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Research Article

Responses of Inbred (*Zea mays indentata* Sturt.) Lines to Different Salt Concentrations

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Abstract: This study was carried out at the Republic of Türkiye, Bursa Uludag University, Faculty of Agriculture, Department of Field Crops' laboratory during December 2018. Five inbred lines (*Zea mays indentata* Sturt.) (Namely, A1, A3, A4, A7, and T2) and five different salt concentrations (0, 50, 100, 150, and 200 mM) were used. The experiment was set up in a randomized plot design with three replicates. Germination percentage (%), shoot length (mm), root length (mm), shoot fresh weight (mg), shoot dry weight (mg), root fresh weight (mg), root dry weight (mg), and their salt tolerance indexes were investigated. The obtained results showed that salt concentrations had a statistically significant effect on all the traits. It was observed that the values obtained for all traits decreased as the salt concentration increased. The salt concentratiıns higher than 50 mM had a significant adverse effect on the traits, and the lowest values were observed at a dose of 200 mM. A3 inbred line was more tolerant of salinity than the other lines in terms of the traits within the lines. To support our results, the detailed, larger pots or field studies should be established, and the obtained results should be evaluated at the level of soil analysis results according to areas.

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1. Introduction

Plants are constantly exposed to a wide range of environmental conditions that can negatively influence their physiological and biochemical processes. These adverse conditions are collectively referred to as "stress" and can be broadly classified into biotic (originating from living organisms) and abiotic (caused by non-living environmental factors) categories (Larcher, 1995). Among abiotic stress factors, salinity is one of the most significant, as it restricts plant growth, development, and productivity by inducing osmotic imbalance, ion toxicity, and nutrient deficiencies (Kacar et al., 2010; Farooq et al., 2015; Islam et al., 2024).

According to the FAO (2021), over 1.4 billion hectares of land worldwide are affected by salinity, with approximately 20% of irrigated lands (277 million hectares) suffering from salt-related degradation. This presents a major challenge to agricultural sustainability, particularly in arid and semi-arid regions. In Türkiye, about 32.5% of irrigated agricultural lands are impacted by salinity, significantly limiting crop yield and soil fertility (Ekmekçi et al., 2005).

Seed germination and early seedling development are among the most sensitive phases of a plant's life cycle to salt stress (Almansouri and Lutts, 2001; Oral et al., 2019; Kizilgeci et al., 2020).

Salinity delays the onset of germination, reduces the germination rate, and inhibits seedling vigor by disrupting water uptake, enzyme function, and cell division. Additionally, salt stress impairs essential physiological processes such as photosynthesis, respiration, and nitrogen assimilation, ultimately reducing biomass and productivity (Hu et al., 2022).

Maize (*Zea mays* L.), one of the world's leading cereal crops, is cultivated on approximately 197.2 million hectares globally and ranks first in total cereal production with over 1.1 billion tons annually (FAO, 2019). Despite its global importance as a food, feed, and industrial crop, maize is considered moderately sensitive to salinity (Maas et al., 1983; Farooq et al., 2015). Salt stress during germination and vegetative stages causes reductions in plant height, biomass accumulation, and final yield. However, substantial genotypic variation in salinity tolerance exists among maize lines and hybrids (Shtereva et al., 2015; Akay et al., 2019), suggesting opportunities for selection and breeding.

The present study aims to evaluate the responses of selected inbred maize lines to different salt concentrations during the germination stage, to identify salt-tolerant genotypes suitable for use in breeding programs and cultivation in salt-affected regions.

2. Materials and Methods

The experiment was conducted in December 2018 at the Laboratory of the Department of Field Crops, Faculty of Agriculture, Bursa Uludağ University. Five maize (*Zea mays* L.) inbred lines (A1, A3, A4, A7, and T2), developed within ongoing hybrid breeding programs, were used as plant materials.

The experiment was arranged in a completely randomized design (CRD) with three replications. To assess the impact of salinity, five different sodium chloride (NaCl) concentrations were applied: 0 (control), 50, 100, 150, and 200 mM L^{-1}. Corresponding electrical conductivity (EC) values were measured as 0.003, 6.40, 12.10, 17.50, and 21.20 dS m^{-1}, respectively.

Before sowing, seeds were surface sterilized by immersion in 1% sodium hypochlorite (NaOCl) solution for 5 minutes, followed by rinsing three times with sterile distilled water to prevent microbial contamination (Yıldız and Er, 2002). Sterilized seeds were then air-dried on sterile filter paper.

For each genotype, 20 seeds were placed on double-layered germination paper in 10 cm diameter sterile Petri dishes. Each dish received 10 mL of NaCl solution corresponding to the assigned treatment. The Petri dishes were incubated in a dark germination chamber maintained at 20 ± 1 °C for 14 days. To prevent salt accumulation, the germination papers and NaCl solutions were replaced every 48 hours.

Seeds were considered germinated when the radicle length reached 2 mm, as defined by Soltani et al. (2006).

On the 10th day of germination, the number of germinated seeds in each dish was counted and used to calculate germination percentage (%), following the method of Scott et al. (1984).

Additionally, five seedlings were randomly selected from each Petri dish and used to measure the following parameters:

Shoot length (mm): From the base to the tip of the coleoptile, using a digital caliper.

Root length (mm): From the base to the apex of the longest primary root.

Shoot and root fresh weight (mg): Measured immediately after harvesting using a precision balance.

Shoot and root dry weight (mg): Determined by drying samples in a forced-air oven at 70 °C for 48 hours, then weighing.

Salt Tolerance Index Calculation

For each trait, the Salt Tolerance Index (STI) was calculated according to the method described by Abdul-Baki and Anderson (1973), by comparing the performance of each line under salt stress to the control condition:

$$STI\ (\%) = \left(\frac{\text{Value under salt stress}}{\text{Value under control}}\right) x\ 100 \quad (1)$$

Germination percentage and STI values were subjected to arcsine transformation before statistical analysis. The data were analyzed using analysis of variance (ANOVA) with the JMP® 13.0

statistical software (SAS Institute Inc., Cary, NC, USA). Treatment means were compared using Fisher's Least Significant Difference (LSD) test at a 5% probability level (P < 0.05).

3. Results and Discussion

The results of the variance analysis were presented in Table 1. The salt concentrations significantly affected all the traits examined, with germination percentage (%), shoot length (mm), root length (mm), root fresh weight (mg), and root dry weight (mg) properties at 1% probability level, shoot fresh weight (mg), and salt tolerance index at 5% probability level. The lines were found to be insignificant in the shoot dry weight (Table 1).

Table 1. Results of analysis of variance

Source of Variance	DF	G	SL	RL	SFW	SDW	RFW	RDW	STI
Lines (L)	4	**	**	**	*	ns	**	**	*
Salt Concentration (SC)	4	**	**	**	**	**	**	**	**
L x SC	16	ns	**	**	**	ns	ns	ns	ns
Error	50								

DF: Degree of freedom, *P<0,05, **P<0,01, ns: no significant, G: Germination, SL: Shoot Length, RT: Root Length, SFW: Shoot Fresh Weight, SDW: Shoot Dry Weight, RFW: Root Fresh Weight, RDW: Root Dry Weight, STI: Salt Tolerance Index.

3.1. Germination percentage (%)

The average germination percentages of the maize lines at different salt concentrations are given in Table 2. The highest germination percentage was obtained from the A3 line with 92.7%, followed by the A4 and A1 lines. It is also seen that the lowest value was obtained from the T2 line with a germination percentage of 65.3%. The salt concentrations significantly affected seed germination. As the salt level increased, the germination percentage decreased, and the lowest germination percentage was obtained from the application of 200 mM NaCl, with 67.0%. The germination rates of all lines decreased with increasing salt concentrations, particularly the T2 line, which was severely affected. Our results are similar to those of many researchers who reported that germination percentages decrease due to increasing salt concentrations (Çarpıcı et al., 2009; Khayatnezhad and Gholamin, 2011; Khodarahmpour et al., 2012; Idikut, 2013; Turk and Eser, 2016; Hassan et al., 2018).

This reduction is commonly attributed to the osmotic effect of salt in the medium, which inhibits water uptake by seeds, thereby delaying or preventing germination (Rehman et al., 1996; Almansouri et al., 2001). Furthermore, high concentrations of Na^+ and Cl^- ions can interfere with cellular metabolism and enzyme activity during germination, as noted by Tuteja (2007) and Islam et al. (2024).

Table 2 also shows a clear genotype × treatment interaction, where line A3 maintained relatively high germination across all salt levels, indicating potential genetic tolerance mechanisms. This is consistent with the findings of Shtereva et al. (2015) and Akay et al. (2019), who reported genotypic variability in maize under saline conditions. The gradual decline in average germination from 95.7% (0 mM) to 67.0% (200 mM) in Table 2 highlights the threshold of salt sensitivity for most lines. Similar dose-dependent effects have been reported in other cereals like wheat and barley under NaCl stress (Soltani et al., 2006; Hu et al., 2022).

Table 2. Mean germination percentage values (%)

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	100.0	98.3	95.0	88.3	61.7	88.7^a
A3	98.3	95.0	95.0	88.3	86.7	92.7^a
A4	96.7	96.7	95.0	91.7	73.3	90.7^a
A7	95.0	95.0	80.0	70.0	65.0	81.0^b
T2	88.3	68.3	63.3	58.3	48.3	65.3^c
Mean	95.7^a	90.7^b	85.7^c	79.3^d	67.0^e	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level. Since the line-salt concentration interaction effect was not significant, no letter was assigned.

This table clearly demonstrates that salinity stress has a genotype-dependent inhibitory effect on maize germination. While A3, A4, and A1 lines showed strong performance even under moderate stress (up to 100 mM), the T2 line was notably sensitive at all levels. This supports the necessity of genotype screening under abiotic stress conditions in maize breeding programs (Pitman and Läuchli, 2002; Farooq et al., 2015).

Shoot length (mm)

As seen in Table 3, the highest value in terms of shoot length was obtained from the application of 0 mM salt concentration, with 59.6 mm. The salt concentrations had significant negative effects on shoot length, and these values decreased as the level of salt concentrations increased, as indicated by several researchers (Okçu et al., 2005; Khodarahmpour et al., 2012; Idikut, 2013; Hassan et al., 2018; Radic et al., 2019). It is observed that the T2 line had the highest value in terms of shoot length (47.6 mm), followed by the A7 line with a little difference, while the A1 line had the lowest value. The different lines gave different responses to different salt concentrations in terms of shoot length; therefore, the line × salt concentration interaction occurred.

This reduction in shoot length under increasing salt concentrations is often attributed to osmotic stress, which limits water uptake, and ionic toxicity, which affects cell division and elongation processes (Maathuis and Amtmann, 1999; Tuteja, 2007).

In particular, Na^+ and Cl^- accumulation can inhibit meristematic activity in the coleoptile region, leading to reduced internodal elongation (Farooq et al., 2015; Hu et al., 2022).

The relatively higher shoot length in T2 and A7 lines at certain salt levels suggests that these lines may possess more efficient water-use traits or hormonal balances (e.g., gibberellin/ABA ratio) conducive to maintaining shoot elongation under stress (Islam et al., 2024).

These findings are also in agreement with Shtereva et al. (2015), who noted that some sweet maize genotypes can sustain shoot growth under moderate salinity due to their inherent genetic plasticity.

The interaction between genotype and salinity level observed in this study emphasizes the importance of using multiple stress indicators—including both shoot and root metrics—for accurate screening of salt tolerance (Soltani et al., 2006).

Table 3. Mean shoot length values (mm)

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	55.3^{b-d}	55.8^{ac}	41.8^{e}	22.9^{fg}	12.7^{h}	37.7^{c}
A3	63.1^{ab}	54.4^{bd}	55.8^{ac}	28.3^{fg}	20.1^{gh}	44.3^{ab}
A4	62.2^{ab}	46.8^{ce}	39.8^{e}	29.6^{f}	29.0^{fg}	41.5^{bc}
A7	54.8^{b-d}	65.2^{a}	47.8^{ce}	39.7^{e}	26.5^{fg}	46.8^{a}
T2	63.0^{ab}	61.6^{ab}	46.0^{de}	39.1^{e}	28.3^{fg}	47.6^{a}
Mean	59.6^{a}	56.7^{a}	46.2^{b}	31.9^{c}	23.3^{d}	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level.

Table 3 illustrates a consistent reduction in shoot length with increasing salinity across all genotypes. While the A3 and A7 lines exhibited relatively stable shoot growth even under 150 mM NaCl, the A1 line was more adversely affected. The lowest value (12.7 mm) was observed in A1 under 200 mM NaCl, indicating its high sensitivity. Interestingly, the T2 line, although sensitive in terms of germination, maintained superior shoot length, suggesting possible compensatory growth mechanisms at early seedling stages. This differential response supports the necessity of evaluating multiple traits when screening for salinity tolerance in maize.

3.2. Root length (mm)

As seen in Table 4, the highest average root length was determined in the A3 line with a 16.4 mm in the maize lines tested. At different salt concentrations, the average highest (21.86 mm) and the average lowest root length (5.8 mm) were found in control plants and 200 mM salt concentrations, respectively. The highest root length value (25.8 mm) was observed in line A3. As is known, the root growth trait of the plant is one of the most important parameters in terms of salt tolerance. High salinity inhibits root and shoot elongation as it slows down the plant's water uptake. Similar results were also determined in the root growth of some legumes under salinity (Bayuelo-Jimenez et al., 2002; Castroluna et al., 2014).

Salt stress impairs root development primarily through osmotic effects and ion toxicity, leading to reduced cell division and elongation in the root apical meristem (Munns and Tester, 2008). The reduction in root length observed under 200 mM NaCl may also be attributed to oxidative damage and cell wall rigidity, as suggested by Zhu (2001) and Parida and Das (2005). Among the tested lines, A3's superior root elongation under salt stress indicates potential mechanisms such as efficient Na^+ exclusion, higher K^+/Na^+ ratios, and better ROS detoxification, which are commonly associated with salinity tolerance in maize and other cereals (Cuin and Shabala, 2007; Roy et al., 2014). Root system traits like length and surface area have increasingly been emphasized in recent years as reliable physiological indicators of salinity tolerance (Uga et al., 2013). This study's results reinforce the concept that root length is not only a physiological trait but also a critical agronomic marker of adaptation to abiotic stress.

Table 4. Mean root length values (mm)

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	21.8^{bc}	16.5^{f}	$11.9^{\imath}$	7.9^{j}	4.9^{m}	12.6^{bc}
A3	25.8^{a}	23.5^{b}	15.2^{fg}	8.4^{j}	9.1^{j}	16.4^{a}
A4	18.9^{de}	$12.3^{h\imath}$	8.9^{j}	5.8^{km}	4.7^{m}	10.1^{d}
A7	22.3^{bc}	17.3^{ef}	$11.3^{\imath}$	$7.5^{j\text{-}l}$	5.4^{lm}	12.7^{b}
T2	20.6^{cd}	14.2^{gh}	$11.3^{\imath}$	7.6^{jk}	4.9^{m}	11.7^{c}
Mean	21.9^{a}	16.8^{b}	11.7^{c}	7.5^{d}	5.8^{e}	

The difference between the means indicated by different letters in the same column is significant at the $P \leq 0.05$ level. Since the line-salt concentration interaction effect was not significant, no letter was assigned.

Table 4 clearly shows a progressive decline in root length as salt concentration increases from 0 to 200 mM across all genotypes. The A3 line stood out by maintaining the highest root length average (16.4 mm), even under elevated salt stress, suggesting its potential for salt-tolerance breeding. In contrast, the A4 and T2 lines exhibited significant sensitivity, especially under 150–200 mM NaCl, where values dropped below 6 mm. This drastic reduction indicates that these lines are more susceptible to osmotic and ionic stresses. Interestingly, the consistency of A3 across all salt levels indicates a stable root growth mechanism, possibly linked to better ion regulation or internal water balance under saline environments. Such root robustness is essential in supporting early seedling establishment, especially in marginal soils. These findings support the utility of root length as a primary trait in salt tolerance evaluation and its integration in early-stage screening protocols for maize.

3.3. Fresh and dry weight of shoot (mg)

The effect of different salt concentrations on fresh shoot weight in maize was shown in Table 5. The shoot weight dramatically reduced with increasing salt concentration. The average shoot fresh weight was highest in the control plants, with a value of 226.6 mg. The lowest value (79.4 mg) was observed at the 200 mM salt concentration. While the A3 line had the highest shoot fresh weight value (167.2), the A1 line had the lowest shoot fresh weight value (147.8). Germination occurred at 200 mM salt stress, but a very low level of shoot development was achieved.

Salt stress often leads to reduced shoot biomass due to impaired cell expansion, lower photosynthetic efficiency, and disruption of hormonal balance, particularly a decline in auxin and gibberellin activity (Zhu, 2001; Tuteja, 2007).

Under saline conditions, Na^+ and Cl^- accumulation in leaf tissues causes stomatal closure and limits CO_2 uptake, which negatively affects shoot growth (Parida and Das, 2005; Munns and Tester, 2008). The ability of A3 and A7 to maintain relatively higher shoot fresh weights under moderate salinity suggests possible osmotic adjustment, better ion homeostasis, and higher chlorophyll retention (Ashraf and Foolad, 2007; Hu et al., 2022).

Table 5. Mean shoot fresh weight values (mg. plant^{-1})

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	219.5^{cd}	215.4^{ce}	156.5^{hı}	101.7^{ln}	46.1^{o}	147.8^{b}
A3	250.4^{ab}	205.0^{cf}	194.5^{dg}	110.7^{km}	75.2^{n}	167.2^{a}
A4	262.8^{a}	177.7^{fh}	139.5^{ıj}	96.1^{l-n}	98.3^{l-n}	154.6^{ab}
A7	189.7^{eg}	230.5^{bc}	194.7^{dg}	132.5$^{ı-k}$	83.7^{mn}	166.2^{a}
T2	210.5^{ce}	206.7^{ce}	173.5^{gh}	121.9^{j-l}	93.5^{l-n}	161.2^{a}
Mean	226.6^{a}	207.1^{b}	171.5^{c}	112.6^{d}	79.4^{e}	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level.

There were significant differences in terms of shoot dry weight values, but lines and line x salt concentration interactions were insignificant. The highest shoot dry weight (22.5 mg) was obtained at the salt concentration of 50 mM, and this value decreased to 10.8 mg at the highest salinity level (200 mM) (Table 6).

The results of our study showed similarities with some early research results. High salinity concentration caused a decrease in shoot dry weight of maize in some studies (Çarpıcı et al., 2009; Khayatnezhad and Gholamin, 2011; Aydınşakir et al., 2013; Hassan et al., 2018).

This decline in shoot dry weight is attributed to reduced photosynthate partitioning and protein synthesis under salt stress, which limits structural biomass development (Parida and Das, 2005; Ashraf and Foolad, 2007).

Similar findings were reported by Negrão et al. (2017), who emphasized that shoot biomass reduction is one of the earliest phenotypic markers of salinity damage in cereal crops.

The mild increase in dry weight at 50 mM may reflect a threshold level where plants still manage physiological compensation, but beyond this point, the stress becomes inhibitory.

Table 6. Mean shoot dry weight values (mg.plant^{-1})

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	22.3	23.1	19.1	12.9	5.5	16.6
A3	21.5	23.8	20.8	15.8	10.3	18.4
A4	26.3	20.3	18.7	14.1	14.7	18.8
A7	18.1	23.9	17.2	14.0	11.3	16.9
T2	19.8	21.4	17.9	14.0	12.1	17.0
Mean	21.6^{a}	22.5^{a}	18.8^{b}	14.1^{c}	10.8^{d}	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level. Since the line-salt concentration interaction effect was not significant, no letter was assigned.

Fresh and dry weight of root (mg)

When the data on root fresh weights of the maize lines germinated under varying salt concentrations were analysed, the highest value was recorded in the A4 line with an average of 312.8 mg. In terms of salt treatments, the maximum root fresh weight was observed under the 0 mM NaCl application, with a mean of 421.5 mg (Table 7). Similarly, root dry weight decreased progressively with increasing salinity. The highest dry root weight, 42.2 mg, was recorded in the 0 mM treatment, while among the lines, A4 again showed the best performance with an average of 33.6 mg (Table 8).

These results clearly demonstrate a significant reduction in both root fresh and dry weight values as salt concentration increased. This trend aligns with the known physiological responses of maize to salinity, wherein osmotic stress and ion toxicity impair water uptake and root development, ultimately reducing cell expansion and elongation (Munns and Tester, 2008; Roy et al., 2014; Parida and Das, 2005).

The A4 line exhibited superior performance under saline conditions, suggesting a relatively higher degree of salt tolerance. This may be attributed to its intrinsic physiological mechanisms or more effective ionic homeostasis, both of which are critical features in salt-tolerant maize genotypes (Flowers and Colmer, 2008; Zörb et al., 2019).

Table 7. Mean root fresh weight values ($mg.plant^{-1}$)

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	404.1	299.7	212.3	130.8	85.7	266.6^{b}
A3	410.1	384.9	279.5	212.1	185.7	294.4^{a}
A4	493.2	362.6	311.0	206.7	190.4	312.8^{a}
A7	427.3	325.4	187.1	161.9	159.4	252.2^{b}
T2	373.0	268.5	210.6	166.8	106.5	225.1^{b}
Mean	421.5^{a}	328.2^{b}	240.1^{c}	175.1^{d}	146.0^{d}	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level.

Our findings are consistent with those of earlier studies, which have reported that increased salinity levels significantly reduce root growth and biomass accumulation in maize and other cereals (Çarpıcı et al., 2009; Khayatnezhad and Gholamin, 2011; Aydınşakir et al., 2013).

Table 8. Mean root dry weight values ($mg.plant^{-1}$)

Lines	Salt Concentration (mM)					Mean
	0	50	100	150	200	
A1	38.8	30.5	22.3	17.5	10.1	23.8^{c}
A3	38.7	39.5	30.4	26.3	22.8	31.6^{ab}
A4	50.4	36.7	33.9	25.1	22.1	33.6^{a}
A7	44.5	39.0	24.5	18.7	20.3	29.4^{b}
T2	38.8	33.5	23.7	17.9	14.1	25.6^{c}
Mean	42.2^{a}	35.8^{b}	26.9^{c}	21.1^{d}	17.9^{e}	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level. Since the line-salt concentration interaction effect was not significant, no letter was assigned.

3.4. Salt tolerance index

The effect of different salt concentrations on the salt tolerance index was found to be statistically significant. The salt tolerance index values of maize lines at different salt concentrations are given in Table 9. The salt tolerance index ranged from 47.4 to 62.6. The A3 line had the highest salt tolerance index (62.3), while the A1 line had the lowest (47.4). While the salt tolerance index value was 82.8 at 50 mM salt concentration, this value decreased to 34.7 at 200 mM salt concentration. Salt stress, which generally became more pronounced beyond 100 mM, caused significant reductions in the salt tolerance index across all lines (Table 9).

Salt tolerance is the ability of plants to sustain growth and development in environments with high salt content (Maathuis and Amtmann, 1999).

Recent research has shown that increasing salt concentrations negatively impact plant growth by disrupting water uptake, ion balance, and cellular homeostasis, which are directly reflected in reduced salt tolerance index values (Munns and Gilliham, 2015; Zhao et al., 2021). These effects include inhibition of root development, stomatal conductance, photosynthetic activity, and protein synthesis—key physiological traits determining salt resilience in maize (Roy et al., 2014; Atta et al., 2023). The superior performance of the A3 and A7 lines indicates a better adaptation to salt stress, likely due to efficient ion exclusion mechanisms, osmoprotectant accumulation, or antioxidative defense systems—widely recognized strategies in salt-tolerant genotypes (Zörb et al., 2019).

Therefore, these genotypes could serve as valuable genetic resources in breeding programs targeting improved salt tolerance in maize.

Table 9. Mean salt tolerance index values

Lines	Salt Concentration (mM)				Mean
	50	100	150	200	
A1	82.7	48.5	37.2	21.1	47.4[b]
A3	89.4	72.1	48.9	38.9	62.3[a]
A4	72.4	60.4	40.4	38.5	52.9[ab]
A7	89.7	61.9	47.2	39.9	59.7[a]
T2	79.9	66.7	50.3	34.9	57.9[ab]
Mean	82.8[a]	61.9[b]	44.8[c]	34.7[c]	

The difference between the means indicated by different letters in the same column is significant at the P≤0.05 level. Since the line-salt concentration interaction effect was not significant, no letter was assigned.

Conclusion

In this study, the effects of different salt concentrations on the germination performance of some inbred maize lines were investigated. Our studies clearly showed that all the traits measured reached the highest values (Tables 2,3,4,5,7, and 8) in the application of 0 mM salt concentration, and the value reduced with increasing salt levels. In particular, the salt concentration of more than 100 mM negatively affected the measured seedling traits. Without exception, the lowest values (Tables 2, 3, 4, 5, 6, 7, and 8) were obtained at a salt concentration of 200 mM. From them, the A3 line was more tolerant to salt stress than the other lines in terms of the traits examined. Therefore, the A3 line is recommended as a parent for future salinity tolerance breeding studies in maize. At the same time, to support our results, the detailed larger pots or field studies should be established, and the obtained results should be evaluated with soil analysis.

These findings provide useful insights into the early-stage physiological responses of maize lines under salt stress and highlight the importance of genotype selection in saline environments.

At the same time, to support our results, larger-scale pot or field studies under natural soil salinity conditions should be established. Evaluating the obtained results in combination with soil chemical properties and salinity profiles will enhance the practical relevance of the findings and contribute to the development of salt-resilient maize cultivars for sustainable crop production.

Ethical Statement

Ethical approval is not required for this study.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Author Contributions

The first and second authors designed the project. The second author assisted the first author in data collection and helped to determine the methodology of the study. The first author tabulated the statistical analysis of the study, followed the official procedures, and wrote the first version of the manuscript. The first author sent the manuscript to the other authors for checking. The third author reviewed and edited the manuscript. After that, the first author sends the manuscript to the journal.

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