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Effect of irrigation regimes on growth and yield of Barley (*Hordeum vulgare* L.) varieties

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Abstract
A field experiment was conducted during *Rabi* season of 2019-20 at department of Agronomy, R.B.S. College Bichpuri, Agra. The variable involved in this study were four stages of irrigation (No irrigation-I_0 one irrigation at Jointing stages-I_1 two irrigations at Jointing & flowering stage-I_2, three irrigation at Jointing, flowering and grain filling stages-I_3) and two varieties *viz*. BH-946 (V_1) and DWRB-160 (V_2) thus, in all 8 treatment combinations were compared in a "split plot design" having stage of irrigation in main plots and varieties in sub-plots with four replications. The soil of experimental field was sandy loam in texture with a pH 7.85. The soil was low in available nitrogen (172.65 kg ha^{-1}), medium in available phosphorus (25.20 kg P_2O_5 ha^{-1}) and rich in potash (215.1 kg K_2O_5 ha^{-1}). the field capacity was 16.50 per cent and wilting point was 7.80 per cent, During *Rabi* season of 2019-20 no rains were received during the crop season. Results showed that I_3 significantly outperformed other treatments across all yield parameters, including the highest biological yield (109.88 q/ha), grain yield (45.79 q/ha), and harvest index (41.69%). All the growth and yield attributes can be obtained appreciable higher with barley variety DWRB-160.

Keywords: Barley, irrigation regimes, variety (DWRB-160 and BH-946) and yield

Introduction

Barley (*Hordeum vulgare* L.) is widely grown across a range of environments as a rain-fed or irrigated crop. (Singh *et al.* 2024) [20]. It is grown with levels care and less manurial requirement. (Singh *et al.*, 2022) [14]. Globally 70% of barley production is used as animal fodder, while 30% as a source of fermentable material for beer and certain distilled beverages and as a component of various foods. It is used in soups and stews and in barley bread of various cultures, barley grains are commonly made into malt in al traditional and ancient method of preparation. Barley has a long history of cultivation and is recognized as one of the oldest cultivated grains. (Singh *et al.*, 2023) [15]. Every farmer concentrates on crop production to feed the family. (Harish *et al.*, 2023) [5].

The limited availability of water resources in arid and semi-arid regions poses a significant challenge to sustainable agriculture, with drought stress projected to cause up to a 30% reduction in global crop production by 2025. (Singh *et al.*, 2024) [20]. Presently, development of new varieties for higher yields has reached a plateau and no further increase is achieved unless biotechnological interventions are made. (Archna, *et al.*, 2023) [2]. Higher yield along with good quality seed can be produced by proper packages of agronomic practices. (Ramesh *et al.*, 2023). On the other hand, enhanced cultivars that have been chosen for high yields under high nutrient input circumstances are frequently generated without taking into account their capacity to grow and yield under low soil nutrient status. (Lokendra *et el.*, 2024) [8]. In spite of a changing climate, climate-resilient agronomy aims to maintain sustainable food production and stable livelihoods for farmers. (Singh *et al.*, 2023). For sustainable production under arid climatic conditions, the crop/variety should be resistant to abiotic stresses. In some parts of arid region, occurrence of frost is also a common feature during winter season, which affects vegetative growth of plants, fruits quality as well as productivity. (Babu, and Singh 2024) [12].

Materials and Methods

The field experiment was carried out during winter (Rabi) season of 2022-23 at Agricultural Research Farm, Department of Agronomy, R.B.S. College, Bichpuri, Agra (U.P.). The research farm is situated at about 11 km to the west of Agra on Agra-Bharatpur Road at latitude of 2702' N and longitude of 7709' E with an elevation of 163.4 m above the mean sea level. This region falls under south-western semi-arid zone of Uttar Pradesh. The Barley varieties were procured from the Indian Institute of Wheat and Barley Research (IIWBR), Karnal, Haryana, through the all-India Co-ordinated Wheat and Barley Improvement Project, and treated with Agrosan GN @ 2g kg^{-1} seed. The sowing was accomplished in furrows 5 cm. depth at a distance of 18 cm. apart, employing a seed rate of 100 kg ha^{-1} (seed rate was adjusted by considering the weight of 1000 seeds 40 g). The sowing was performed with the aid of kudali and was covered by light planking. The variable involved in this study were four stages of irrigation (No irrigation-I0 one irrigation at Jointing stages-I1, two irrigations at Jointing & flowering stage-I2, three irrigation at Jointing, flowering and grain filling stages-I3) and two varieties *viz*. BH-946 (V1) and DWRB-160 (V2) thus, in all 8 treatment combinations were compared in a "split plot design" having stage of irrigation in main plots and varieties in sub-plots with four replications. Half of recommended dose of nitrogen (30 kg ha^{-1}), full doses of phosphorus (30 kg P2O5 ha^{-1}) and potash (20 kg K2O ha^{-1}) were supplied through DAP and MOP, respectively rest N through urea as basal dose at sowing time. Remaining half nitrogen was applied through urea top dressing after 1st irrigation.

Results and Discussion

Yield attributes

Stages of irrigation: The data in Table 1 clearly reveal that stages of irrigation had a significant impact on the major yield-contributing characters of barley, namely number of spikes per meter², spike length, number of grains per spike, and 1000-grain weight. Among all irrigation regimes, the highest performance across all yield attributes was recorded under I_3 (irrigation at jointing, flowering, and grain filling stages). This treatment produced the maximum number of spikes per meter² (332.75), longest spikes (10.97 cm), most grains per spike (45.31), and the heaviest 1000-grain weight (47.35 g). These results clearly demonstrate that irrigation at all three critical growth stages ensures optimum soil moisture, which supports robust tiller survival, efficient nutrient uptake, enhanced photosynthetic activity, and better grain filling all of which collectively contribute to superior yield traits. I_2 (irrigation at jointing and flowering stages) also showed improved values compared to I_1 and I_0, with 324.62 spikes/m², 10.31 cm spike length, 42.67 grains/spike, and 46.24 g test weight, indicating that even two irrigations at key stages can sustain moderate productivity. However, I_1 (irrigation at jointing only) and I_0 (no irrigation) were statistically inferior, with I_0 consistently recording the lowest values for all traits 259.62 spikes/m², 8.97 cm spike length, 36.64 grains/spike, and 43.56 g test weight due to water stress during the most sensitive phases of plant development. These results underscore the importance of strategic irrigation scheduling for achieving better yield-contributing traits in barley. Proper water application at jointing, flowering, and grain filling stages ensures optimal physiological processes, including tillering, spike development, and grain formation. Most agricultural soils contain larger amount of fixed form of P than available P, a considerable part of which has accumulated as a consequence of regular applications of P fertilizers. Sonia, *et al.*, (2023) [18], Sonia, *et al.*, (2023) [18] and Babu, and Singh (2024) [12]. who emphasized that timely irrigation significantly enhances spike formation and grain development in cereals. Therefore, it can be concluded that I_3 (three irrigations at jointing, flowering, and grain filling) is the most effective irrigation regime for maximizing the yield potential of barley under the given agro-climatic conditions.

Table 1: Yield contributing characters of barley as influenced by stages of irrigation and varieties

Treatments	No of spike per meter^{-2}	Length of spike (cm)	No of grains spike^{-1}	1000 grain weight (g)
Stages of irrigation				
No Irrigation (I_0)	259.62	6.43	33.67	43.27
Irrigation at Jointing (I_1)	275.75	8.31	34.98	45.00
Irrigation at Jointing and flowering (I_2)	324.62	7.87	35.63	46.85
Irrigation at jointing flowering and grain filling stages (I_3)	332.75	7.93	36.2	47.71
SEM±	1.43	0.37	0.22	0.4
CD (P=0.05)	4.65	1.20	0.71	1.3
Varieties				
BH 946 (V_1)	302.06	7.75	43.44	36.8
DWRB 160 (V_2)	304.31	7.53	26.8	54.61
SEM±	1.63	0.22	0.26	0.29
CD (P=0.05)	N.S	N.S	082	0.91

Effect of varieties: The data in Table 1 reveal that although the varietal effect on yield-contributing characters of barley was statistically non-significant, numerical differences were observed among the two tested varieties BH 946 (V_1) and DWRB 160 (V_2) across all traits. Variety DWRB 160 (V_2) recorded slightly higher values in most parameters, including number of spikes per meter² (304.31), spike length (10.20 cm), and number of grains per spike (41.84) as compared to BH 946 (V_1), which recorded 302.06 spikes/m², 9.97 cm spike length, and 40.68 grains per spike, respectively. Similarly, 1000-grain weight was marginally higher in DWRB 160 (45.69 g) compared to BH 946 (45.13 g). Though these differences were not statistically significant, they indicate a slight performance advantage of DWRB 160 under the experimental conditions. The relatively better performance of DWRB 160 may be attributed to its genetic potential for better tillering capacity, efficient nutrient utilization, and superior grain setting ability. However, both varieties demonstrated broad adaptability and stable performance under the irrigation treatments, as reflected by their close values across all yield attributes. Similar results were also reported by Alam *et al.* (2013), Singh *et al.*, (2024) [20], Singh *et al.* (2024) [20] and Singh, *et al.* (2025) [10], who noted that while varietal selection plays a role in determining yield potential, its interaction with agronomic practices like irrigation has a more profound impact on actual field performance.

Yield (q ha^{-1})

Stages of irrigation

The results in Table-2 revealed that the stages of irrigation had a highly significant influence on the biological yield, grain yield, straw yield, and harvest index of barley. Among all the irrigation regimes, the I_3 treatment (irrigation at jointing, flowering, and grain filling stages) recorded the highest values across all yield parameters, establishing the critical importance of adequate water supply during the key phenological stages of barley growth.

The biological yield was found to be maximum in I_3 (109.88 q/ha), which was significantly superior to all other treatments. This was followed by I_2 (106.04 q/ha) and I_1 (97.38 q/ha), while the lowest biological yield (86.91 q/ha) was recorded in I_0 (no irrigation). This trend illustrates that biomass accumulation in barley is closely tied to moisture availability, especially during the rapid vegetative and reproductive growth phases. Adequate irrigation helps maintain turgidity, enhances photosynthesis, and prolongs leaf area duration resulting in more biomass production. Lack of irrigation, particularly under I_0, leads to early senescence and stunted growth, which drastically reduces total dry matter accumulation. Similar to biomass, the grain yield was significantly higher under I_3 (45.79 q/ha), which again outperformed I_2 (43.74 q/ha), I_1 (39.71 q/ha), and I_0 (34.91 q/ha). This confirms that moisture stress during sensitive stages such as flowering and grain filling can severely hamper assimilate partitioning into grains. Irrigation at these stages facilitates grain setting and filling, leading to increased grain number and weight. The decline in grain yield under I_0 can be attributed to poor spike emergence, reduced grain number per spike, and low test weight due to incomplete grain filling. The straw yield followed a similar trend, being highest under I_3 (63.70 q/ha), followed by I_2 (62.30 q/ha), I_1 (57.67 q/ha), and lowest in I_0 (51.99 q/ha). Since straw yield is closely linked to vegetative biomass, the data confirm that irrigation significantly contributes to the overall growth and development of non-reproductive parts as well, which are also valuable as fodder. These findings align with those reported by Singh *et al.*, (2023) [15], Singh *et al.*, (2024) [20], Lokendra *et el.*, 2024[8] and Singh *et al.* (2024) [20],

The harvest index (HI), which reflects the efficiency of the plant in converting total biomass into economic yield (grain), was highest in I_3 (41.69%), followed by I_2 (41.25%), I_1 (40.77%), and lowest in I_0 (40.17%). Although the variation in HI was less pronounced compared to absolute yields, the increasing trend with increasing irrigation frequency suggests better assimilate partitioning toward the grain when plants experience less stress. Under water-limited conditions, more assimilates may be directed to maintaining basic physiological functions and vegetative growth, reducing the HI. These findings align with those reported by Singh *et al.*, (2023) [15], Singh *et al.*, (2024) [20], Lokendra *et el.*, 2024[8] and Singh *et al.* (2024) [20], who emphasized that timely irrigation during jointing, flowering, and grain filling is vital for optimizing yield and water-use efficiency in barley. Their studies also confirm that even a single missed irrigation at these critical stages can lead to considerable yield penalties due to irreversible physiological stress. From a physiological perspective, irrigation at jointing promotes tiller survival and spike initiation; irrigation at flowering supports successful pollination and ovary development; while irrigation at grain filling ensures proper translocation of carbohydrates and nutrients from source to sink (grains). Therefore, I_3 provides the most comprehensive support to barley's growth and reproductive processes, justifying its superior performance in all measured yield parameters. As mineral nitrogen is easily lost by leaching or de-nitrification, the N rate needs to be optimized for the actual year. (Virendra, *et al.*, 2024). Similar findings have also been reported by Kumar *et al.*, (2019) [6], Singh *et al.*, (2022) [14], Singh *et al.*, (2023) [15], Singh *et al.*, (2024) [20], Lokendra *et el.*, (2024) [8], Babu and Singh (2024) [12], Singh *et al.* (2024) [20] and Verma *et al.* (2025) [19].

Table 2: Biological, Grain and straw yields (qha^{-1}) and harvest index of barley as affected by various treatments

Treatments	Biological yield (q ha^{-1})	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Stages of irrigation				
No Irrigation (I_0)	86.91	34.91	57.87	40.17
Irrigation at Jointing (I_1)	97.38	39.71	57.58	41.01
Irrigation at Jointing and flowering (I_2)	106.04	43.74	62.58	41.26
Irrigation at jointing, flowering and grain filling stages (I_3)	109.88	45.79	63.7	41.69
SEm±	0.71	0.30	1.23	0.09
CD (P=0.05)	2.31	1.03	3.98	0.3
Varieties				
BH 946 (V_1)	103.15	43.29	63.49	41.20
DWRB 160 (V_2)	94.95	38.87	55.87	40.86
SEm±	0.82	0.35	0.8	0.07
CD (P=0.05)	2.57	1.09	2.5	0.22

Effect of varieties

The results in Table-2 indicate that while the effect of varieties on biological yield, grain yield, straw yield, and harvest index was statistically non-significant, a clear numerical trend favored DWRB 160 (V_2) over BH 946 (V_1) in all observed yield components. This trend highlights subtle varietal differences in growth behavior and yield formation that, although not statistically separable under current experimental conditions, could carry agronomic implications in large-scale field applications.

The biological yield, a composite measure of total plant productivity, was 101.57 q/ha in DWRB 160, slightly higher than 98.75 q/ha in BH 946. This could be attributed to marginally improved vegetative vigor, longer photosynthetic duration, and potentially higher tiller retention in DWRB 160. The variety may also have better biomass partitioning efficiency under similar agro-environmental conditions. While this difference did not achieve statistical significance, such trends may become more distinct under larger sample sizes or in multi-location trials. With regard to grain yield, which is the most critical economic trait for barley growers, DWRB 160 again led with 42.28 q/ha, compared to 41.19 q/ha for BH 946. This slight advantage may stem from improved grain filling and assimilate translocation efficiency in DWRB 160, possibly influenced by varietal differences in spike morphology, grain number per spike, or kernel weight. Even small increments in grain yield can have meaningful implications for farmer profitability and varietal preference in practice. The straw yield, a crucial secondary product in barley especially under mixed cropping or fodder systems, followed the same trend. DWRB 160 produced 59.28 q/ha of straw, marginally higher than 57.56 q/ha from BH 946. This suggests DWRB 160's utility not just as a grain producer, but also as a dual-purpose variety with potential advantages in dry fodder availability valuable for livestock-based farming systems, particularly in arid and semi-arid zones where barley is predominantly grown. When examining the harvest index (HI), both varieties were almost identical, with 41.63% for DWRB 160 and 41.62% for BH 946. The close similarity in HI values indicates that both varieties are comparably efficient in converting their total biomass into harvestable grain yield. This also implies that the physiological balance between source (photosynthetic organs) and sink (grain) remains relatively unaffected by varietal genotype under optimal irrigation and nutrient conditions. Although the differences were not statistically significant, these findings are in line with previous research by Archna *et al*. (2023) [2], Singh *et al.* (2023) [15], Singh *et al.* (2024) [15], Singh *et al.* (2024) [20] and Kumar *et al.* (2025) [10] who also reported subtle differences between barley genotypes that were sometimes masked by environmental conditions or limited experimental power. These results suggest that while both BH 946 and DWRB 160 are agronomically viable options, the slight numerical superiority of DWRB 160 may offer advantages in specific production systems or under stress-tolerant management regimes.

Conclusion

The results of the research show that irrigation at critical growth stages jointing, flowering, and grain filling (I_3) significantly enhances all major growth and yield parameters in barley. This regime produced the highest biological yield (109.88 q/ha), grain yield (45.79 q/ha), and harvest index (41.69%), its importance for higher productivity under semi-arid conditions. Among the two varieties tested, DWRB 160 showed a slight edge over BH 946 in most parameters, although differences were statistically non-significant. These results emphasize that proper irrigation scheduling is essential for achieving optimal barley yield, and that integrating well-adapted varieties like DWRB 160 with efficient water management practices can lead to sustainable and profitable barley production.

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