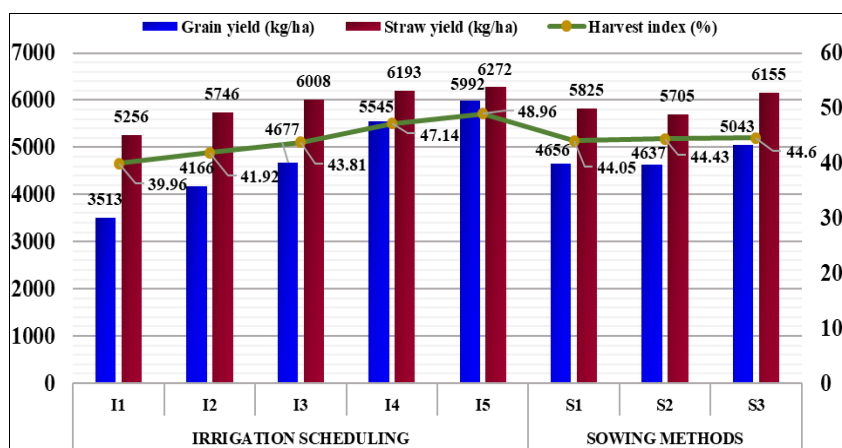


Fig 2: Grain yield, straw yield (kg/ha) and harvest index (%) of wheat as influenced by irrigation scheduling and sowing methods

4. Conclusion

On the basis of results summarized above, it can be concluded that among different irrigation schedules, the higher growth, yield attributes and yield were recorded when irrigation was applied at CRI + 10 days interval followed by irrigation at CRI + tillering + jointing + flag Leaf + pre-anthesis + milking + dough stages. Minimum growth and yield parameters were observed in irrigation scheduled at CRI + tillering + jointing + milking stages.

Among the sowing methods significantly higher growth and yield was recorded in criss-cross sowing methods.

5. Acknowledgement

For scientific studies, support, technical guidance, authors are grateful to Director of Research and Dean PG Studies, for their kind support during research. We are thankful to Anand Agricultural University, Anand, for providing the necessary knowledge and facilities during investigation.

6. Competing interests

The authors declare that there is no conflict of interest related to this article.

7. Author's contribution

Het U. Patel: Conceptualization, methodology, data collection, analysis, writing and editing.

Vinod B. Mor: Conceptualization, discussion, review, editing and supervision.

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