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The Effect of Salt Stress on The Growth of Maize

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ABSTRACT
The experiment was carried out in the laboratory of the Department of Crops - faculty of Agriculture - Omar Al-Mukhtar University for 2022y, to study the effect of salt stress on the growth characteristics of the triple hybrid 253 of Zea maize crop, using a completely random design. The treatments included (0, 25, 50, and 75 mM) of NaCl by three replicates. 10 seeds were placed in each Petri dish. Measurements were taken for the growth stage of each treatment. the Results found that increasing the concentration of NaCl led to a decrease in wet-dry weight, and radical length. However, was found that there was an increase of these traits at a concentration of 50 mM compared to a concentration of 25 mM, and the growth traits decreased at a concentration of 75 mM. As well as an increase in sodium chloride concentration led to a decrease in the germination rate, germination speed, germination strength index, and plumule wet weight, The highest values were at a concentration of 0.0 mM and the lowest at a concentration of 75 mM. The decrease reached a significant degree for each of the plumule lengths and the dry weights of plumule. The highest values were at a concentration of 0.0mM and the lowest was at a concentration of 75 mM.

INTRODUCTION

Zea mays L., commonly known as yellow maize, is one of the most important field crops in the world. It plays a crucial role in food and economic security due to its extensive use in human and animal nutrition, as well as its significance in various industries. However, its productivity is subjected to multiple environmental stresses, including salinity, which poses a major challenge in arid and semi-arid regions (Munns & Tester, 2008). Salinity reduces the available water potential for plants and inhibits vital biological processes within them, leading to an overall decrease in agricultural productivity (Essa, 2002) .

Salinity stress significantly impacts the early stages of growth, particularly the germination phase, as it leads to a reduction in both germination rate and speed due to its negative effects on water and essential nutrient uptake (Khan et al., 2009). Studies have shown that salinity stress inhibits root and shoot elongation due to osmotic imbalance and the accumulation of toxic ions in plant tissues (Ghoulam et al., 2002). According to Ashraf and Harris (2004), salinity stress also weakens the activity of vital enzymes, reducing germination efficiency and early growth. Moreover, yellow maize is considered a salt-sensitive crop, particularly at high concentrations of sodium chloride, which leads to a decrease in both the wet and dry weights of roots and shoots. This effect is particularly evident at concentrations exceeding 75 millimoles of sodium chloride (Zeng et al., 2001). Conversely, some studies have shown that moderate concentrations may stimulate a temporary adaptive response in the plant, enhancing root and shoot growth in certain cases (Munns & Tester, 2008)

Physiologically, salinity stress induces ionic imbalances within plant cells, leading to increased sodium accumulation and reduced potassium levels. This imbalance affects vital processes such as photosynthesis and ion transport (Flowers & Colmer, 2008). According to Essa (2002), salinity stress also inhibits the activity of enzymes necessary for starch degradation in seeds, resulting in decreased germination rate and vigor.

In addition, the cultivation of yellow maize faces increasing challenges due to the use of irrigation water with high salinity content, particularly in arid regions. This issue necessitates intensive studies to understand the effects of salinity on yellow maize and to determine the thresholds that the plant can tolerate (Ghoulam et al., 2002). To achieve these objectives, the current study aims to evaluate the impact of different concentrations of sodium chloride on the wet and dry weights of roots and shoots, root and shoot lengths, germination percentage, germination rate, and seedling vigor index.

Research Objectives

To evaluate the salt tolerance of maize (Zea mays) to salinity levels in soil solutions.

Previous Studies

Yellow corn is considered a salt-sensitive crop (Katerji et al., 2000). As salinity increases, water potential rises, leading to reduced available water, which results in decreased germination rates and slower growth. Salinity stress is one of the physiological stresses that hinders germination, as higher concentrations in the soil negatively affect absorption and disrupt ion balance, consequently impacting vital cellular processes (Hamdia and El-okmy, 1997).

Tsakalidi and Barouchas (2011) found that increasing salinity levels in the plant environment affects enzyme activity, and maize is one of the most salt-sensitive crops, particularly during early developmental stages, although its tolerance increases in later stages (Majid and Gholamin, 2011). Ridwan (1983) suggests that the importance of salt-tolerant crops increases in arid and semi-arid regions. The successful germination of seeds in surface areas with the highest salt concentrations is influenced by two factors: the number of irrigations and the amount of water applied, as well as the rapid growth of the root to reach subsurface regions where salt concentration is lower (Paslernack et al., 1979).

Many plant species, including various crops, exhibit inhibited growth at high salinity concentrations (Huseen et al., 2010; Carpici et al., 2009). In a study using sodium chloride concentrations of 0, 50, 100, 150, 200, and 250 mM, germination rates and seedling dry weight decreased, with the lowest results observed at 250 mM. Leyla et al. (2012) also reported that the addition of saline concentrations (0, 100, 200, and 500 mM) resulted in negative effects on germination speed, germination strength, root length, and shoot length.

Yellow Corn and Salinity Stress. Yellow corn is considered a salt-sensitive crop, with numerous studies demonstrating the impact of salinity stress on its growth and various germination stages.

In a study by Katerji et al. (2000), researchers examined the effects of salinity stress on yellow corn and found that increasing salt concentrations in the soil reduce the water potential available to the plant, leading to decreased germination rates and slower growth. The study concluded that there are significant differences at salinity levels exceeding 100 mM, where germination rates dropped from 90% to 55% with increasing sodium chloride concentrations.

Additionally, the study by Hamdia and El-okmy (1997) investigated the effect of salinity stress on nutrient absorption in yellow corn, revealing that higher salt concentrations disrupt the ion balance within cells. The results indicated that root length decreased from 5.2 cm to 2.8 cm at a concentration of 100 mM sodium chloride, with clear significant differences observed.

Impact of Salinity on Corn Growth

Tsakalidi and Barouchas (2011) conducted a study on the effects of salinity concentrations on the enzyme activity responsible for germination in maize. The results indicated that germination was negatively affected with increasing salinity, with germination rates decreasing from 85% to 40% at a concentration of 150 mM. They also noted that the effect was less pronounced in the later growth stages.

Meanwhile, Majid and Gholamin (2011) investigated the impact of salinity during different growth stages of yellow corn. They found that the plant tolerated salinity better in later stages compared to the germination phase. The results showed that the final plant height decreased from 120 cm to 85 cm at a concentration of 200mM sodium chloride, with significant differences observed.

The study by Pasternack et al. (1979) focused on the effect of salt distribution in the soil on germination speed. It was found that repeated irrigation with small amounts of water reduces the impact of salinity on germination. The results indicated that germination speed increased by 25% when surface salt concentrations were reduced compared to higher concentrations.

Huseen et al. (2010) demonstrated that sodium chloride concentrations exceeding 100 mM significantly reduce germination speed and root length. The results showed that root length decreased from 6.1 cm to 2.3 cm, with clear significant differences observed.

Effects of Salinity on Corn Seedlings

The study by Carpici et al. (2009) investigated the impact of salinity on the dry weight of seedlings, finding that dry weight decreased by 30% as salt concentrations increased from 0 to 150 mM. Significant differences were observed among the various concentrations.

Leyla et al. (2012) tested the effects of sodium chloride concentrations (0, 100, 200, and 500 mM) on yellow corn. The results showed that germination speed decreased from 7.2 days to 4.5 days with increasing concentration, with significant differences at all levels.

The research by Almodares et al. (2007) demonstrated that salinity stress at a concentration of 150 mM reduces shoot length by 40% compared to plants not exposed to salinity. The researchers also noted significant differences in growth rates.

In contrast, the study by Flowers and Colmer (2008) confirmed that salinity stress negatively affects vital processes in plants, including yellow corn. The results indicated a decrease in germination rates from 90% to 60% at high salinity concentrations, with significant differences observed.

Salinity Stress and Corn Growth

Munns and Tester (2011) clarified that salinity stress affects plant growth by reducing water absorption and increasing the accumulation of toxic ions within tissues. The study showed that germination rates decreased from 80% to 45% as salt concentrations increased from 0 to 200 mM, with significant differences observed.

The study by Ashraf and Harris (2011) indicated that salinity stress inhibits metabolic processes such as photosynthesis and nutrient transport. The results demonstrated that root length decreased from 5.5 cm to 3.2 cm when salt concentration was raised to 150 mM, with clear significant differences.

Khan et al. (2009) investigated the effects of salinity on yellow corn, finding that the dry weight of the plant decreased by 35% at salinity concentrations exceeding 100 mM. The study also confirmed that statistical differences were significant at higher concentrations.

Zeng et al. (2001) found that high salt concentrations lead to reduced germination and slowed growth rates. At a concentration of 200 mM sodium chloride, germination rates dropped from 92% to 50%, with significant differences observed at all levels.

Salinity Stress and Corn Seedling Development

The study by Essa (2002) demonstrated the impact of salinity stress on shoot and root length in yellow corn. The results indicated that shoot length decreased from 4.2 cm to 2.1 cm at salinity concentrations exceeding 150 mM, with significant differences observed among treatments.

Ghoulam et al. (2002) focused on the effect of salinity on ionic growth in yellow corn. The results showed a significant reduction in potassium content and an increase in sodium accumulation within the root, leading to a 40% reduction in growth at a concentration of 150 mM.

Kilic and Yagmur (2011) found that salinity stress reduces the activity of enzymes involved in seed germination. The researchers observed that germination speed decreased from 6 days to 3 days at high salinity concentrations, with significant differences between treatments.

The study by Chartzoulakis et al. (2004) investigated the effects of salts on germination and growth in yellow corn. The results indicated that germination was reduced by 50% at salinity concentrations exceeding 200 mM, and the study also showed a negative impact on the dry weight of the plants.

Effects of Salinity on Enzyme Activity and Growth

The study by Almansouri et al. (2001) found that salinity stress leads to a decrease in the activity of the enzyme amylase, which is responsible for starch breakdown during germination. The results indicated that germination rates declined from 88% to 40% as salinity concentration increased to 150 mM, with clear significant differences observed.

Rahman et al. (2008) demonstrated that salinity stress reduces the rate of cell division in both the root and shoot. The results showed that root length decreased from 5.8 cm to 2.9 cm at a concentration of 150 mM, with significant differences noted.

Materials and Methods

The experiment was conducted in the Plant Laboratory at the Higher Institute of Agricultural Science Technologies in 2024 to test the salt tolerance of the triple hybrid corn 253 during the germination phase. A complete randomized design was employed with four treatments: 0, 40, 50, and 75 mM sodium chloride. The treatments were randomly distributed across three replications, with 10 seeds placed in each dish. Measurements for growth traits were taken for each treatment.

Studied Traits:

1. Days to Germination..: Measured from the start of germination according to Shojani (2002).
2. Germination Percentage..: Estimated following ISTA (2005) standards .
3. Length of Root and Shoot (cm)**: Three random samples were taken from each treatment after 14 days of germination (AOSA, 1983).
4. Fresh and Dry Weight of Root and Shoot**: Measured after 14 days of germination.
5. Germination Strength**: Calculated as the germination percentage multiplied by the sum of shoot and root lengths, according to Arafa et al. (2009).
6. Germination Rate**: Calculated using the formula GR = NX/DX (Ellis and Roberts, 1980).
7. Statistical Analysis**: Conducted using GENSTAT software, with means compared using the Least Significant Difference (LSD) method (Gomez and Gomez, 1984).

Results and Discussion

1. Fresh Weight

Table 1 shows that the highest value for root fresh weight was observed at the 50 mM sodium chloride treatment, with an average of 0.350 g, followed by the control treatment (without sodium chloride) at an average of 0.327 g. The 25 mM treatment had an average of 0.223 g, while the lowest value was recorded at the 75 mM level, with an average of 0.230 g.

For shoot fresh weight, the highest value was observed in the control treatment, averaging 0.437 g. There were no significant differences at the 25 mM and 50 mM levels, with values of 0.437 g and 0.410 g, respectively. The lowest value was recorded at the 75 mM level, averaging 0.350 g.

Comparing the means revealed no significant differences among the treatments regarding the effect of sodium chloride on root and shoot fresh weights. This aligns with the findings of Hamdia and El-okmy (1997), who confirmed that salinity stress reduces nutrient and water absorption, leading to decreased fresh weight in plants. The increased root fresh weight at the 50 mM concentration is consistent with the observations of Munns and Tester (2008), who noted that plants may exhibit temporary adaptive responses at moderate salinity levels.

Furthermore, Essa (2002) indicated that high salt concentrations lead to a marked decrease in fresh weight due to the negative impact on water absorption, which is evident at the 75 mM level. Additionally, Carpici et al. (2009) demonstrated that plant fresh weight is significantly affected at high salinity concentrations, with clear significant differences noted among various levels. Finally, this is in agreement with Zeng et al. (2001), who reported that salinity stress at low or moderate concentrations can temporarily stimulate growth before leading to significant inhibition at high concentrations.

2- Dry Weight

From the table, it is observed that the dry weight of the root was highest at the 50 mM sodium chloride level, averaging 0.039 g. No significant differences were noted between the control treatment and the 75 mM level, with values of 0.031 g at both levels. The lowest value was recorded at the 25 mM level, with an average of 0.030 g .

For shoot dry weight, the highest value was observed in the control treatment, averaging 0.053 g, followed by the 25 mM treatment with an average of 0.0497 g, and then the 50 mM level with an average of 0.0443 g. The lowest value was at the 75 mM level, averaging 0.033 g. Similar to fresh weight, the differences between the means did not reach statistical significance.

These findings are consistent with the study by Ghoulam et al. (2002), which found that increased salt concentrations lead to sodium accumulation and decreased potassium levels, negatively affecting root growth and reducing dry weight at high concentrations. The slight increase in dry weight at the 50 mM concentration aligns with the observations of Munns and Tester (2008), who indicated that plants can exhibit adaptive responses at moderate salinity levels, explaining the higher values at this level.

Furthermore, Essa (2002) showed that salinity stress reduces dry weight due to decreased water absorption and efficiency of metabolic processes, a clear reflection of the effects observed at the 75 mM level. Additionally, Carpici et al. (2009) noted that high salinity concentrations lead to reduced dry weight in plants, particularly in shoots, with significant differences among various levels. These results support the findings of Zeng et al. (2001), who confirmed that salinity stress at low to moderate levels can temporarily enhance dry weight before significantly decreasing at high concentrations.

Table 1: Effect of Sodium Chloride on Fresh and Dry Weights of Root and Shoot.

Attributes/ Transactions	Wet weight of the ruisha (g)	Wet weight of root (g)	Dry weight of root (g)	Dry weight of the raisha (g)
0	0.327	0.0310	0.437	**0.0497**
25	0.223	0.0300	0.437	**0.0443**
50	0.350	0.0390	0.410	**0.033**
75	0.230	0.0310	0.350	**-**
F	-	-	-	**0.029**
	0.138	280.0	0.1417	**LSD**

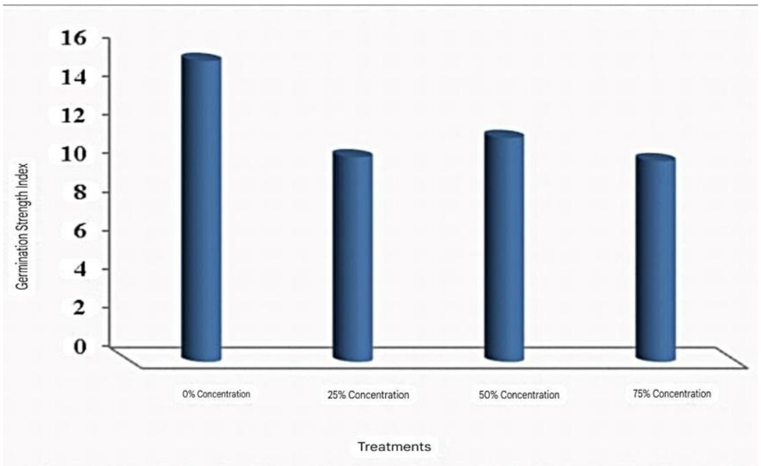


Figure (1): Average wet weight of the root.

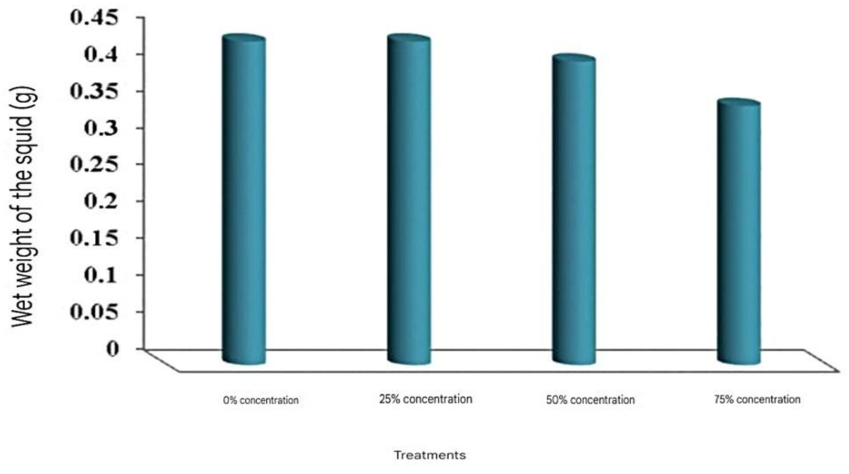


Figure (2): Average wet weight of the ruwisha.

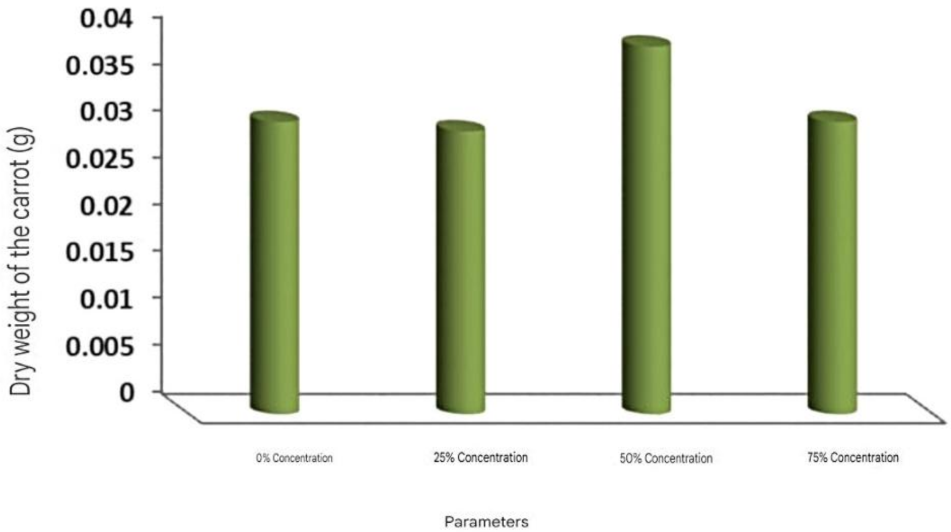


Figure (3): Average dry weight of the root.

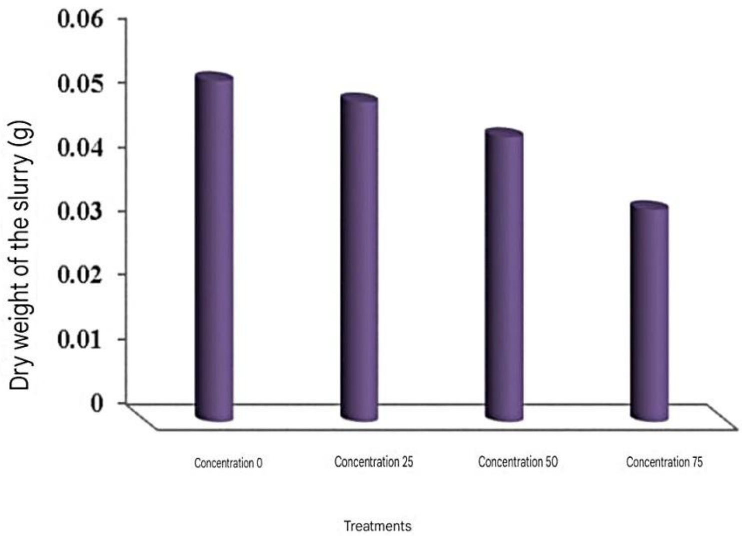


Figure (4): Average dry weight of the ruwisha.

3-Root Length

From Table 2.4, it is observed that the highest value for root length was recorded in the control treatment (without sodium chloride), averaging 4.97 cm, followed by the 50 mM treatment with an average of 3.27 cm. The lowest value was at the highest concentration of 75 mM, averaging 2.10 cm. In comparison, the effect of sodium chloride is clearly evident, as root length significantly decreased with increasing concentration, indicating the impact of salinity stress on root elongation.

This finding is consistent with the study by Ghoulam et al. (2002), who noted that salinity stress inhibits root elongation due to the accumulation of toxic ions and reduced water availability for the plant. The gradual decrease in root length with increasing salt concentration aligns with the observations of Essa (2002), which indicated that salinity stress reduces root length due to decreased water absorption efficiency. Furthermore, Zeng et al. (2001) confirmed that high salt concentrations significantly reduce root growth, with shorter lengths recorded at higher concentrations.

The results support the findings of Munns and Tester (2008), who stated that the negative effect of salinity stress on root length is associated with increased external osmotic pressure, which prevents cell elongation. Lastly, these results are in agreement with Carpici et al. (2009), who clarified that salinity stress clearly reduces root elongation, with significant Shoot Length

4-differences observed among the various concentrations

Regarding shoot length, the highest value was observed in the control treatment (without sodium chloride), averaging 4.33 cm, followed by the 25 mM treatment with an average of 3.10 cm, and then the 50 mM concentration with an average of 2.63 cm. The lowest value was recorded at the 75 mM concentration, averaging 2.93 cm. The results indicate that increasing sodium chloride concentration leads to reduced shoot elongation, with significant differences noted among the various treatments.

This finding is consistent with the study by Hamdia and El-okmy (1997), which indicated that salinity stress inhibits shoot growth due to decreased absorption of water and essential nutrients, impairing the plant's ability to elongate. The gradual decrease in shoot length with increasing salt concentration aligns with the results of Essa (2002), which confirmed that salinity stress reduces shoot elongation due to negative effects on metabolic processes within the seed.

The findings are further supported by Ghoulam et al. (2002), who observed that increased salinity inhibits the activity of cells responsible for shoot elongation, leading to a clear reduction in growth. Additionally, Munns and Tester (2008) explained that salinity stress causes the accumulation of toxic ions within plant tissues, which inhibits cell division and elongation.

Finally, Zeng et al. (2001) confirmed that the negative impact of high salt concentrations is more pronounced in early growth stages, with significant reductions in both shoot and root elongation observed at elevated Shoot Length

4-Concentrations

Regarding shoot length, the highest value was observed in the control treatment (without sodium chloride), averaging 4.33 cm, followed by the 25 mM treatment with an average of 3.10 cm, and then the 50 mM concentration with an average of 2.63 cm. The lowest value was recorded at the 75 mM concentration, averaging 2.93 cm. The results indicate that increasing sodium chloride concentration leads to reduced shoot elongation, with significant differences noted among the various treatments.

This finding is consistent with the study by Hamdia and El-okmy (1997), which indicated that salinity stress inhibits shoot growth due to decreased absorption of water and essential nutrients, impairing the plant's ability to elongate. The gradual decrease in shoot length with increasing salt concentration

aligns with the results of Essa (2002), which confirmed that salinity stress reduces shoot elongation due to negative effects on metabolic processes within the seed.

The findings are further supported by Ghoulam et al. (2002), who observed that increased salinity inhibits the activity of cells responsible for shoot elongation, leading to a clear reduction in growth. Additionally, Munns and Tester (2008) explained that salinity stress causes the accumulation of toxic ions within plant tissues, which inhibits cell division and elongation.

Finally, Zeng et al. (2001) confirmed that the negative impact of high salt concentrations is more pronounced in early growth stages, with significant reductions in both shoot and root elongation observed at elevated concentrations.

5-Germination Percentage

The highest germination percentage was observed in the control treatment (without sodium chloride), averaging 76.7%, followed by the 50 mM concentration with an average of 58%. The percentage clearly decreased at the 25 mM concentration to 53.3%, and was lowest at the 75 mM concentration, with a percentage of 52.7%. It is evident that salinity stress negatively affects the germination percentage, as the rate decreases with increasing sodium chloride concentration.

This finding is consistent with the study by Khan et al. (2009), which indicated that salinity stress reduces germination percentage due to increased osmotic pressure and decreased absorption of water necessary for the germination process. Essa (2002) also demonstrated that germination percentage significantly declines at high salinity concentrations due to the inhibition of enzymatic activity required to initiate the germination process.

Additionally, Zeng et al. (2001) showed that salinity at low to moderate concentrations may allow for germination, but high concentrations, such as 75 mM, lead to a substantial reduction in germination percentage. Ghoulam et al. (2002) confirmed that salinity stress affects the ionic and water balance in seeds, resulting in a marked inhibition of germination.

Finally, the study by Munns and Tester (2008) supports these results, noting that salinity stress in the early stages significantly impacts the seeds' ability to absorb water and expand, leading to a gradual decrease in germination percentage with increasing salinity.

6-Germination Rate

The germination rate showed the highest value in the control treatment (without sodium chloride), averaging 10.5, followed by the 50 mM treatment with an average of 3.4. The rate significantly decreased at the 25 mM concentration to 2.95, and was lowest at the 75 mM concentration, averaging 2.84. These results confirm that salinity stress clearly reduces the germination rate with increasing salt concentration.

This finding is consistent with the study by Essa (2002), which indicated that salinity stress reduces the germination rate due to the inhibition of water absorption necessary to initiate metabolic processes within the seeds.

Additionally, Khan et al. (2009) demonstrated that increased salinity slows down the germination process due to its negative effect on the activity of enzymes responsible for starch breakdown and its conversion into simple sugars that nourish the embryo.

The results are further supported by Zeng et al. (2001), who showed that salinity stress reduces water absorption rates and leads to a significant delay in germination time, with clear differences observed at high concentrations. Furthermore, Ghoulam et al. (2002) indicated that salinity stress disrupts the ionic balance within seeds, reducing the germination rate.

Finally, the study by Munns and Tester (2008) confirmed that the negative impact of salinity stress is clearly evident in the early stages of germination, causing a notable delay due to increased osmotic pressure that hinders the water absorption necessary to initiate germination.

7-Germination Strength Index

The highest value for the Germination Strength Index was recorded in the control treatment (without sodium chloride), averaging 15.59, followed by the 50 mM concentration with an average of 11.6, then the 25 mM concentration with an average of 10.6, and finally the 75 mM concentration with an average of 10.4. This indicates that germination strength is negatively affected by increasing salinity, as it declines with rising sodium chloride concentration.

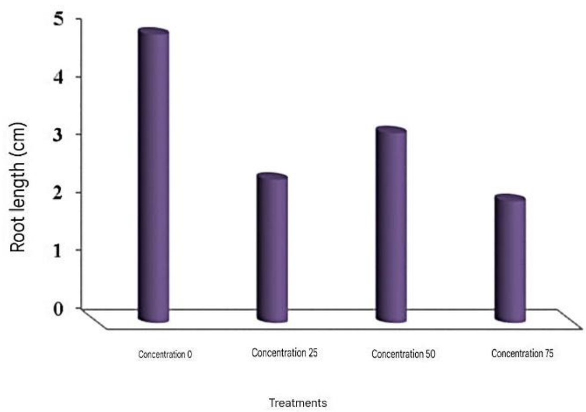
This finding is consistent with the study by Essa (2002), which indicated that salinity stress reduces germination strength due to its negative impact on metabolic processes within the seeds and inhibition of water absorption. Additionally, Khan et al. (2009) demonstrated that increased salt concentrations lead to a significant decline in the seeds' ability to germinate and grow rapidly, which is reflected in the reduced Germination Strength Index.

The results are further supported by Zeng et al. (2001), who showed that salinity stress at high concentrations decreases both the percentage and rate of germination, leading to a lower strength index due to delays in vital processes. Furthermore, Ghoulam et al. (2002) noted that salinity stress causes an imbalance in ionic and water content, reducing germination strength due to its negative effects on enzymatic activity and the internal structure of the seeds.

Finally, the study by Munns and Tester (2008) confirmed that plants under salinity stress lose their ability to maintain the physiological processes necessary for robust germination, resulting in a decreased Germination Strength Index with increasing salinity concentration.

Table 2: Effect of Sodium Chloride on Root and Shoot Length, Germination Percentage, Germination Rate, and Germination Strength Index

Feather length	Root length	Germination rate	Germination speed	Evidence of germination strength	
4.33	4.97	76.7	10.5	15.59	0
3.10	2.47	53.3	2.95	10.6	25
2.63	3.27	58	3.4	11.6	50
2.93	2.10	72.5	2.84	10.4	75
*	*	-	-	-	F
0.441	0.831	36.46	9.75	7.82	LSD



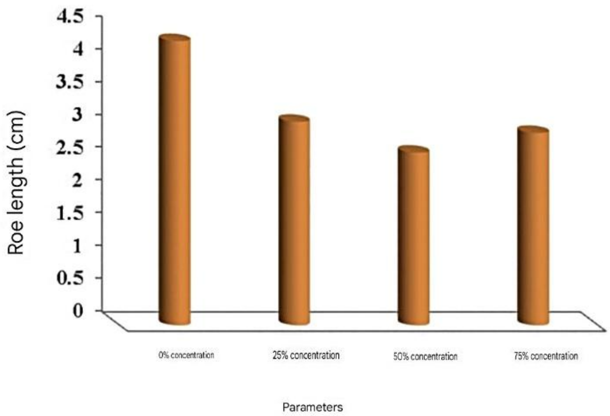


Figure (5): Average root length

Figure (6): Average length of the ravine

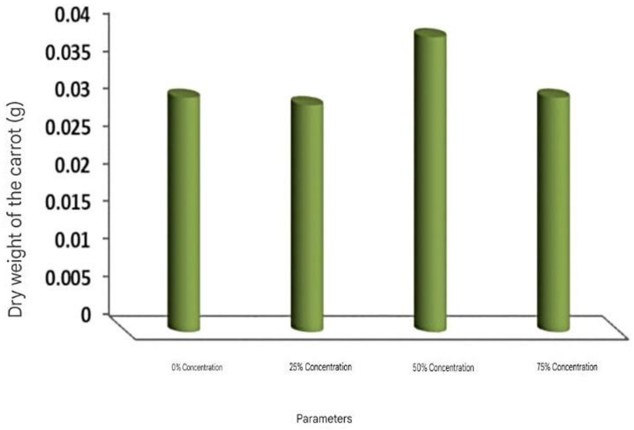


Figure (7): Average germination rate

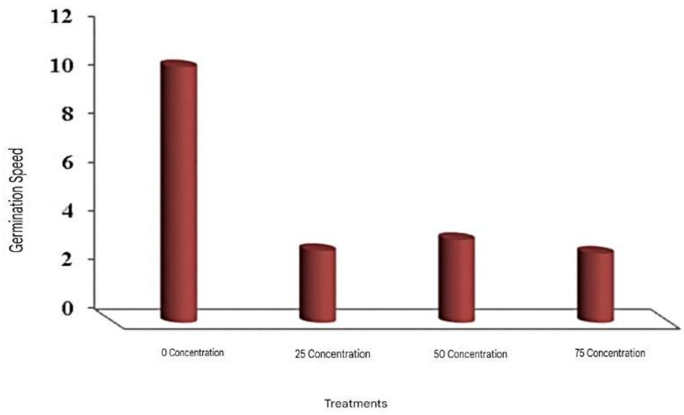


Figure (8): Average germination speed

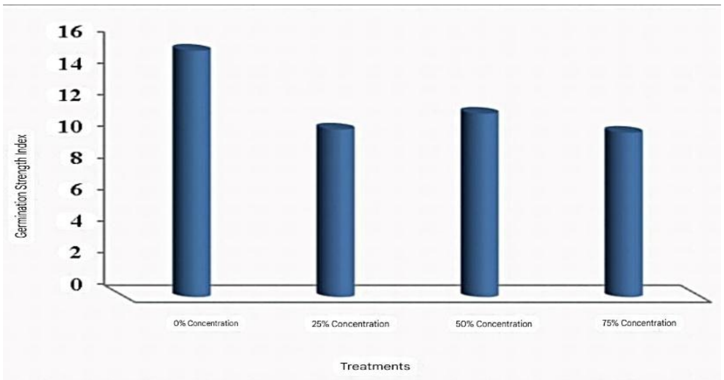


Figure (9): Germination strength index

Recommendations

1- It is recommended to cultivate maize in low-salinity soils, utilizing high-quality irrigation water with low salt content to ensure good growth and increased productivity.
2- The use of soil amendments, such as organic matter and agricultural lime, is suggested to mitigate the negative effects of sodium chloride.

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