



# Screening of Wheat Varieties under Different Levels of Saline Water Irrigation

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## *Authors' contributions*

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **Abstract**

Evaluating growth and yield-related parameters, including plant height, number of leaves, biomass, grain yield and straw yield, under controlled saline irrigation allows the identification of cultivars capable of sustaining performance under stress. This approach supports the selection of resilient varieties and contributes to the sustainability of cereal cropping systems in silty clay soils under dryland conditions, ensuring both crop productivity and long-term soil health. The present study aimed to screen wheat varieties under different levels of saline water irrigation. A factorial experiment based on a completely randomised design with five replications was used. The factors studied were salinity stress with four levels: control, 5, 10 and 15 dS m<sup>-1</sup>, and five wheat cultivars, K-8962, K-8434, K-9644, K-9465 and K-9006, subjected to imposed salinity stress. The study evaluated plant height, number of leaves per plant, number of tillers, leaf area, dry weight, number of ears per plant, straw yield, grains per plant, harvest index and test weight of five wheat (*Triticum aestivum* L.) cultivars under four salinity levels. Increasing salinity stress negatively influenced both morphological and yield parameters. Principal component analysis and hierarchical clustering were used to estimate genotype performance based on morphological and reproductive traits. Better results were observed in K-8434 and K-9006 than in the other cultivars.

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## 1. Introduction

Saline irrigation, while providing an alternative water source, inevitably introduces salts into the soil, potentially altering soil physicochemical properties, reducing nutrient availability and impairing crop performance. The extent of these impacts is influenced by soil texture, initial salinity levels, irrigation practices and crop characteristics (Manhou et al., 2025; Dhakal et al., 2025; Johnson, 2013). Wheat is the most widely cultivated cereal crop and is the second most important staple food crop. Globally, wheat is an important food grain and ranks third in total cereal production (734 million tonnes), after maize (1,148 million tonnes) and rice (782 million tonnes) (FAO, 2018).

The major wheat-producing states of India are Uttar Pradesh, Punjab, Madhya Pradesh, Haryana and Rajasthan, with production of 31.88, 17.85 and 15.91 million tonnes in Uttar Pradesh, Punjab and Madhya Pradesh, respectively. In Uttar Pradesh, wheat productivity is lower than in Punjab and Haryana. However, Uttar Pradesh ranks first in percentage share of wheat production (31.53%), followed by Punjab (17.77%) and Madhya Pradesh (14.52%) (Department of Agriculture & Farmers Welfare, 2018), and the total saline soil area in India is 6.74 million ha.

These saline soils are suitable for salt-resistant varieties. Wheat varieties can help minimise food scarcity because they have several desirable characteristics, such as agronomic adaptability, ease of grain storage and ease of converting grain into flour for edible, palatable and acceptable foods. Expanding the discourse on water stress effects, recent studies have examined its impact on winter wheat. Findings suggest that moderate and severe stress conditions can significantly reduce photosynthetic parameters, leading to decreases in height, biomass and grain size. Notably, mild stress conditions may be considered optimal for winter wheat growth, supporting sustained production and efficient use of natural water resources. Overall, research on water stress effects on crop growth and yield highlights the critical importance of water availability during all growth stages. In addition, this research offers valuable insights for optimising water management practices to achieve improved agricultural outcomes (Chawla & Balasaheb, 2023).

Salinity stress is considered a major abiotic stress affecting wheat production. Plant species differ in their salinity tolerance (Sairam et al., 2002; Siddiqui et al., 2017). In addition to the known components of osmotic stress and ion toxicity, salt stress also results in oxidative stress (Ashraf, 2004; Shafi et al., 2009; Bakht et al., 2011). Wheat is more tolerant at the germination stage but highly sensitive to salinity at later stages. Salt stress results in a considerable decrease in the fresh and dry weights of leaves, stems, tillers, fertile tillers and roots (Chartzoulakis & Klapaki, 2000).

Several studies have shown that plant exposure to salinity at the early seedling stage causes greater yield loss than exposure at a later stage of growth (Gill, 1990; Pasternak et al., 1979). Nevertheless, tolerance observed at the early vegetative stage is of great importance because many workers have emphasised that assessing salt tolerance at the vegetative stage of a plant species is of considerable value in determining the ultimate tolerance of the species (Ashraf & McNeilly, 1988; Ashraf & Waheed, 1990; Ashraf & Wu, 1994; Aziz et al., 2008). There is a strong correlation between salt exclusion and salt tolerance in many species (Munns & James, 2003; Lee et al., 2003). Wheat is moderately tolerant to salt, with a threshold of 6 dS m<sup>-1</sup> without yield loss and 50% yield loss at 13 dS m<sup>-1</sup> (Maas & Hoffman, 1977).

Although salt-tolerant wheat genotypes have been evaluated in different environments, comparative information on the performance of K-8962, K-8434, K-9644, K-9465 and K-9006 under graded saline irrigation levels in the experimental conditions of Kanpur remains limited within the present study context.

Selection of salt-tolerant wheat genotypes may be a feasible and economical approach for utilising salt-affected areas. The varietal differences in salinity tolerance that exist among crop plants can be utilised through screening programmes by exploiting appropriate traits for salt tolerance (Kingsbury et al., 1984). Therefore, the present study aimed to screen wheat varieties under different levels of saline water irrigation based on morphological and yield-related traits.

## 2. Materials and Methods

The experiment was conducted at the Department of Crop Physiology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002, during 2018-2019. A factorial experiment based on a completely randomised design with five replications was used. The factors studied were soil salinity stress (four levels: control, 5, 10 and 15 dS m<sup>-1</sup>) and five wheat cultivars (K-8962, K-8434, K-9644, K-9465 and K-9006) subjected to imposed salinity stress conditions.

The samples were air-dried, pulverised and sieved in the laboratory to make a homogeneous mixture. The physicochemical properties of the soil were as follows: sandy loam texture, field capacity of 25.3%, pH 7.9 (soil: distilled water, 1:1) and electrical conductivity of 0.5 dS m<sup>-1</sup>. One hundred clay pots of 12-inch size were selected and thoroughly washed. The inner portion of each pot was lined with a polythene sheet to prevent the loss of water and other elements. The pots were divided into 20 groups for five treatments, including the control. The pots were arranged in a completely randomised design with five replications of each treatment. All pots received 150 mg N kg<sup>-1</sup> soil (urea 46%), 20 mg P kg<sup>-1</sup> soil (K<sub>2</sub>HPO<sub>4</sub>·3H<sub>2</sub>O) and some microelements up to 5 mg kg<sup>-1</sup>. The seeds were treated with 98% ethanol for about 20 s, washed three times with distilled water and kept at 20 °C for one week. After germination, seedlings were thinned to four plants in each pot. Decalcified water (for control treatments) and water containing dissolved CaCl<sub>2</sub> concentrations of 2.10 g, 4.20 g and 6.32 g, giving 5, 10 and 12 dS m<sup>-1</sup>, and NaCl concentrations of 0.5 g, 1.0 g and 1.5 g, giving 5, 10 and 15 dS m<sup>-1</sup>, were added up to field capacity. The salinity treatments were applied at the tillering stage, and irrigation before this time was the same for all pots with normal water (Kumar et al., 2012). Data were recorded for the following morphological and yield parameters.

### 2.1 Plant Height (cm)

Plant height was measured from the base of the plant to the growing tip of the main tiller with the help of a metre scale, averaged and expressed in centimetres. Data were recorded at the initial tillering, tillering and anthesis stages.

### 2.2 Number of Leaves Per Plant

Leaves were counted manually in pots of all genotypes. Data were recorded at the initial tillering, tillering and anthesis stages.

### 2.3 Number of Tillers Per Plant

Tillers were counted manually in pots of all genotypes. Data were recorded at the tillering and anthesis stages.

### 2.4 Leaf Area (cm<sup>2</sup>)

The total leaf area of all counted leaves was measured with the help of a leaf area meter (Systronics Leaf Area Meter 211). Data were recorded at the initial tillering, tillering and anthesis stages.

### 2.5 Dry Weight (g plant<sup>-1</sup>)

Roots and shoots were excised and placed in an oven (NSW-142) at 105 °C for 5 min and then at 65 °C until constant weight. Dry weight was measured using an electrical balance. Data were recorded at the initial tillering, tillering and anthesis stages.

## 3. Results and Discussion

### 3.1 Morphological Characters

From Table 1, plant height is basically a genetically controlled character, but it is also influenced by stresses such as salinity. The present investigation revealed greater plant height in the control pots (T<sub>0</sub>), followed by T<sub>1</sub> (5 dS m<sup>-1</sup>), whereas T<sub>2</sub> and T<sub>3</sub> drastically reduced plant height. This might be due to salinity stress. As the salinity level increased, plant height decreased. Among the varieties, less reduction was noted in K-8434 and K-9006 than in the other varieties. Minimum plant height was recorded in variety K-9644.

**Table 1. Effect of different levels of salinity on plant height and no of leaves (cm), No of tillers, Leaf area(cm<sup>2</sup>), Dry weight (g) of wheat varieties at tillering and anthesis stage**

Genotypes/ Salinity levels (EC dSm <sup>-1</sup> )	Plant height(cm)			Number of leaves/plant			No of tillers		Leaf area(cm <sup>2</sup> )			Dry weight(g)	
	30	60	90	30	60	90	60	90	30	60	90	60	90
<b>K-9644</b>													
control	12.47	33.25	54.41	10.28	11.58	23.28	3.82	5.40	104.01	300.80	453.16	1.39	3.08
5	11.40	33.16	53.36	10.10	9.35	19.17	3.68	4.45	102.74	245.71	394.70	1.07	2.90
10	10.74	32.59	52.36	8.54	8.55	17.27	3.45	3.30	102.47	236.12	304.46	0.95	2.24
15	8.69	29.27	48.30	7.05	7.25	14.08	3.21	2.91	96.33	220.53	110.75	0.83	1.83
Mean	10.83	32.07	52.11	8.99	9.18	18.45	3.54	4.02	101.39	250.79	315.77	1.06	2.51
<b>K-8962</b>													
Control	11.61	34.27	55.18	10.42	11.58	22.62	4.60	4.75	108.39	368.04	421.42	1.50	3.93
5	11.35	33.36	53.56	8.70	9.35	19.59	3.76	4.57	103.43	349.94	336.46	1.25	3.19
10	11.19	32.15	52.76	8.53	8.55	17.35	3.74	3.54	102.92	282.48	263.54	1.10	2.64
15	9.46	31.11	49.56	7.25	7.25	15.22	3.57	3.19	96.40	252.27	231.69	0.92	2.30
Mean	10.90	32.73	52.76	8.73	9.18	18.70	3.92	4.01	102.79	313.18	313.28	1.19	3.01
<b>K-9465</b>													
Control	13.58	34.28	55.68	10.58	13.63	23.57	4.61	5.44	112.82	369.05	455.64	1.47	4.08
5	13.14	33.33	54.76	9.24	11.65	21.09	4.55	5.11	103.27	350.56	298.29	1.33	3.32
10	12.48	32.16	52.73	9.15	9.54	19.50	4.14	4.26	102.50	331.71	265.53	1.23	2.62
15	10.27	30.34	49.90	7.32	7.53	16.75	3.53	3.55	97.79	311.08	259.07	1.20	2.38
Mean	12.37	32.53	53.27	9.07	10.59	20.23	4.21	4.59	104.09	340.60	319.63	1.31	3.10
<b>K-8434</b>													
Control	14.50	34.82	56.66	10.29	14.18	24.11	4.77	5.94	117.49	370.72	482.49	1.61	4.27
5	13.42	34.50	55.45	9.86	13.62	21.44	4.62	5.32	106.40	361.89	445.37	1.48	3.43
10	12.73	33.26	53.42	9.43	12.19	20.75	4.30	4.35	105.56	352.41	427.41	1.27	3.36
15	11.16	30.56	50.46	7.92	8.45	17.24	4.17	3.93	99.10	310.21	411.41	1.12	3.26
Mean	12.95	33.29	54.00	9.38	12.11	20.89	4.46	4.89	107.14	348.81	441.67	1.37	3.58
<b>K-9006</b>													
Control	13.86	34.40	56.28	10.53	13.75	23.76	4.59	5.51	115.44	369.87	472.98	1.52	4.15
5	13.60	33.75	55.28	9.55	12.12	21.05	4.52	5.16	107.61	355.31	351.26	1.32	3.34
10	12.52	32.60	52.45	9.39	10.81	19.93	4.29	4.32	103.69	345.63	340.34	1.29	2.75
15	10.32	30.50	50.28	7.54	8.09	17.06	3.71	3.81	98.29	312.14	320.54	1.05	2.61
Mean	12.57	32.81	53.57	9.25	11.19	20.45	4.28	4.70	106.26	345.74	4.70	1.29	3.21
V	0.31	0.31	0.20	0.09	0.06	0.18	0.11	0.09	0.33	1.11	1.17	0.05	0.04
T	0.28	0.28	0.17	0.08	0.06	0.16	0.10	0.08	0.30	0.99	1.04	0.04	0.03
CD at 5% (Vx T)	0.62	0.62	0.39	0.17	0.13	0.37	0.23	0.17	0.67	2.22	2.34	0.09	0.08

From Table 1, leaf area showed the minimum adverse effect at 5 dS m<sup>-1</sup> compared with the other salinity treatments. All varieties showed maximum leaf area at the tillering stage, whereas a considerable decrease occurred at the anthesis stage, resulting in reduced plant biomass (Jaleel et al., 2007). From Table 1, tiller production per plant was minimum at the initial tillering stage; thereafter, it increased up to the tillering stage and was reduced later. Salinity levels above 5 dS m<sup>-1</sup> and up to 10 dS m<sup>-1</sup> showed a significant reduction at the initial tillering, tillering and post-anthesis stages of plant growth, respectively, and at 15 dS m<sup>-1</sup>, tiller production was drastically reduced. The K-8434 variety showed maximum tiller production, followed by K-9006, while the lowest tiller number was observed in K-9644.

From Table 1, dry weight was minimum at the tillering stage and maximum at the anthesis stage. The total dry weight increased about three times from the tillering to the anthesis stage. An increase in the level of salinity above 5 dS m<sup>-1</sup> showed a reduction in tillers at the initial tillering, tillering and anthesis stages. Variety K-8434 accumulated maximum dry weight, whereas variety K-9644 showed poor performance; similar results were obtained by Wyn Jones (1981).

As salinity levels increased, dry weight gradually decreased. Maximum growth characters were recorded in the control pots. Under saline-irrigated conditions, 5 dS m<sup>-1</sup> recorded less reduction in growth compared with the other saline treatments. Salinity reduced plant height, tiller number and dry weight. Similar findings were also reported earlier by Shitole (2011) and Negrão et al. (2017).

### 3.2 Yield Characters

Yield components are directly associated with the economic yield of the crop. Thus, any improvement in yield components will certainly affect crop yield.

From Table 2, yield characters such as number of panicles, length of panicle and number of grains per panicle were recorded as maximum in the control pots of the five varieties. Among saline-irrigated pots, 5 dS m<sup>-1</sup> irrigation showed maximum yield, whereas 15 dS m<sup>-1</sup> irrigation showed low yield characters. A decrease in average grain yield of wheat from 5.02 to 3.16 Mg ha<sup>-1</sup> as irrigation water salinity increased from 0.4 to 8.4 dS m<sup>-1</sup> was also reported earlier by Phogat et al. (2011). The number of seeds per panicle and test weight were significantly higher under 5 dS m<sup>-1</sup> compared with the other saline-water-irrigated pots. Lower test weight and number of seeds per panicle were recorded in the 15 dS m<sup>-1</sup> saline-irrigated pots.

Seed yield is a manifestation of morpho-physiological, biophysical, chemical and growth parameters. In the present investigation of saline water irrigation, the control pots showed maximum yield, while the 5 dS m<sup>-1</sup> treatment showed minimum yield reduction compared with the other treatments.

Harvest index of tolerant varieties was relatively higher than that of other varieties when high-salinity irrigation water was applied. K-8434 showed a higher harvest index than other varieties. Application of 5 dS m<sup>-1</sup> saline irrigation water to wheat genotypes had only a slight effect and proved better among all salinity levels. Spike number per plant, spike length, number of spikelets per spike, straw weight, grain yield, 1000-grain weight and harvest index declined with increasing salinity level, which ultimately caused yield loss. Similar findings were also reported by Asgari et al. (2012).

**Table 2. Effect of different levels of salinity on yield parameters of wheat varieties at harvesting stage**

Genotypes/ Salinity levels (EC dSm <sup>-1</sup> )	No of ears/plant	Grains/plant	Straw yield g/plant	Harvest index	Test weight
K-9644					
control	4.05	7.11	9.54	42.69	38.23
5	1.92	5.43	7.93	40.62	38.11
10	1.55	3.14	5.74	35.35	36.01
15	1.47	2.44	4.94	33.05	34.34
Mean	2.25	4.53	7.04	37.93	36.67
K-8962					
Control	3.74	6.97	10.54	39.83	37.39
5	3.09	5.26	8.74	37.55	36.57

Genotypes/ Salinity levels (EC dSm <sup>-1</sup> )	No of ears/plant	Grains/plant	Straw yield g/plant	Harvest index	Test weight
10	2.28	3.35	6.44	34.25	35.31
15	1.92	2.65	5.25	33.54	34.46
Mean	2.76	4.56	7.74	36.29	35.93
<b>K-9465</b>					
Control	4.45	7.23	10.31	41.25	39.41
5	3.44	5.33	8.47	38.64	38.43
10	2.52	3.56	6.15	36.66	36.48
15	2.19	2.64	4.85	35.26	34.42
Mean	3.15	4.69	7.44	37.95	37.19
<b>K-8434</b>					
Control	4.42	7.57	11.32	40.05	39.51
5	3.75	6.82	10.54	39.26	39.17
10	3.34	5.24	8.45	38.27	36.59
15	3.08	4.34	7.06	38.05	35.57
Mean	3.65	5.99	9.34	38.90	37.71
<b>K-9006</b>					
Control	4.25	6.73	10.51	39.02	39.45
5	3.58	6.36	10.40	37.94	38.47
10	2.81	5.54	9.21	37.54	36.48
15	2.49	4.35	7.54	36.55	34.75
Mean	3.28	5.74	9.41	37.77	37.29
V	0.13	0.02	0.03	0.02	0.22
T	0.12	0.02	0.03	0.02	0.19
CD at 5% (Vx T)	0.26	0.04	0.07	0.04	

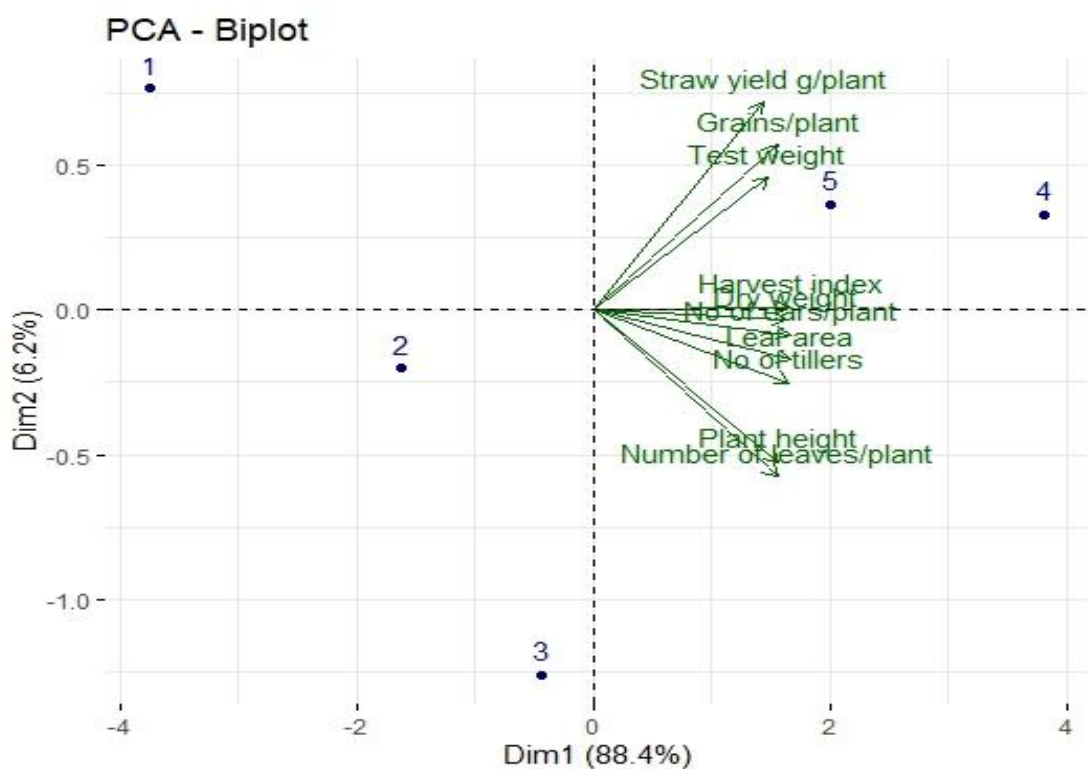
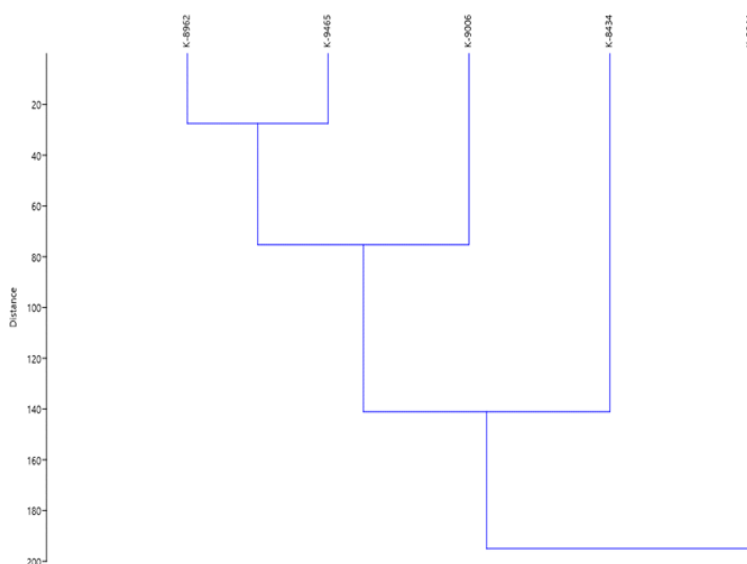


Fig. 1. PCA-Biplot; correlation and salinity tolerant contribution among the parameters of morphological and yield parameters with genotypes at reproductive stage

In Fig. 1, PCA analysis conducted at the reproductive stage under 15 dS m<sup>-1</sup> showed that grain yield, straw yield, test weight and harvest index per plant loaded on the upper side, indicating that these traits contributed to genotype tolerance. Dry weight, number of ears, number of tillers, plant height and number of leaves per plant moderately contributed to tolerance. An angle between traits of <90° indicates a positive correlation (0 to 1), >90° indicates a negative correlation (-1 to 0), and 180° indicates a perfect negative correlation (Orhun, 2020; Al-Naggar et al., 2020). From the genotype point of view, genotypes K-9006 and K-8434 loaded on the positive side of the PCA, indicating that they were more tolerant compared with the other genotypes.



**Fig. 2. Cluster analysis among the genotypes at reproductive stage**

The wheat genotypes investigated for salinity tolerance were classified based on hierarchical clustering, which indicated that K-9006 and K-8434 formed separate clusters, whereas K-8962 and K-9465 were close to each other. Lower inter-cluster distance indicates less diversity between the genotypes (Kumar et al., 2012; Arief et al., 2017; Riaz et al., 2020).

#### 4. Conclusion

The study indicates that increasing salinity stress reduced the morphological and yield-related performance of the evaluated wheat varieties under the tested conditions. The 5 dS m<sup>-1</sup> salinity level caused the least adverse effect, whereas higher levels, particularly 10 and 15 dS m<sup>-1</sup>, were associated with greater reductions in plant height, leaf area, tiller production, dry weight, yield components, straw yield, test weight and harvest index. Among the evaluated genotypes, K-8434 and K-9006 performed better than the other cultivars under saline irrigation, suggesting comparatively greater tolerance at both vegetative and reproductive stages. The PCA and hierarchical clustering results supported the differentiation of genotypes based on morphological and yield-related traits, with grain yield, straw yield, test weight and harvest index contributing to tolerance assessment. These findings support the usefulness of systematic screening under graded saline irrigation for identifying wheat genotypes that maintain comparatively stable growth and yield traits under salinity stress and for guiding further evaluation of promising varieties.

#### 5. Limitation

The study was conducted using pot-based screening under one set of experimental conditions and included only five wheat varieties and four salinity levels. Therefore, the observed varietal responses should be interpreted within the tested environment, growth stages and measured morphological and yield-related traits. Field validation across seasons, soil types and broader germplasm would strengthen the applicability of the findings.

## Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

## Competing Interests

Authors have declared that no competing interests exist.

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