



Seed Priming-Mediated Salt Tolerance in Maize: A Study on Early Growth Responses

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Abstract

Maize (*Zea mays* L.) is one of the world's leading cereal crops which is essential for food, feed and industrial applications. Despite its significance, maize is moderately sensitive to salinity which adversely affects seed germination, early growth and overall productivity, particularly in arid and semi-arid regions. Seed priming has proven to be a practical and cost-effective method for enhancing salt tolerance and improving early seedling performance. This study aimed to evaluate the effects of different seed priming methods on the early growth of maize genotypes under salinity stress. The experiment was conducted in the green house of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during winter 2025. A total of 10 maize genotypes (PBG-575, PBG-9608, PBG-477, PBG-1020, PBG-238, PBG-150, PBG-6189, PBG-31, PBG-76 and PBG-240) were treated with four priming treatments (control, hydropriming, halopriming with 50 mM CaCl₂ and osmopriming with 2% KNO₃) and exposed to three salinity levels (0, 100 mM, and 150 mM NaCl). Data were recorded for different morphological and physiological responses and analyzed using three-way ANOVA and correlation analysis. Results refined that hydropriming and halopriming effectively alleviated the substantial detrimental effects exerted by saline conditions on seedling growth, vigor and biochemical content. Among genotypes, PBG-238 and PBG-477 exhibited superior salt tolerance while genotypes PBG-1020, PBG-6189, PBG-31 and PBG-76 were highly sensitive. Increase in salinity stress elevated the detrimental impact on seedlings. Among the applied seed priming treatments halopriming and hydropriming showed optimal influence on seed performance. The study indicates the potential of integrating seed priming with salt-tolerant genotypes for improved maize establishment in saline conditions.

Keywords: Hydropriming, Halopriming, Osmopriming, Vigor, Biochemical content

Introduction

Maize (*Zea mays* L.) is considered one of the three predominant cereal crops globally, in conjunction with rice and wheat, and together these grains supply about 94% of the world's total food resources (Ranum *et al.*, 2014). Its nutritional value and adaptability to various climates make it a good option for cultivation in different agro-climatic regions. Owing to good nutritional efficacy for both humans and animals, maize acts as a staple food and industrial crop cultivated across numerous regions worldwide and is known as the "Queen of Cereals" (Agarwal *et al.*, 2018). It is cultivated across two primary cultivation seasons (spring and autumn) and used broadly in food, feed and biofuel industries (Waqas *et al.*, 2017). From the nutritional perspective, it is a good reservoir of vitamins and minerals and is processed to form corn flour, popcorn, bread, beverages, porridges, dextrose, corn syrup, wax, cosmetics, corn flakes and chemical substances used for leather tanning (Khan *et al.*, 2010). Regardless of its

substantial importance, maize remains relatively susceptible to abiotic stress particularly salinity, which detrimentally influenced seed germination, early growth and overall yield (Ors *et al.*, 2021). Soil salinization is a key impediment in arid and semi-arid regions where excessive salt concentrations in the soil reduce water uptake, undermine metabolic functions and substantially impair crop establishment (Ouzemou *et al.*, 2025). Although salinity affects all growth stages but seed germination is notably vulnerable to elevated salt concentrations. Salinity significantly modulates seed germination by reducing the germination percentage and delaying germination time as salt concentrations increase (Ibrahim, 2016). High salt concentration adversely impacts the processes of seedling development, vegetative growth, flowering and fruit setting. Consequently, it causes a decline in the overall yield potential and deteriorates the quality attributes of the crop (Ors *et al.*, 2021). To alleviate these constraints, seed priming (controlled hydration)

emerged as a sustainable and cost-efficient strategy that augments stress tolerance, improves seedling vigor and promotes uniform emergence (Marthandan *et al.*, 2020). It also stimulates metabolic responses required for seed sprouting without initiating emergence of radicle (Farooq *et al.*, 2007). Seed priming promotes expedited and more uniform seedling emergence and improves seed tolerance to environmental stressors (Afzal *et al.*, 2016). Diverse seed priming approaches such as hydro-priming, halo-priming and osmo-priming have proven effective to counteract salinity-induced growth inhibition in crops (Nawaz *et al.*, 2013). These treatments elevate enzymatic activity, maintain membrane integrity and regulate osmotic balance, allowing plants to cope with high salt during developmental phases (Rhaman, 2025). Various organic and inorganic salts have been widely used in seed priming to augment the vitality of seeds in different crops. However, limited research has addressed the comparative effectiveness of these priming methods in maize particularly under controlled salinity conditions (Akter *et al.*, 2018). The study focused on the genetic variations that respond to such abiotic stress to find tolerant genotypes, point out important tolerant traits and figure out the most prone phase throughout the ontogeny of plants (development and early plant growth) for recommending appropriate measures to mitigate salinity effects (Hmissi *et al.*, 2023).

Given the increasing threat of soil salinization and the growing demand for sustainable maize production, it is crucial to identify effective priming techniques and salt-tolerant genotypes. This study aims to evaluate the morpho-physiological response of primed maize seeds under salinity stress and to identify genotypes with improved performance during early growth stages.

Materials and methods:

Experimental detail:

Pre-basic seed of maize genotypes was collected from the Maize Breeding and Genetics Lab, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. The current experiment was carried out in the greenhouse during winter 2025. The experiment was implemented following a completely randomized design (CRD) with a three-factor factorial arrangement. The study encompassed three factors i.e. genotypes (PBG-575, PBG-9608, PBG-477, PBG-1020, PBG-238, PBG-150, PBG-6189, PBG-31, PBG-76 and PBG-240), salinity levels (0, 100mM (S_1) and 150mM (S_2)) and priming sources (Control, hydro-priming with distilled water (T_1), halo-priming with $CaCl_2$ (T_2) and osmo-priming with KNO_3 (T_3)). For hydro-priming, seeds were immersed in distilled water for 24 hours at ambient room temperature.

For halo-priming, seeds were incubated in 50mM solution of calcium chloride ($CaCl_2$) for 24 hours at ambient room temperature. For osmo-priming, the seeds were immersed in a 2% solution of KNO_3 for 24 hours at ambient room temperature. The $NaCl$ solutions were applied to the plants as needed for irrigation, depending on the moisture requirements of the growing medium. The plants were maintained under their respective salinity treatments until 21 days, when morphological and physiological data were recorded to evaluate the effects of salinity and seed-priming treatments on maize growth and salt tolerance.



Figure I: Maize plants grown under different salinity levels and seed priming treatments in the greenhouse.

At 21 days after sowing, data were recorded for parameters like root length (RL; cm), shoot length (SL; cm), coleoptile length (CL; cm), seedling length (SL; cm), fresh weight of seedling (FWS; g), dry weight of seedling (DWS; g), root-shoot ratio (RSR), germination percentage (GP; %), seedling vigor index (SVI), moisture content (%), starch content (%), protein content (%), acid detergent fiber (ADF; %), neutral detergent fiber (NDF; %) and salinity tolerance index (STI). Root-shoot ratio was measured using to the formula given by Nour *et al.*, (1978).



Figure II: Determination of physiological content using a Near-Infrared (NIR) Analyzer

Germination was monitored daily over a 10-day period by recording the visible emergence of the radicle. Germination percentage was quantified by the methodology adapted by Jalal *et al.*, (2019). Seedling vigor index was computed following the methodology described

by Baki and Anderson (1973). The total length of the seedling was calculated following the protocol described by Shruti *et al.*, (2024). Physiological parameters (moisture, protein, starch, acid detergent fiber, neutral detergent fiber and salinity tolerance index) were measured as percentages using near-infrared reflectance (NIR) by following the approach of Gorji *et al.*, (2024). The salinity tolerance index was calculated by following the strategy of Kim *et al.*, (2018).

Data Analysis

Statistical evaluation of experimental data was carried out using a three-way analysis of variance (ANOVA) following Steel *et al.* (1997) using Statistix 8.1 Software. The analysis incorporated three independent factors; salinity levels, seed priming treatments and maize genotypes. Correlation analysis was followed to evaluate the correlation coefficient between diverse morpho-physiological traits following the approach described by Kwon and Torrie (1964).

Results

Analysis of Variance

The analysis of variance (ANOVA) showed that all three main factors i.e. maize varieties, levels of salinity and priming treatments had a statistically notable influence on seedling-related traits. The mean square values presented in Table 1 reveal highly significant effects ($p \leq 0.01$) for all traits under study, demonstrating the existence of considerable genetic diversity among the tested genotypes and strong influences of both abiotic stress (salinity) and seed enhancement techniques (priming). Among the main effects, salinity stress emerged as the most dominant factor affecting early seedling performance. This was evident from the high mean square values for root length, shoot length and germination percentage. These findings confirm

that salinity exerts a profound negative impact on initial plant growth, hampering root and shoot development as well as germination efficiency. The consistent significance of salinity across all traits further emphasizes its widespread physiological impact on maize seedlings. Similarly, priming treatments significantly influenced all recorded traits. The effects were particularly notable for traits such as root length, shoot length and seed vigor index suggesting that priming substantially enhances seedling vigor and early vegetative growth even under saline conditions. This indicates that priming has the tendency to mitigate the detrimental influence of saline conditions and improve seed metabolic readiness. Genotypic variation among maize varieties was statistically significant for all seedling traits, including physiological parameters such as moisture content, starch, protein contents, acid detergent fiber (ADF) and neutral detergent fiber (NDF). This confirms the genetic potential for selecting superior maize genotypes with enhanced seedling vigor and tolerance to salt stress. Traits like root-shoot ratio (RSR), fresh weight and dry weight of seedlings showed significant varietal differences, suggesting differential adaptability among inbred lines. Interaction effects were also highly significant. The variety $\times$ salinity ($V \times S$), variety $\times$ priming ($V \times P$), salinity $\times$ priming ($S \times P$) and variety $\times$ salinity $\times$ priming ($V \times S \times P$) interactions influenced all the traits to a statistically significant extent. Though the mean squares for interaction effects were generally lower than the main effects. Their significance indicates that the performance of maize varieties depends on specific combinations of stress and treatment. This underscores the complexity of genotype-by-environment interactions and highlights the importance of evaluating multiple factors simultaneously in breeding programs.

Table I. Mean square values from analysis of variance for seedling traits of maize accessions under varieties, salinity and priming

SOV	Varieties/Genotypes	Salinity	Priming	V x S	V x P	S x P	V x S x P	Error
DF	9	2	3	18	27	6	54	240
RL	879.20**	16633.31**	623.30*	56.66**	1.33**	7.50**	0.20**	0.1
SL	565.51**	10698.30**	400.90*	36.40**	0.80**	4.80**	0.10**	0.1
CL	14.92**	282.533*	10.597*	0.963**	0.022**	0.128**	0.003**	0.002
SDL	2251.50**	42597.7*	1596.10**	145**	3.20**	19.10**	0.40**	0.03
FWS	0.7943**	15.021**	0.5629*	0.0506**	0.0011**	0.0066**	0.0002**	0.0001
DWS	0.06785**	1.29283*	0.04815**	0.00454**	0.00011**	0.00057**	0.00002**	0.00001
RSR	0.00203**	0.04247*	0.002**	0.0001671**	0.000007521**	0.0002953**	0.000004434*	2.3E-05

GP	3161.40*	59814.30*	2241.81**	203.55**	4.62**	26.85**	0.60**	0.3
SVI	1182.70**	22377.11**	838.60*	76.10**	1.70**	10**	0.20**	0.1
Moisture	2244.50**	42465**	1591.30**	144.50**	3.20**	19.10**	0.40**	0.2
Starch	885.10**	16744.90**	627.50*	57**	1.30**	7.50**	0.20**	0.1
Protein	41.001**	776.018*	29.081*	2.644**	0.059**	0.348**	0.008**	0.005
ADF	251.91**	4765.86*	178.59*	16.22**	0.36**	2.14**	0.05**	0.02
NDF	1136.30**	21496.40**	805.60*	73.10**	1.60**	9.70**	0.20**	0.1
STI	53424*	1010759*	37878**	3440**	77**	453**	11**	6

**= highly significant differences $p < 0.01$, SOV= Source of variation, DF= Degree of freedom RL= Root length, SL= Shoot length, CL= Coleoptile length, SDL= Seedling length, FWS= Fresh weight of seedling, DWS= Dry weight of seedling, GP= Germination percentage, SVI= Seedling vigor index, ADF= Acid detergent fiber, NDF= Neutral detergent fiber, STI= Salinity tolerance index

Table II. Mean values for the genotypes

Genotypes	PBG-575	PBG-9608	PBG-477	PBG-1020	PBG-238	PBG-150	PBG-6189	PBG-31	PBG-76	PBG-240
RL	38.339	35.774	42.173	30.408	42.594	36.206	30.775	33.174	27.634	36.492
SL	29.747	27.689	32.822	23.386	33.16	28.036	23.681	25.606	21.162	28.266
CL	4.9964	4.6631	5.4958	3.9636	5.5503	4.7181	4.0103	4.3236	3.6017	4.7556
SDL	61.352	57.247	67.488	48.661	68.163	57.938	49.248	53.089	44.223	58.398
FWS	1.1525	1.0764	1.2683	0.9142	1.2811	1.0892	0.9256	0.9989	0.8314	1.0972
DWS	0.3369	0.3156	0.3717	0.2683	0.3753	0.3192	0.2708	0.2922	0.2439	0.3211
RSR	1.2936	1.295	1.2892	1.3033	1.2886	1.2958	1.3056	1.3017	1.3122	1.2953
GP	72.703	67.838	79.973	57.663	80.772	68.657	58.358	62.91	52.404	69.201
SVI	44.468	41.492	48.915	35.269	49.403	41.993	35.694	38.479	32.052	42.326
Moisture	61.258	57.161	67.384	48.586	68.058	57.849	49.171	53.008	44.156	58.308
Starch	37.22	34.642	41.061	29.258	41.484	35.075	29.625	32.033	26.476	35.362
Protein	8.2803	7.7253	9.1075	6.5669	9.1986	7.8192	6.6464	7.1644	5.9681	7.8811
ADF	20.522	19.149	22.574	16.276	22.799	19.38	16.472	17.758	14.792	19.532
NDF	43.584	40.669	47.943	34.567	48.422	41.158	34.985	37.714	31.414	41.484
STI	289.13	269.13	319.02	227.31	322.3	272.5	230.17	248.88	205.69	274.74

RL= Root length, SL= Shoot length, CL= Coleoptile length, SDL= Seedling length, FWS= Fresh weight of seedling, DWS= Dry weight of seedling, GP= Germination percentage, SVI= Seedling vigor index, ADF= Acid detergent fiber, NDF= Neutral detergent fiber, STI= Salinity tolerance index.

Total 10 maize genotypes were evaluated for morphological and physiological traits under salinity stress conditions (Table 2). Notable variations were observed among genotypes for root length, shoot length, coleoptile length and seedling length indicating significant genetic diversity in response to saline environments. PBG-238 exhibited the highest values for root, shoot and seedling lengths demonstrating superior early growth potential while PBG-76 recorded the lowest shoot and seedling lengths suggesting its vulnerability under stress conditions. Coleoptile length was higher in PBG-238 supporting better emergence and early vigor. Fresh and dry weights of seedlings further emphasized genotype performance under stress. PBG-238 and PBG-477 exhibited greater fresh and dry weight implying their higher

biomass accumulation. The root-shoot ratio (RSR), a marker of water and nutrient uptake balance, remained relatively stable across genotypes suggesting a consistent adaptation strategy in most lines. Germination percentage was highest in PBG-238 followed closely by PBG-477 indicating enhanced seed viability and early establishment capacity under salt stress. Seedling vigor index (SVI), a critical parameter for early-stage plant performance, was notably high in PBG-238 affirming its stress resilience. Moisture content and starch levels also peaked in the same genotype supporting its metabolic stability under adverse conditions. Protein concentration was highest in PBG-238 making it nutritionally valuable. Additionally, PBG-238 showed superior fiber content, important for fodder quality. The salinity tolerance

index (STI) further validated the potential of PBG-238 and PBG-477, respectively. These genotypes demonstrated promising performance across all evaluated parameters, making them strong candidates for salt-affected areas.

Correlation Studies

Results presented in table-3 showed the genotypic correlation analysis across control and two salt-induced stress levels (100 mM and 150 mM NaCl) and revealed dynamic and condition-specific associations among morphological and physiological traits of maize at early growth stages. Across all conditions, a consistent and strong positive relationship was observed among root length (RL), shoot length (SL), coleoptile length (CL) and seedling length (SDL). Under control conditions, RL revealed a significant positive association with CL but a negative association with seed vigor index (SVI). SVI was positively correlated with SL and seedling length under both salinity levels. Fresh weight of seedling (FWS) demonstrated strong positive associations with seedling length and SVI under S_1 and a moderate correlation with dry weight of seedling (DWS) across both stress levels. DWS also showed a strong correlation with FWS and moisture content under salt stress. Root-shoot ratio (RSR) was positively linked to FWS and SL under S_1 . However, at 150 mM (S_2) this relationship weakened possibly due to salt-induced growth inhibition. Starch content exhibited significant positive correlations with FWS and RSR under S_1 while under S_2 , it had strong negative correlations with ADF and NDF. Protein content showed a negative relationship with seedling length. A highly consistent and strong positive correlation between ADF and NDF was observed under all conditions. Under stress, NDF showed significant positive associations with SL and SVI in S_1 while a negative relationship with starch and protein was noted in S_2 .

Results presentation in Table 4 shows the Pearson's correlation coefficient of morpho-physiological attributes of maize seedlings treated with hydro-priming, halo-priming and osmo-priming under 150 mM NaCl. Seedling length showed strong positive correlations with RL, SL, FWS, DWS, and SVI across all priming treatments, especially under S_1 . In case of S_2 , hydro-priming exhibited the strongest correlation (e.g., SL vs. seedling length). Osmo-priming showed a negative or non-significant trend for seedling traits under S_2 , indicating sensitivity to high salinity. SVI was positively correlated with RL, SL, Seedling Length, FWS and DWS under all treatments at both salinity levels. The strongest correlation under hydro-priming with S_2 , was with seedling length and FWS. Under osmo-priming with S_2 , SVI had negative associations with seedling traits like RL and Seedling Length. RSR was positively correlated with DWS and SVI under hydro-priming with S_1 but negatively associated under osmo-priming. Osmo-priming with S_2

showed a strong negative correlation between RSR and DWS. GP% showed mostly weak and non-significant correlations with growth traits. Halo-priming with S_2 showed positive correlation with protein content but negative with starch and ADF/NDF. Starch showed negative correlations with ADF and NDF under all treatments, especially under halo-priming and osmo-priming with S_2 . Protein had a negative correlation with fiber content (ADF/NDF) under all treatments, particularly halo-priming with S_2 . Moisture content was negatively correlated with seedling traits under all treatments, especially osmo-priming with S_2 . STI correlated positively with seedling traits (RL, SL, FWS, SVI) under hydro- and halo-priming, especially with S_1 ; strongest in hydro-priming with S_1 with RSR and SVI; negatively correlated with starch, ADF, and NDF, indicating that lower structural carb content aligns with better stress tolerance.

Table III. Genotypic correlation coefficient among seedling traits of maize under control, 100 mM NaCl and 150 mM NaCl.

		RL	SL	CL	SDL	FWS	DWS	RSR	GP	SVI	Moisture	Starch	Protein	ADF	NDF
RL	S1	1													
	S2		0.38*	0.35 ^{NS}	0.94**	0.091 ^{NS}	-	0.26 ^{NS}	-0.12 ^{NS}	-0.14 ^{NS}	-0.61**	-0.25 ^{NS}	-0.23 ^{NS}	-0.18 ^{NS}	0.16 ^{NS}
SL	S1	0.18 ^{NS}	1												
	S2	-0.01 ^{NS}		0.21 ^{NS}	0.61**	0.67**	0.02 ^{NS}	0.16 ^{NS}	0.12 ^{NS}	0.13 ^{NS}	-0.26 ^{NS}	0.31 ^{NS}	-0.32 ^{NS}	-0.53**	-0.53**
CL	S1	0.12 ^{NS}	0.39*	1											
	S2	0.62**	0.43*		0.37*	0.05 ^{NS}	0.03 ^{NS}	0.61**	0.11 ^{NS}	0.23 ^{NS}	0.15 ^{NS}	0.13 ^{NS}	-0.46**	0.15 ^{NS}	0.07 ^{NS}
SDL	S1	0.82**	0.66**	0.33 ^{NS}	1										
	S2	0.75**	0.63**	0.74**		0.4*	-	0.33 ^{NS}	-0.13 ^{NS}	-0.001 ^{NS}	-0.52**	-0.06 ^{NS}	-0.27 ^{NS}	-0.36**	-0.11 ^{NS}
FWS	S1	0.31 ^{NS}	0.42*	0.02 ^{NS}	0.45**	1									
	S2	-0.21 ^{NS}	0.31 ^{NS}	-0.02 ^{NS}	0.07 ^{NS}		0.52**	0.11 ^{NS}	-0.05 ^{NS}	0.59**	0.12 ^{NS}	0.34 ^{NS}	-0.24 ^{NS}	-0.45**	-0.60**
DWS	S1	0.31 ^{NS}	0.14 ^{NS}	-0.04 ^{NS}	0.23 ^{NS}	-0.18 ^{NS}	1								
	S2	-0.03 ^{NS}	0.63**	0.20 ^{NS}	0.37*	0.38*		-0.23 ^{NS}	0.02 ^{NS}	0.93**	0.52**	-0.04 ^{NS}	-0.19 ^{NS}	0.26 ^{NS}	-0.06 ^{NS}
RSR	S1	-0.14 ^{NS}	0.56**	0.23 ^{NS}	0.25 ^{NS}	0.67**	-0.58**	1							
	S2	0.01 ^{NS}	-0.23 ^{NS}	-0.05 ^{NS}	-0.14 ^{NS}	0.17 ^{NS}	-0.38*		-0.22 ^{NS}	0.10 ^{NS}	0.15 ^{NS}	0.21 ^{NS}	-0.24 ^{NS}	-0.05 ^{NS}	-0.09 ^{NS}
GP	S1	-0.19 ^{NS}	0.17 ^{NS}	-0.02 ^{NS}	-0.05 ^{NS}	0.33 ^{NS}	0.24 ^{NS}	0.25 ^{NS}	1						
	S2	-0.23 ^{NS}	0.19 ^{NS}	-0.17 ^{NS}	-0.072 ^{NS}	0.23 ^{NS}	0.06 ^{NS}	0.14 ^{NS}		-0.06 ^{NS}	0.07 ^{NS}	-0.12 ^{NS}	-0.07 ^{NS}	0.23 ^{NS}	0.18 ^{NS}
SVI	S1	0.10 ^{NS}	0.62**	0.20 ^{NS}	0.40*	0.42*	0.60**	0.25 ^{NS}	0.62**	1					
	S2	0.02 ^{NS}	0.42*	0.21 ^{NS}	0.28 ^{NS}	0.53**	0.56**	0.49**	0.11**		0.59**	0.10 ^{NS}	-0.28 ^{NS}	0.20 ^{NS}	-0.16 ^{NS}
Moisture	S1	0.30 ^{NS}	0.35 ^{NS}	0.15 ^{NS}	0.41*	-0.16 ^{NS}	0.68**	-0.29 ^{NS}	-0.01 ^{NS}	0.42*	1				
	S2	0.29 ^{NS}	-0.18 ^{NS}	-0.11 ^{NS}	0.08 ^{NS}	-0.11 ^{NS}	0.11 ^{NS}	0.03 ^{NS}	-0.31 ^{NS}	0.12 ^{NS}		0.18 ^{NS}	0.04 ^{NS}	0.54**	-0.01 ^{NS}
Starch	S1	-0.13 ^{NS}	0.17 ^{NS}	0.09 ^{NS}	-0.05 ^{NS}	0.57**	-0.30 ^{NS}	0.47**	0.23 ^{NS}	0.17 ^{NS}	-0.17 ^{NS}	1			
	S2	-0.16 ^{NS}	-0.26 ^{NS}	-0.21 ^{NS}	-0.29 ^{NS}	0.1 ^{NS}	-0.04 ^{NS}	0.42*	-0.28 ^{NS}	0.41*	0.52**		-0.21 ^{NS}	-0.54**	-0.88**
Protein	S1	-0.33 ^{NS}	-0.22 ^{NS}	0.12 ^{NS}	-0.34 ^{NS}	-0.22 ^{NS}	-0.14 ^{NS}	-0.15 ^{NS}	-0.10 ^{NS}	-0.23 ^{NS}	-0.26 ^{NS}	0.07 ^{NS}	1		
	S2	-0.21 ^{NS}	-0.27 ^{NS}	-0.29 ^{NS}	-0.36*	-0.22 ^{NS}	-0.29 ^{NS}	0.33 ^{NS}	-0.23 ^{NS}	0.05 ^{NS}	0.44*	0.59**		-0.01 ^{NS}	0.01 ^{NS}
ADF	S1	-0.20 ^{NS}	0.12 ^{NS}	-0.13 ^{NS}	-0.18 ^{NS}	-0.40*	0.37*	-0.19 ^{NS}	0.06 ^{NS}	0.12 ^{NS}	0.42*	-0.24 ^{NS}	-0.07 ^{NS}	1	
	S2	0.11 ^{NS}	0.37*	0.10 ^{NS}	0.32 ^{NS}	0.18 ^{NS}	0.30 ^{NS}	-0.50**	0.30 ^{NS}	-0.26 ^{NS}	-0.34 ^{NS}	-0.87**	-0.57**		0.77**
NDF	S1	-0.18 ^{NS}	0.54**	-0.08 ^{NS}	0.08 ^{NS}	-0.27 ^{NS}	0.52**	-0.07 ^{NS}	0.13 ^{NS}	0.46**	0.53**	-0.26 ^{NS}	-0.19 ^{NS}	0.74**	1
	S2	-0.23 ^{NS}	0.14 ^{NS}	0.09 ^{NS}	-0.06 ^{NS}	0.06 ^{NS}	-0.22 ^{NS}	-0.08 ^{NS}	0.32 ^{NS}	-0.26 ^{NS}	-0.94**	-0.68**	-0.42*	0.48**	
STI	S1	0.24 ^{NS}	-0.02 ^{NS}	0.38*	0.18 ^{NS}	0.34 ^{NS}	0.21 ^{NS}	0.09 ^{NS}	0.30 ^{NS}	0.39*	0.29 ^{NS}	0.32 ^{NS}	-0.12 ^{NS}	-0.19 ^{NS}	-0.34 ^{NS}
	S2	0.02 ^{NS}	0.10 ^{NS}	0.21 ^{NS}	0.07 ^{NS}	0.33 ^{NS}	-0.11 ^{NS}	0.72**	0.02 ^{NS}	0.67**	-0.09 ^{NS}	0.36*	0.23 ^{NS}	-0.44*	0.06 ^{NS}

Significance level< 0.05, **= Highly significant, *= Significant, NS= Non-significant

Upper diagonal= Control

Lower diagonal: S1= 100 mM NaCl and S2= 150 mM NaCl

RL= Root length, SL= Shoot length, CL= Coleoptile length, SDL= Seedling length, FWS= Fresh weight of seedling, DWS= Dry weight of seedling, GP= Germination percentage, SVI= Seedling vigor index, ADF= Acid detergent fiber, NDF= Neutral detergent fiber, STI= Salinity tolerance index

Table IV: Correlation coefficient among seedling traits of maize hydropriming, halopriming and osmo-priming under 100 mM NaCl and 150 mM NaCl

		RL	SL	CL	SDL	FWS	DWS	RSR	GP	SVI	Moisture	Starch	Protein	ADF	NDF	STI	
	RL	1	0.02 ^{NS}	0.14 ^{NS}	0.83 ^{**}	0.14 ^{NS}	0.05 ^{NS}	0.13 ^{NS}	-0.17 ^{NS}	-0.05 ^{NS}	0.34 ^{NS}	-0.32 ^{NS}	0.03 ^{NS}	0.32	0.29 ^{NS}	0.29 ^{NS}	T1S1
			0.33 ^{NS}	0.32 ^{NS}	0.96 ^{**}	0.65 ^{**}	0.58 ^{**}	-0.24 ^{NS}	-0.31 ^{NS}	0.44 [*]	0.11 ^{NS}	-0.26 ^{NS}	-0.05 ^{NS}	-0.06 ^{NS}	-0.36 [*]	0.27 ^{NS}	T2S1
			0.38 [*]	0.51 ^{**}	0.48 ^{**}	0.63 ^{**}	0.46 ^{**}	0.34 ^{NS}	0.08 ^{NS}	0.62 ^{**}	0.09 ^{NS}	-0.07 ^{NS}	-0.06 ^{NS}	0.24 ^{NS}	0.32 ^{NS}	-0.03 ^{NS}	T3S1
T1S2	SL	0.36 [*]	1	0.44 [*]	0.55 ^{**}	0.45 ^{**}	0.39 [*]	0.08 ^{NS}	-0.11 ^{NS}	0.13 ^{NS}	0.31 ^{NS}	-0.38 [*]	-0.07 ^{NS}	0.45 ^{**}	0.35 ^{NS}	0.12 ^{NS}	T1S1
T2S2		0.43 [*]		-0.22 ^{NS}	0.39 [*]	0.65 ^{**}	0.41 [*]	0.08 ^{NS}	-0.05 ^{NS}	0.10 ^{NS}	0.45 ^{**}	-0.16 ^{NS}	0.10 ^{NS}	0.18 ^{NS}	-0.13 ^{NS}	-0.02 ^{NS}	T2S1
T3S2		-0.40 [*]		0.27 ^{NS}	-0.05 ^{NS}	-0.19 ^{NS}	0.03 ^{NS}	-0.12 ^{NS}	0.27 ^{NS}	-0.03 ^{NS}	-0.50 ^{**}	0.54 ^{**}	-0.05 ^{NS}	-0.39 [*]	-0.44 ^{**}	0.22 ^{NS}	T3S1
T1S2	CL	-0.26 ^{NS}	0.14 ^{NS}	1	0.31 ^{NS}	0.34 ^{NS}	0.20 ^{NS}	0.23 ^{NS}	0.01 ^{NS}	0.26 ^{NS}	0.04 ^{NS}	-0.12 ^{NS}	-0.32 ^{NS}	0.31 ^{NS}	0.24 ^{NS}	0.34 ^{NS}	T1S1
T2S2		0.38 [*]	0.58 ^{**}		0.32 ^{NS}	-0.03 ^{NS}	0.26 ^{NS}	-0.12 ^{NS}	-0.09 ^{NS}	0.29 ^{NS}	-0.16 ^{NS}	-0.19 ^{**}	-0.09 ^{NS}	0.02 ^{NS}	-0.02 ^{NS}	0.35 ^{NS}	T2S1
T3S2		-0.44 [*]	0.60 ^{**}		0.56 ^{**}	0.36 [*]	0.37 [*]	-0.11 ^{NS}	0.05 ^{NS}	0.24 ^{NS}	-0.25 ^{NS}	0.03 ^{NS}	0.04 ^{NS}	-0.09 ^{NS}	0.03 ^{NS}	-0.02 ^{NS}	T3S1
T1S2	SDL	0.77 ^{**}	0.86 ^{**}	-0.08 ^{NS}	1	0.39 [*]	0.23 ^{NS}	0.12 ^{NS}	-0.20 ^{NS}	0.03 ^{NS}	0.47 ^{**}	-0.49 ^{**}	-0.02 ^{NS}	0.53 ^{**}	0.43 [*]	0.32 ^{NS}	T1S1
T2S2		0.95 ^{**}	0.66 ^{**}	0.49 ^{**}		0.66 ^{**}	0.69 ^{**}	-0.34 ^{NS}	-0.38 ^{NS}	0.36 [*]	0.17 ^{NS}	-0.19 ^{NS}	-0.06 ^{NS}	0.04 ^{NS}	-0.36 [*]	0.29 ^{NS}	T2S1
T3S2		0.87 ^{**}	-0.19 ^{NS}	-0.17 ^{NS}		0.62 ^{**}	0.30 ^{NS}	0.14 ^{NS}	0.01 ^{NS}	0.46 ^{**}	0.05 ^{NS}	-0.03 ^{NS}	0.23 ^{NS}	0.07 ^{NS}	0.12 ^{NS}	-0.36 [*]	T3S1
T1S2	FWS	0.53 ^{**}	0.89 ^{**}	0.12 ^{NS}	0.89 ^{**}	1	0.55 ^{**}	0.01 ^{NS}	-0.21 ^{NS}	0.74 ^{**}	0.36 [*]	-0.11 ^{NS}	0.03 ^{NS}	0.29 ^{NS}	0.01 ^{NS}	0.52 ^{**}	T1S1
T2S2		0.16 ^{NS}	0.23 ^{NS}	0.47 ^{**}	0.25 ^{NS}		0.51 ^{**}	0.07 ^{NS}	-0.38 [*]	0.21 ^{NS}	0.21 ^{NS}	-0.39 [*]	-0.36 [*]	0.28 ^{NS}	0.04 ^{NS}	0.40 [*]	T2S1
T3S2		0.22 ^{NS}	0.05 ^{NS}	0.04 ^{NS}	0.11 ^{NS}		0.19 ^{NS}	0.49 ^{**}	0.08 ^{NS}	0.48 ^{**}	0.26 ^{NS}	-0.20 ^{NS}	0.15 ^{NS}	0.39 [*]	0.53 ^{**}	-0.34 ^{NS}	T3S1
T1S2	DWS	0.44 [*]	0.79 ^{**}	0.11 ^{NS}	0.74 ^{**}	0.79 ^{**}	1	0.26 ^{NS}	-0.39 ^{NS}	0.67 ^{**}	0.22 ^{NS}	0.19 ^{NS}	0.29 ^{NS}	-0.05 ^{NS}	-0.29 ^{NS}	0.57 ^{**}	T1S1
T2S2		0.60 ^{**}	0.53 ^{**}	0.29 ^{NS}	0.68 ^{**}	0.48 ^{**}		-0.48 ^{**}	-0.32 ^{NS}	0.24 ^{NS}	0.12 ^{NS}	-0.26 ^{NS}	-0.25 ^{NS}	0.31 ^{NS}	-0.01 ^{NS}	0.55 ^{**}	T2S1
T3S2		0.02 ^{NS}	-0.28 ^{NS}	-0.04 ^{NS}	-0.05 ^{NS}	-0.12 ^{NS}		-0.02 ^{NS}	-0.06 ^{NS}	0.69 ^{**}	0.02 ^{NS}	-0.11 ^{NS}	-0.03 ^{NS}	0.04 ^{NS}	0.14 ^{NS}	0.05 ^{NS}	T3S1
T1S2	RSR	0.54 ^{**}	0.36 [*]	0.09 ^{NS}	0.59 ^{**}	0.44 ^{**}	0.09 ^{NS}	1	0.23 ^{NS}	0.22 ^{NS}	0.23 ^{NS}	0.18 ^{NS}	0.37 [*]	-0.22 ^{NS}	-0.19 ^{NS}	0.18 ^{NS}	T1S1
T2S2		-0.46 ^{**}	0.04 ^{NS}	-0.14 ^{NS}	-0.38 [*]	-0.33 ^{NS}	-0.64 ^{**}		0.16 ^{NS}	0.09 ^{NS}	-0.27 ^{NS}	-0.02 ^{NS}	-0.13 ^{NS}	-0.14 ^{NS}	0.31 ^{NS}	-0.08 ^{NS}	T2S1
T3S2		-0.17 ^{NS}	0.43 [*]	0.24 ^{NS}	-0.14 ^{NS}	0.27 ^{NS}	-0.87 ^{**}		0.23 ^{NS}	0.65 ^{**}	0.41 [*]	-0.28 ^{NS}	-0.27 ^{NS}	0.33 ^{NS}	0.42 [*]	0.22 ^{NS}	T3S1
T1S2	GP	0.11 ^{NS}	0.26 ^{NS}	-0.11 ^{NS}	0.24 ^{NS}	0.32 ^{NS}	0.22 ^{NS}	0.03 ^{NS}	1	-0.29 ^{NS}	0.08 ^{NS}	0.02 ^{NS}	0.09 ^{NS}	-0.09 ^{NS}	-0.03 ^{NS}	-0.29 ^{NS}	T1S1
T2S2		0.11 ^{NS}	0.10 ^{NS}	0.31 ^{NS}	0.12 ^{NS}	-0.21 ^{NS}	-0.27 ^{NS}	0.10 ^{NS}		0.18 ^{NS}	-0.26 ^{NS}	0.44 [*]	0.24 ^{NS}	-0.51 ^{**}	-0.27 ^{NS}	-0.13 ^{NS}	T2S1
T3S2		0.12 ^{NS}	0.24 ^{NS}	0.13 ^{NS}	0.19 ^{NS}	0.13 ^{NS}	-0.28 ^{NS}	0.35 ^{NS}		0.07 ^{NS}	-0.12 ^{NS}	0.05 ^{NS}	0.09 ^{NS}	-0.16 ^{NS}	-0.01 ^{NS}	0.02 ^{NS}	T3S1

		RL	SL	CL	SDL	FWS	DWS	RSR	GP	SVI	Moisture	Starch	Protein	ADF	NDF	STI	
T1S2	SVI	0.65**	0.82**	0.18 ^{NS}	0.91**	0.85**	0.80**	0.65**	0.18 ^{NS}	1	-0.01 ^{NS}	0.26 ^{NS}	0.21 ^{NS}	-0.07 ^{NS}	-0.29 ^{NS}	0.70**	T1S1
T2S2		0.45**	0.71**	0.32 ^{NS}	0.62**	0.39*	0.83**	-0.17 ^{NS}	-0.21 ^{NS}		-0.13 ^{NS}	0.01 ^{NS}	0.22 ^{NS}	-0.25 ^{NS}	-0.26 ^{NS}	0.12 ^{NS}	T2S1
T3S2		-0.44**	0.47**	0.54**	-0.45**	0.26**	-0.03 ^{NS}	0.37*	0.07 ^{NS}		0.33 ^{NS}	-0.23 ^{NS}	-0.16 ^{NS}	0.28 ^{NS}	0.35 ^{NS}	0.15 ^{NS}	T3S1
T1S2	Moisture	0.22 ^{NS}	-0.33 ^{NS}	0.17 ^{NS}	-0.34 ^{NS}	-0.42*	-0.38*	-0.17 ^{NS}	-0.05 ^{NS}	-0.34 ^{NS}	1	-0.36*	0.12 ^{NS}	0.37*	0.13 ^{NS}	-0.06 ^{NS}	T1S1
T2S2		-0.31 ^{NS}	-0.15 ^{NS}	0.15 ^{NS}	-0.33 ^{NS}	-0.26 ^{NS}	-0.34 ^{NS}	0.30 ^{NS}	-0.04 ^{NS}	-0.23 ^{NS}		-0.45**	0.24 ^{NS}	0.65**	0.19 ^{NS}	-0.48**	T2S1
T3S2		0.23 ^{NS}	-0.51**	-0.61**	0.01 ^{NS}	-0.68**	0.14 ^{NS}	-0.27 ^{NS}	-0.03 ^{NS}	-0.41**		-0.84**	-0.02 ^{NS}	0.85**	0.81**	-0.21 ^{NS}	T3S1
T1S2	Starch	0.53**	0.21 ^{NS}	-0.55**	0.45**	0.41*	0.33 ^{NS}	0.14 ^{NS}	-0.05 ^{NS}	0.28 ^{NS}	-0.41*	1	0.58**	-0.87**	-0.91**	-0.02 ^{NS}	T1S1
T2S2		0.07 ^{NS}	-0.09 ^{NS}	-0.28 ^{NS}	0.03 ^{NS}	-0.27 ^{NS}	-0.21 ^{NS}	0.18 ^{NS}	0.38*	-0.14 ^{NS}	-0.61		0.26 ^{NS}	-0.68**	-0.66**	-0.03 ^{NS}	T2S1
T3S2		-0.35 ^{NS}	0.26 ^{NS}	-0.17 ^{NS}	-0.46**	-0.17 ^{NS}	0.35 ^{NS}	-0.19 ^{NS}	-0.29 ^{NS}	0.19 ^{NS}	0.15 ^{NS}		0.15 ^{NS}	-0.71**	-0.86**	-0.01 ^{NS}	T3S1
T1S2	Protein	-0.14 ^{NS}	0.01 ^{NS}	-0.07 ^{NS}	-0.03 ^{NS}	-0.07 ^{NS}	-0.13 ^{NS}	0.03 ^{NS}	-0.19 ^{NS}	-0.08 ^{NS}	0.24 ^{NS}	0.05 ^{NS}	1	-0.51**	0.31 ^{NS}	0.05 ^{NS}	T1S1
T2S2		-0.08 ^{NS}	-0.16 ^{NS}	-0.23 ^{NS}	-0.08 ^{NS}	-0.14 ^{NS}	-0.06 ^{NS}	0.08 ^{NS}	-0.12 ^{NS}	-0.02 ^{NS}	-0.07 ^{NS}	0.35 ^{NS}		-0.31 ^{NS}	-0.45**	-0.58**	T2S1
T3S2		0.28 ^{NS}	-0.76**	-0.53**	0.11 ^{NS}	-0.55**	0.19 ^{NS}	-0.33 ^{NS}	0.03 ^{NS}	-0.45**	0.90**	-0.10 ^{NS}		0.14 ^{NS}	-0.15 ^{NS}	-0.48**	T3S1
T1S2	ADF	-0.08 ^{NS}	0.52**	0.33 ^{NS}	0.26 ^{NS}	0.32 ^{NS}	0.34 ^{NS}	0.02 ^{NS}	0.12 ^{NS}	0.32 ^{NS}	0.19 ^{NS}	-0.56**	-0.05	1	0.88**	0.11 ^{NS}	T1S1
T2S2		-0.14 ^{NS}	0.19 ^{NS}	0.22 ^{NS}	-0.01 ^{NS}	0.11 ^{NS}	0.09 ^{NS}	-0.05 ^{NS}	0.06 ^{NS}	0.16 ^{NS}	0.41 ^{NS}	-0.66**	-0.24 ^{NS}		0.76**	-0.04 ^{NS}	T2S1
T3S2		-0.14 ^{NS}	0.37*	0.57**	0.22 ^{NS}	0.18 ^{NS}	-0.44*	0.43*	0.18 ^{NS}	0.35 ^{NS}	-0.62**	-0.46**	-0.49**		0.78**	-0.17 ^{NS}	T3S1
T1S2	NDF	-0.48**	0.03 ^{NS}	0.56**	-0.27 ^{NS}	-0.18 ^{NS}	-0.12 ^{NS}	-0.11 ^{NS}	0.08 ^{NS}	-0.09 ^{NS}	0.21 ^{NS}	-0.94**	-0.05 ^{NS}	0.72**	1	-0.06 ^{NS}	T1S1
T2S2		-0.46**	-0.11 ^{NS}	-0.07 ^{NS}	-0.38*	0.05 ^{NS}	-0.19 ^{NS}	0.13 ^{NS}	-0.18 ^{NS}	-0.11 ^{NS}	0.48**	-0.76**	-0.27 ^{NS}	0.78**		0.05 ^{NS}	T2S1
T3S2		-0.16 ^{NS}	0.59**	0.65**	0.06 ^{NS}	0.58**	-0.35 ^{NS}	0.52**	0.32 ^{NS}	0.51**	-0.84**	-0.30 ^{NS}	-0.79**	0.68**		-0.17 ^{NS}	T3S1
T1S2	STI	0.53**	-0.01 ^{NS}	-0.14 ^{NS}	0.34 ^{NS}	0.12 ^{NS}	0.02 ^{NS}	0.65**	-0.13 ^{NS}	0.35 ^{NS}	-0.12 ^{NS}	0.47**	0.11 ^{NS}	-0.57**	-0.55**	1	
T2S2		0.38*	0.41*	0.18 ^{NS}	0.43*	0.31 ^{NS}	0.63**	-0.23 ^{NS}	-0.29 ^{NS}	0.59**	-0.04 ^{NS}	-0.06 ^{NS}	0.07 ^{NS}	0.02 ^{NS}	-0.35 ^{NS}		
T3S2		0.12 ^{NS}	-0.15 ^{NS}	0.37*	0.09 ^{NS}	0.11 ^{NS}	0.02 ^{NS}	0.12 ^{NS}	-0.22 ^{NS}	0.46**	-0.13 ^{NS}	-0.31 ^{NS}	0.05 ^{NS}	0.34 ^{NS}	0.22 ^{NS}		

Significance level<0.05, **= Highly significant, *= Significant, NS= Non-significant

Upper diagonal= Hydropriming (T1), halopriming (T2) and osmo-priming (T3) under 100mM salinity level (S1)

Lower diagonal: Hydropriming (T1), halopriming (T2) and osmo-priming (T3) under 150mM salinity level (S2)

RL= Root length, SL= Shoot length, CL= Coleoptile length, SDL= Seedling length, FWS= Fresh weight of seedling, DWS= Dry weight of seedling, GP= Germination percentage, SVI= Seedling vigor index, ADF= Acid detergent fiber, NDF= Neutral detergent fiber, STI= Salinity tolerance index.

Discussion

A critical abiotic stress is salinity that substantially hampers maize (*Zea mays* L.) growth and development, particularly during early seedling stages. The initial phases of crop establishment are highly sensitive to environmental conditions. Salinity stress impairs these stages by inducing osmotic and ionic stress, which together hinder germination and restrict subsequent seedling growth (Shah *et al.*, 2021). Within the framework of present study, salinity stress notably impacted key traits such as root length, shoot length, seedling length and seedling vigor index. Salinity has a pronounced negative impact, strongly inhibiting root elongation. Priming also affects radicle growth but the effect is smaller than salinity. Genotypes PBG-477 and PBG-238 showed superior root and shoot growth, demonstrating strong early vigor under saline conditions. These findings support the investigation of Khan *et al.*, (2016) and Jalal *et al.*, (2019) who observed prolonged roots in primed seeds in comparison to the unprimed seeds. Similarly, shoot length decreases as the salinity level increases and priming helps slightly. This study deviates from the findings of Olayinka *et al.*, (2023) who noted the absence of significant interaction between cultivar and stress. Maize seeds primed with potassium nitrate exhibited greater shoot length as published by Khan *et al.*, (2016).

Seedling length (SDL) significantly decreased by salinity-induced stress resulting from osmotic imbalance and toxic ion accumulation. Significant genotypic effect highlighted the presence of variability among maize cultivars in their inherent growth potential. Seedling length (SDL) and root length (RL) were highest in PBG-477 suggesting robust physiological resilience. Seed priming suggesting their role in alleviating stress and promoting seedling development under salinity affected environment. The same was published by Shruti *et al.*, (2024), who found that priming significantly increased seedling length while salinity had a negative impact on seedling length. The interaction between salinity and priming showed significant differences in seedling length across all salinity levels. This pattern aligns with the observations made by Basra *et al.*, (2006) in wheat.

Salinity stress induced a decrease in seedling fresh and dry weights, demonstrating reduced cell expansion and water retention. This is consistent with research showing clear genotypic difference in seedling growth under salinity conditions (Iqbal *et al.*, 2020). The salinity effect exerted a strong inhibitory impact on FWS, reflecting the well-established osmotic and ionic stress response in seedlings exposed to saline soil as demonstrated by Zahra *et al.*, (2020). Genotype PBG-477 exhibited the highest fresh and dry weights under saline stress, indicating better osmotic adjustment. These findings support the work of Masuda *et al.*

(2021), who documented enhanced water retention traits in salt-tolerant maize lines. Similarly, dry matter percentage was higher under lower salinity conditions than under higher salinity as it endorse the findings of Shruti *et al.*, (2024). Similar improvements in dry weight of both roots and shoots have been reported by Abraha and Yohannes, (2013) in maize using NaCl priming via enhanced antioxidant capacity and membrane integrity. Priming significantly mitigated biomass losses under stress. Hydro-primed seeds showed superior biomass accumulation due to improved membrane stability and efficient mobilization of reserves. The interactions suggest that priming efficacy for improving seedling biomass is highly genotype-dependent and sensitive to salinity levels, as already reported by Zhang *et al.*, (2023).

Salinity negatively affects germination percentage (GP), mainly owing osmotic imbalance and ion-induced toxicity. The decrease in germination percentage with increasing salt concentrations could be associated with the buildup of harmful ions, a reduction in the osmotic potential of the growth solution or an imbalance in the remobilization of seed reserves. This decline in germination percentage due to higher salinity levels is consistent with the findings of Ashkan and Jalal, (2013). Liu *et al.*, (2015) observed that reduced germination under saline conditions was associated with decreased water potential and limited water availability to the seeds. Similarly, Okello *et al.*, (2022) indicating that priming seeds of the medicinal plant *Aspilia Africana* with KNO₃ for 6 and 12 hours significantly improved germination parameters, highlighting the potential of seed priming in alleviating the detrimental effects induced by salinity stress. However, PBG-477 and PBG-238 maintained higher GP indicating stronger tolerance. These findings endorse the results of Chaudhary *et al.* (2017), who observed significant variability among genotypes in germination efficiency under salt stress.

Likewise, SVI was highest in PBG-238 and PBG-477 making them suitable for saline-prone regions. Seed priming significantly improved the seedling vigor index under salinity stress as these findings align with the study of Shruti *et al.*, (2024), who found that priming maize seeds with KNO₃ significantly enhanced seedling vigor index. Similarly, Filho, (2015) revealed that seedling vigor index of wheat exhibited a significant decline with increasing salinity levels. Seeds primed with KNO₃ recorded the highest vigor index at 0 dS/m, indicating optimal conditions for early growth. An enhancement of salt concentration induced a decline in moisture content. Zulkadir (2025), found that an increase in salt concentrations decreases germination and related parameters including the moisture content of seedlings. Priming significantly improves the moisture retention in all treatments by stabilizing membranes and enhancing osmotic

adjustments. The same was found by Kakar *et al.*, (2023) who published that seed priming and its interactions significantly reduce the osmotic stress and improve the agro-physiological traits of maize under osmotic stress condition. Salinity stress negatively impacted starch and protein contents in most genotypes. Nonetheless, PBG-477 and PBG-238 maintained higher starch and protein content which may be attributed to efficient nitrogen assimilation and carbohydrate partitioning under stress. Concordant results were published by Sghayar *et al.*, (2023) who found that sodium accumulation in seedling tissues of wheat markedly disrupted the mobilization of carbohydrates and proteins by suppressing the activities of key enzymes such as amylases and proteases. However, this inhibitory effect was considerably reduced in seeds that underwent priming treatment. Priming notably improved these biochemical attributes. Hydro-priming and halo-priming helped to preserve starch and protein levels by stabilizing key metabolic processes, whereas osmo-priming showed moderate enhancement. The priming effect implies that seed priming enhances protein content under salinity by activating antioxidant systems, stabilizing membranes and promoting nitrogen metabolism. Karimi *et al.*, (2025) demonstrated that Salicylic acid priming mitigates the inhibitory effect of salt stress and increases total leaf protein content. Gerna *et al.* (2018) and Lee and Kim (2000) reported that priming stimulates the enzymatic synthesis and functional activation essential for the degradation and mobilization of stored food reserves, thereby increasing the efficiency of the germination process.

Salt stress significantly influences ADF in seedlings as it is indicated by Arshad *et al.*, (2017) that during mild stress, ADF reduced in alfalfa cultivars as compared to the control. The priming effect indicates that seed priming reduces ADF accumulation under salt stress. These findings are consistent with Patel *et al.*, (2023) who found that maize seeds priming for 6 hours by 0.5 % ZnSO₄ lower the ADF content as compared to the control. Significant interaction effects imply that the influence of priming on ADF is both genotype-specific and salinity-dependent. Tondey *et al.*, (2021) revealed that when fodder seeds of maize were treated with ZnONPs (20 mg L⁻¹), it significantly increased vegetative and yield parameters, ADF and hemicellulose content. Salinity stress lowered the NDF as it is indicated by Owensby *et al.*, (1996) who found that increase in salt stress reduces nitrogen and protein content and ultimately quality parameters like NDF. The similar results were published by Arshad *et al.*, (2017). Furthermore, all interaction effects, genotype × salinity, genotype × priming, salinity × priming and the three-way interaction, were also statistically significant, demonstrating that fiber composition is affected by the combined influence of genotype, salinity intensity and

priming treatment. Tondey *et al.*, (2021) revealed that the application of ZnONPs (40 mg L⁻¹) ameliorated parameters like NDF, chlorophyll content, soil nitrogen and phosphorous and cellulose content.

The Salinity Tolerance Index (STI), which assesses plant performance under both stress and control conditions, ranked PBG-238 and PBG-477 as top performers. Priming further enhanced STI values across treatments, especially with hydro-priming and halo-priming, indicating greater adaptability and recovery under stress. This study confirms the report of Masuda *et al.*, (2021) who found that STI acts as a vital criterion factor for the screening cultivars adapted to saline environments. Ehtaiwesh and Almajdob, (2021) published that salinity stress significantly decreased the STI but priming improved the STI as compared to non-primed seeds. Significant positive correlations were observed between seedling length, fresh weight and SVI, confirming co-regulated growth patterns under stress. Correlation matrices revealed that priming strengthened associations between morphological and physiological traits. For example, hydro-priming with 150 mM NaCl treatment showed strong correlations between RL, SL, SVI, fresh weight and STI, confirming its effectiveness in improving early-stage stress resilience and reinforcing its value in enhancing salt tolerance. Across all conditions, a consistent and strong positive relationship was observed among root length (RL), shoot length (SL), coleoptile length (CL) and seedling length as reported by Chaudhary *et al.*, (2017). Osmo-priming improved early traits but with some trade-offs between shoot and root growth. These findings reflect the prospective ability of priming to alleviate ionic and osmotic stress by triggering metabolic readiness and improving water uptake efficiency during seed imbibition.

Under osmo-priming, negative correlations between shoot and root traits suggested a resource allocation trade-off. Such trait relationships provide insights into genotype-specific adaptive strategies and can guide indirect selection for salt tolerance. Dry weight exhibited strong correlations with SVI under priming treatments, indicating that priming facilitates better dry matter partitioning and growth efficiency under saline conditions. Negative correlations between starch and fiber (ADF, NDF) components across priming treatments suggest an internal reallocation of assimilates towards energy metabolism over structural development under stress. This shift highlights the metabolic buffering role of priming in stress adaptation. Significant STI correlations with SVI and biomass traits under primed conditions validate STI as an effective integrative indicator for screening for stress-resilient genotypes. Findings demonstrate that seed priming significantly improves salinity resilience through coordinated

morphological, biochemical and physiological modifications indicated by Sghayar *et al.*, (2023).

Conclusion

This study revealed that seed priming significantly promotes the seedling establishment phase and salinity tolerance of maize by enhancing key morpho-physiological traits. The comprehensive evaluation of maize genotypes under varying salinity and priming treatments revealed significant genetic diversity and adaptive responses across morphological and physiological traits. Genotypes PBG-238 and PBG-477 consistently outperformed in traits such as root and shoot length, seedling vigor index, biomass, germination rate and salinity tolerance index making them ideal candidates for breeding programs targeting salt-affected environments. In contrast, genotypes PBG-1020, PBG-6189, PBG-31 and PBG-76 consistently performed poorly under salinity even with priming indicating its susceptibility to salt stress. The integration of seed priming particularly hydro and halo-priming proved effective in mitigating salinity-induced damage by enhancing seedling establishment, biomass accumulation and biochemical stability. Positive correlations among traits like seedling length, dry weight and STI under priming conditions underscore their utility as selection criteria. These findings advocate for the combined use of genotype screening and seed priming technologies to enhance crop performance and stability under saline agroecosystems.

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