JOURNAL OF
INTERDISCIPLINARY
PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 4 No. 3, pp. 61-69, March 2026

Original Article

Effects of Water Stress Induced by Sorbitol and Sodium Chloride on Seedling Parameters of Corn (*Zea mays* L.)

***Paul John A. Plecis*[1], *Dorothy A. Antesa*[2]**

Author Information:

[1]Graduate School Department, Notre Dame of Dadiangas University, General Santos City, Philippines

[2]Graduate School Department, Notre Dame of Marbel University, Koronadal City, South Cotabato, Philippines

Correspondence:
paulplecis@gmail.com

Article History:

Date received: May 27, 2025
Date revised: January 27, 2026
Date accepted: February 6, 2026

Recommended citation:

Plecis, P.J., & Antesa, D. (2026). Effects of water stress induced by Sorbitol and Sodium chloride on seedling parameters of Corn (*Zea mays* L.). *Journal of Interdisciplinary Perspectives*, 4(3), 61-69.
https://doi.org/10.69569/jip.2025.459

Abstract. Drought and salinity are two principal abiotic stresses that can affect the physiological status of organisms by altering metabolism, growth, and development, including seed germination, seedling growth and vigor, vegetative growth, flowering, and fruit development, thereby reducing economic yield and the quality of produce. Understanding germination and seedling development under stressful conditions is crucial for early seedling establishment. In this study, corn (*Z. mays*) was analyzed for tolerance to water and salt stress during germination and early seedling growth. Seed germination, seedling length, dry and fresh weight, seed vigor, and other parameters were recorded. The results revealed that as water stress increased, corn (Z. mays) germination was delayed and decreased, from 98% (control) to 34% (-15 bar) in sorbitol and from 94% (control) to 44% (15 bar) in saline solution. Dry and fresh shoot and root weights, along with their lengths, decreased as water and salt stress levels increased. Seed vigor and salt tolerance index of corn (*Z. mays*) showed a decreasing pattern as the salt stress level increased. These results could help identify a tolerant corn variety (Z. mays) that can be studied further and economically exploited.

Keywords: *Corn (Z. mays); Seed germination; Sodium chloride; Sorbitol; Water stress.*

As the world faced the effects of climate change, extreme droughts became more frequent and severe under future climates. Prolonged dry spells reduce water availability for agriculture, impairing crop growth and productivity. As a result, the overall yield of crops essential for human and animal consumption declines, posing a direct threat to food security. According to the UN Food and Agriculture Organization (2024), 1.4 billion hectares of global land are affected by salinity, and an additional 1 billion hectares are at risk. Excess salt can affect agriculture, with potential crop-yield losses of around 70% (Harvey, 2024). Hence, innovative strategies and approaches are needed to address the challenges faced by the agricultural sector.

In the United States of America, new management approaches and technologies are used in the US Corn Belt to increase yields despite a changing climate, such as using soil maps and satellite-based yield estimates to assess soil moisture retention (Lobell et al., 2020). Also, various biotech companies are developing drought-tolerant transgenic plants in China (wheat and cotton), Brazil (soybeans), the Czech Republic (tomatoes), and the Philippines (rice). While current research and innovation focus on improving resilience in crops of high economic value, limited data investigate the physiological responses of seeds, specifically in corn, under controlled stress conditions, and there is a need for screening methods to assess crop stress tolerance from early developmental stages, which is critical for early selection.

In the Philippines, the 2019 El Niño greatly affected the agricultural sector, causing 7.96 billion pesos in crop damage (Institute of Environmental Science and Meteorology of the University of the Philippines Diliman, 2020). The damage from the 2019 El Niño event reduced corn and rice production, resulting in a total loss of 447,889 metric tons across 277,889 hectares and affecting 247,610 farmers (Mogato, 2019). The Department of Agriculture (DA) urged farmers to plant climate-resilient crops to cope with the prolonged dry season and the effects of El Niño (Agoot, 2023). Despite the agricultural sector's vulnerability in the Philippines to extreme climate events, few studies have evaluated maize's physiological responses to controlled stress during early developmental stages in a local setting. Most existing research focuses on plant growth at later stages. At the same time, limited attention has been paid to the physiological responses of maize seeds during germination and early seedling development under controlled stress conditions.

Drought and salinity are two principal abiotic stresses that affect crop productivity and threaten plant growth (Alghamdi, 2024). Both stresses induced physiological, biochemical, morphological, and metabolic changes to the plant growth and productivity (Alghamdi, 2024). To overcome these effects, selecting drought-tolerant seeds and promoting effective physiological responses to salinity by alleviating cellular hyperosmolarity and ion disequilibrium must be considered. Using osmotic agents such as sodium chloride and sorbitol to induce stress during germination and seedling growth offers a practical approach for screening and selecting resilient varieties to improve seedling establishment.

This study aimed to evaluate the physiological responses of maize (*Zea mays* L.) seeds and seedlings under controlled drought and salinity stress conditions induced by sorbitol and sodium chloride, respectively. Specifically, this study sought answers to the following:

a) What is the physiological and morphological response of corn (*Z. mays* L.) to sorbitol-induced water deficit in terms of shoot and root length, germination percentage and rate, initiation and completion days of seed germination, and the total fresh and dry weight of shoot and root?
b) What is the effect of sodium chloride-induced salt stress on corn (*Z. mays* L.) in terms of shoot and root length, germination percentage and rate, initiation and completion days of seed germination, total fresh and dry weight of shoot and root, relative water content, strong seed index, and salt tolerance index?
c) Is there a significant difference in the different levels of external water and salinity stress to the root and shoot length of corn (*Z. mays* L.) induced by sorbitol and sodium chloride?

Methodology

Plant Material and Chemicals

The experiment used corn (*Z. mays* L.) seeds of the Filipina 370 variety, which is a locally available cultivar. Seeds were sourced from a certified agricultural supplier in Barangay Dadiangas South, General Santos City, to ensure viability and uniformity. The following analytical-grade chemicals were also used in the study: sorbitol ($C_6H_{14}O_6$) to induce water stress; sodium chloride (NaCl) to induce salt stress; sodium hypochlorite (NaOCl, 1%) for seed surface sterilization; and distilled water for solution preparation and seed rinsing. All glassware (petri dishes, beakers, graduated cylinders) was sterilized in a sterilizer before use. A digital balance, stirring rod, dissecting kit, mortar and pestle, and ruler were used to handle and measure seeds.

Preparation of Water Stress Solutions (Sorbitol-Induced)

In the drought-stress simulation, external water stress levels of -5, -10, and -15 bars were prepared using sorbitol ($C_6H_{14}O_6$) dissolved in distilled water. The concentrations were determined based on established osmotic pressure relationships.

Table 1. *Sorbitol ($C_6H_{14}O_6$) Concentrations in Inducing Water Stress*

Ψos Level (Bar)	Sorbitol (g/L of Distilled Water)
0	0
-5	37.27
-10	74.54
-15	111.80

Preparation of Salt Stress Solutions (NaCl-Induced)

In the salinity-stress simulation, external salinity levels of -5, -10, and -15 bars were prepared by dissolving sodium chloride (NaCl) in distilled water. The concentrations were determined based on solute-water potential relationships.

Table 2. *Sodium Chloride (NaCl) Concentrations in Inducing Salinity Stress*

Ψos Level (Bar)	NaCl (g/L of Distilled Water)
0	0
-5	7.00
-10	14.00
-15	21.00

Seed Sterilization and Rinsing

The maize (*Z. mays* L. cv. Filipina 370) seeds were surface-sterilized to reduce microbial contamination. The seeds were immersed in a 1% (v/v) sodium hypochlorite (NaOCl) solution and agitated for 5 minutes. After sterilization, the seeds were rinsed twice with distilled water to remove any residual bleach. The sterilized seeds were then air-dried on paper towels under ambient conditions before being used in germination experiments.

Germination Test

After sterilization and air-drying, ten (10) maize (*Z. mays* L. cv. Filipina 370) seeds were placed in a sterile 10 cm petri dish lined with two layers of moistened paper towels. For each treatment, 5 mL of the test solution (sorbitol or sodium chloride at -5, -10, or -15 bar osmotic potentials) or distilled water (control) was added to the petri dishes. The treatment was replicated five (5) times. The petri dishes were maintained in a controlled environment with a 12-hour light/dark cycle and a temperature range of 14 °C to 24 °C. The seeds were observed daily for 15 days, and germination was considered successful when the radicle reached at least 2 mm in length.

Germination and Growth Parameters

Germination Rate and Percentage

The corn (*Z. mays* L. cv. Filipina 370) seeds were considered germinated if the radicle was 2 mm long. The germination percentage and rate were determined by counting the number of germinated seeds daily over 15 days. The Germination Percentage (GP) and Germination Rate (GR) were calculated using the following formulas:

Germination Percentage (GP):

$$GP = \frac{number\ of\ total\ germinated\ seeds}{total\ number\ of\ seeds\ tests}\ x\ 100$$

Germination Rate (GR):

$$GR = \frac{number\ of\ germinated\ seeds}{day\ of\ first\ count} + \cdots \frac{number\ of\ germinated\ seeds}{day\ of\ final\ count}$$

Length and Weight (Fresh and Dry) of Shoot and Root

The root and shoot lengths and the early-seedling fresh and dry weights of corn (Z. mays L. cv. Filipina 370) seeds were measured on the 15th day using a ruler and a digital balance. The shoot and root dry weights were recorded after oven drying at 60°C for 20 minutes. The fresh weight (FW) percentage reduction and dry weight (DW) percentage reduction were calculated using the formulas:

Fresh Weight Percentage Reduction (FWPR%):

$$FWPR\% = 100\ x\ [1 - (\frac{fresh\ weight_{salt\ stress}}{fresh\ weight_{control}})$$

Dry Weight Percentage Reduction (DWPR%):

$$DWPR\% = 100\ x\ [1 - (\frac{dry\ weight_{salt\ stress}}{dry\ weight_{control}})$$

Relative Water Content (RWC)

Relative Water Content (RWC) is an important indicator of plant water status. Relative Water Content (RWC) is a physiological indicator that measures the hydration level of seedlings under drought stress (Sapes & Sala, 2021). The water content relative to the fresh weight was calculated as described by Sumithra et al. (2006).

Relative Water Content (RWC):

$$RWC\% = 100\ x\ [\frac{(FW - DW)}{FW}]$$

Seed Vigor (SV) and Salt Tolerance Index (STI)

Seed vigor is an interaction of characteristics considered attributes of physiological potential, such as germination speed, seedling growth, ability to germinate above or below optimal temperatures, and other aspects of stress tolerance. To determine the seed vigor, the strong seed index of Abdul and Anderson (1970) was used.

Strong Seed Index:

$$SSI = \frac{germination\ percentage\ x\ means\ of\ seedling\ length\ (root + shoot)}{100}$$

Salt Tolerance Index (STI) is quantified by the ratio, respectively, to the controlled, of the total dry weight in salt stress, in percent, and calculated by the equation below:

Salt Tolerance Index (STI):

$$STI\% = 100\ x\ \frac{total\ dry\ weight_{salt\ stress}}{total\ dry\ weight_{control}}$$

Statistical Analysis

Descriptive statistics, such as means and percentages, were used to describe the data. The researcher used a one-way analysis of Variance (ANOVA) in a completely randomized design (CRD) with equal replication to determine significant differences in shoot and root length across levels of external water and salinity stress. The LSD (Least Significant Difference) test was used to compare treatment means and establish which treatment means significantly differed.

Ethical Considerations

This study did not involve human or animal subjects; therefore, ethical approval was not required. All experimental procedures were conducted in accordance with the guidelines for laboratory practices and environmental safety. The plant material was obtained from a certified agricultural supplier and was handled with care to minimize waste and environmental impact. Safety protocols were strictly followed throughout the study, such as wearing gloves and masks. Also, COVID-19 health and safety protocols were followed during the study under the General Community Quarantine (GCQ), including social distancing, proper sanitation, a quarantine pass, and the use of personal protective equipment (PPE). Regulations on waste disposal were also followed to prevent environmental contamination.

Results and Discussion

Germination Rate, Germination Percentage, and Initiation and Completion Days of Seed Germination of Corn (*Z. mays* L.)

In the plant life cycle, seed germination indicates seed viability and vigor under different environmental conditions. Thus, assessing seed germination across various seedling parameters, such as germination rate, percentage, and initiation and competition days, provides insight into the successful establishment of seeds under stress conditions. Tables 3 and 4 present the germination rate, germination percentage, and initiation and competition days of seed germination of Corn (*Z. mays* L.) under sorbitol-induced and sodium chloride-induced stress.

Table 3. *Germination Rate and Percentage of Corn (Z. mays L.) Induced by Sorbitol and Sodium Chloride*

Water/Salt Stress Level	Germination Rate and Percentage			
	Sorbitol	**%**	**Sodium Chloride**	**%**
0	19.19	98.00%	17.88	94.00%
-5	15.81	92.00%	17.33	98.00%
-10	9.28	64.00%	10.92	88.00%
-15	4.45	34.00%	3.17	44.00%

Table 4. *Initiation and Completion Days of Seed Germination of Corn (Z. mays L.)*

Water/Salt Stress Level	Sorbitol		Sodium Chloride	
	Initiation	**Completion**	**Initiation**	**Completion**
0	2	5	2	10
-5	2	7	2	10
-10	3	9	3	14
-15	4	10	6	14

The results (see Table 3) showed that the germination rate and percentage of corn (*Z. mays* L.) declined as the severity of external water or salt stress increased. At 0 bar, the seed exhibited the highest germination rates with 19.19 (98.00%) for sorbitol and 17.88 (94.00%) for sodium chloride. As the stress increases, the germination rate and percentage decrease by 4.45 (34.00%) for sorbitol and 3.17 (44.00%) for sodium chloride at -15 bar. In the initiation and completion of seed germination (see Table 4), the results showed that seed germination is delayed as salt and water stress increase. At 0 bar, germination begins on day 2 and is complete in days 5 and 10 for sorbitol and sodium chloride, respectively. However, as the salt and water stress increases, the initiation and competition days of seed germination of Corn (*Z. mays* L.) were delayed under -10 and -15 bars at day 3 (initiation) and Day 10 to 14 (competition) for sorbitol and sodium chloride, respectively. This indicates that prolonged stress affects the germination process.

The decrease in seed germination as the water and salinity stress increases aligns with existing research. According to Uçarlı (2020), salt stress affects seed germination and establishment through osmotic stress, ion toxicity, and oxidative stress by decreasing the amounts of GA, which is a seed germination stimulant, altering the permeability and water behavior of the seeds. In the study, delayed germination initiation and completion are associated with reduced Gibberellin (GA) levels and increased ABA levels. Abscisic acid (ABA) is a plant hormone that triggers responses to drought, including stomatal closure, root system modulation, and metabolic alterations (Aslam et al., 2022). Thus, corn (Z. mays L.) likely increases ABA accumulation in response to osmotic stress, thereby triggering adaptive responses to maintain cellular homeostasis.

Shoot and Root Length of Corn (*Z. mays* L.) under Sorbitol-Induced and Sodium Chloride-Induced Stress

In seed germination, the primary root or radicle is the first organ to appear, which grows downward into the soil for anchorage and absorption of nutrients and water for plant development. The shoot emerges from the plumule and grows upward, a process essential for photosynthesis. Both the shoot and the root need to emerge from the seed to establish essential physiological functions in the plant. Tables 5, 6, 7, 8, and 9 present the shoot and root length of Corn (*Z. mays* L.) induced by sorbitol and sodium chloride, and the summary of Analysis of Variance (ANOVA) and the Least Significant Difference (LSD) test for treatment means.

Table 5. *Shoot and Root Length of Corn (Z. mays L.) Induced by Sorbitol and Sodium Chloride (cm)*

Water/Salt Stress Level	Sorbitol		Sodium Chloride	
	Shoot Length	**Root Length**	**Shoot Length**	**Root Length**
0	1.76	7.97	2.23	7.68
-5	0.60	5.06	0.76	4.74
-10	0.27	1.16	0.12	0.64
-15	0.08	0.28	0.05	0.18

Table 6. *Summary of Analysis of Variance of Shoot and Root Length under Sorbitol-Induced Stress*

Source of Variation	df	Shoot Length			Root Length		
		SS	**MS**	**F-value**	**SS**	**MS**	**F-value**
Treatment	3	8.505	2.835	32.769**	190.976	63.659	23.146**
Error	16	1.384	0.087		44.005	2.750	
Total	**19**	**9.890**			**234.981**		

** - significant at 1%

Table 7. *Least Significant Difference (LSD) Table for Treatment Means under Sorbitol-Induced Stress*

Water Stress Level	Shoot Length		Root Length	
	Means	Difference from the Control	Means	Difference from the Control
0	1.76	---	2.23	---
-5	0.60	1.16**	0.76	2.91^{ns}
-10	0.27	1.49**	0.12	6.81**
-15	0.08	1.68**	0.05	7.69**

** - significant at 1%
^{ns} – not significant
$LSD_{.01}$ = 3.029

Table 8. *Summary of Analysis of Variance of Shoot and Root Length under Sodium Chloride-Induced Stress*

Source of Variation	df	Shoot Length			Root Length		
		SS	MS	F-value	SS	MS	F-value
Treatment	3	16.813	5.604	40.131**	190.165	63.388	38.545**
Error	16	2.234	0.140		26.313	1.645	
Total	**19**	**19.047**			**216.478**		

** - significant at 1%

Table 9. *Least Significant Difference (LSD) Table for Treatment Means under Sodium Chloride-Induced Stress*

Salt Stress Level	Shoot Length		Root Length	
	Means	Difference from the Control	Means	Difference from the Control
0	2.33	---	7.68	---
-5	0.76	1.57**	4.74	2.93**
-10	0.12	2.21**	0.64	7.04**
-15	0.05	2.28**	0.18	7.50**

** - significant at 1%
$LSD_{.01}$ = 2.343

The results (see Table 5) showed that under sorbitol-induced stress, shoot and root lengths decreased from 1.76 cm and 7.97 cm at 0 bar to 0.60 cm and 5.06 cm at -5 bar, 0.27 cm and 1.16 cm at -10 bar, and 0.08 cm and 0.28 cm at -15 bar, respectively. The Analysis of Variance (see Table 6) revealed that there is a significant difference in the shoot and root length among treatments (*$p<0.001$),* with the Least Significant Difference (LSD) test (see Table 7) showing a significant decrease in shoot and root length in varying osmotic levels, specifically at -10 and -15 bar. This implies that the more negative the water potentials, the more the elongation of the shoot and the root is inhibited. Sodium chloride-induced stress (see Table 5) showed that the shoot and root length decreased from 2.23 cm and 7.68 cm at 0 bar, 0.76 cm and 4.74 cm at -5 bar, 0.12 cm and 0.64 cm at -10 bar, and 0.05 cm and 0.18 cm at -15 bar, respectively. The Analysis of Variance (see Table 6) revealed a significant difference among treatments for both shoot and root lengths ($p<0.001$). The Least Significant Difference (LSD) test showed significant differences at all stress levels compared to the control group. The results reveal a significant reduction in shoot and root lengths of Corn (*Z. mays* L.) under increasing osmotic stress.

This implied that drought and salinity stress significantly impair early vegetative development in corn (*Z. mays* L.). Lamaoui et al. (2018) reported that osmotic stress limits water uptake, decreases cell turgidity, and inhibits the elongation of young tissues. The reduction in shoot and root growth in Corn (Z. mays L.) supports the idea that higher stress levels sharply reduce vegetative development, and that the shoot and root systems are sensitive to water deficits or salinity stress during early growth stages. The biological sensitivity of the root and shoot systems is due to the accumulation of toxic ions during the first contact with the saline solution (Marschner, 1995). That affects the hormonal regulation, water status, and enzymatic activities of plants (Islam et al., 2024). The key hormones involved and their effects are the reduction of Auxin (Indole-3-Acetic Acid, IAA) levels and transporter expression (Ribba et al., 2020), and suppression of GA biosynthesis, leading to shortened shoots and reduced seed vigor (Chauhan et al., 2019). The results emphasize that stress-response indicators are seedling traits of corn (Z. mays L.) and can be used to screen corn genotypes for tolerance to drought and salinity. Tolerant lines at the seedling stage can improve crop productivity in arid or saline environments.

Fresh Weight Percentage (FWPR%), Dry Weight Percentage Reduction (DWPR%), and Relative Water Content (RWC%) in Shoot and Root of Corn (*Z. mays* L.) under Sorbitol-Induced and Sodium Chloride-Induced Stress

In seed development, assessing shoot and root weight and moisture content is essential for measuring plant growth. Fresh weight refers to a plant's recorded weight after harvest, while dry weight is the recorded weight after the plant is oven-dried to remove water. Relative Water Content (RWC) is an important indicator of water status in plants, reflecting the balance between water supply to leaf tissue and transpiration rate (Lugojan & Ciulca, 2011). Tables 10, 11, and 12 present the percentage reductions in fresh and dry weight and the relative water content of the shoot and root of Corn (*Z. mays* L.) induced by sorbitol and sodium chloride.

Table 10. *Fresh Weight Percentage Reduction (FWPR%) and Dry Weight Percentage Reduction (DWPR%) in Shoot and Root of Corn (Z. mays L.) under Sorbitol-Induced Stress*

Water Stress Level	Shoot						Root					
	FWS	FWC	FWPR%	DWS	DWC	DWPR%	FWS	FWC	FWPR%	DWS	DWC	DWPR%
-5	1.00	1.50	33.33	0.50	0.90	44.44	1.30	1.80	27.78	0.80	1.40	42.86
-10	0.60	1.50	60.00	0.20	0.90	77.78	0.80	1.80	55.56	0.40	1.40	71.43
-15	0.10	1.50	93.33	0.10	0.90	88.89	0.50	1.80	72.22	0.10	1.40	92.86

(FWS = Fresh Weight Sample, FWC = Fresh Weight Control, FWPR% = Fresh Weight Percentage Reduction, DWS = Dry Weight Sample, DWC = Dry Weight Control, DWPR% = Dry Weight Percentage Reduction)

Table 11. *Fresh Weight Percentage Reduction (FWPR%) and Dry Weight Percentage Reduction (DWPR%) in Shoot and Root of Corn (Z. mays L.) under Sodium Chloride-Induced Stress*

Water Stress Level	Shoot						Root					
	FWS	FWC	FWPR%	DWS	DWC	DWPR%	FWS	FWC	FWPR%	DWS	DWC	DWPR%
-5	1.20	1.30	7.69	0.50	0.80	37.50	1.60	2.10	23.81	1.20	1.40	14.29
-10	0.20	1.30	84.62	0.10	0.80	87.50	0.50	2.10	76.19	0.20	1.40	85.71
-15	0.10	1.30	92.31	0.10	0.80	87.50	0.20	2.10	90.48	0.10	1.40	92.86

(FWS = Fresh Weight Sample, FWC = Fresh Weight Control, FWPR% = Fresh Weight Percentage Reduction, DWS = Dry Weight Sample, DWC = Dry Weight Control, DWPR% = Dry Weight Percentage Reduction)

The results (see Table 10) showed that under sorbitol-induced stress, the FWPR and DWPR for the shoot were 33.33% and 44.44%, respectively, while the root FWPR was 27.78% and the DWPR was 42.86% at -5 bar. At -10 bar, reductions are evident for FWPR and DWPR: 60.00% and 77.78% for the shoot and 55.56% and 71.43% for the root. At -15 bar, biomass loss was more pronounced with FWPR and DWPR: 93.33% and 88.89% in the shoot and 72.22% and 92.86% in the root. The findings reveal that the corn's biomass decreases as the water stress increases due to impaired physiological processes of the Corn (*Z. mays* L.) under higher water stress.

In sodium chloride-induced stress (see Table 11), the FWPR and DWPR for the shoot were 7.69% and 37.50%, respectively, in the shoot and 23.81% and 14.29% in the root at -5 bar. At -10 bar, the FWPR and DWPR for the shoot increased to 84.62% and 87.50%, respectively, in the shoot, and 76.19% and 85.71% for the root. At -15 bar, the FWPR and DWPR reached 92.31% and 87.50% for the shoot, while the FWPR and DWPR of the root were 90.48% and 92.86%, respectively. The results indicate that the salinity stress induced reductions in the biomass of the shoot and root of Corn (*Z. mays* L.).

Table 12. *Relative Water Content (RWC%) in Shoot and Root of Corn (Z. mays L.) Induced by Sodium Chloride*

Salt Stress Level	Shoot			Root		
	FW	DW	RWC%	FW	DW	RWC%
0	1.30	0.80	38.46	2.10	1.40	33.33
-5	1.20	0.50	58.33	1.60	1.20	25.00
-10	0.20	0.10	50.00	0.50	0.20	60.00
-15	0.10	0.10	0.00	0.20	0.10	50.00

(FW = Fresh Weight, DW = Dry Weight, RWC% = Relative Water Content)

The results (see Table 12) showed that relative water content (RWC) is a critical indicator of plant water status, particularly in retaining water and maintaining turgor pressure under stress conditions. At 0 bar, the shoot and root tissues recorded an RWC of 8.46% and 33.33%, respectively. At -5 bar, the shoot and root RWC increased to 58.33% in the shoot and 25.00% in the root. At -10 bar, RWC decreases in the shoot at 50.00% and increases in the root at 60.00%. However, at -15 bar, the RWC in the shoot dropped to 0.00% while the root remained at 50.00%. The results implied that under high salinity stress, shoot tissues are more sensitive to dehydration, whereas roots exhibit adaptation to varying salinity, but RWC decreases as salinity increases.

The reductions in the fresh and dry weights of shoot and root issues in increasing osmotic stress implied the physiological impact of water and salinity stress on the growth of corn (*Z. mays* L.). These findings aligned with previous reports on the increasing osmotic stress to plant growth. The study of Li et al. (2023) reveals that 10 mM sorbitol significantly alleviated growth inhibition caused by drought stress, which was attributed to antioxidant enzyme activities, accumulation of osmoprotectants like proline and soluble sugars, and upregulation of genes related to sorbitol synthesis. These physiological attributes helped maintain relative water content (RWC) and reduce oxidative damage across varying osmotic stress concentrations. In addition, Henry et al. (2015) examined how salt stress affects trehalose metabolism in maize and found that it led to an accumulation of trehalose-6-phosphate in plant tissues, resulting in changes in kernel development and seed set. Hence, the physiological response of Corn (*Z. mays* L.) revealed that adjustment mechanisms are important and exhibited in the tolerance of Corn (*Z. mays* L.) to varying osmotic stress, such as the accumulation of osmoprotectants and antioxidant enzyme activation to mitigate the impact.

Strong Seed Index (SSI) and Salt Tolerance Index (STI) of Corn (*Z. mays* L.) under Sodium Chloride-Induced Stress

Seed vigor is a key component of crop seed performance, defining their ability to germinate and establish seedlings, including germination speed, seedling growth, and the capacity to germinate under varied environmental conditions (Finch-Savage & Bassel, 2016). On the other hand, it is important to assess seed salt tolerance to develop plant varieties that can survive and complete their life cycle under saline conditions, using the Salt Tolerance Index (STI). Tables 13 and 14 present the Strong Seed Index (SSI) and Salt Tolerance Index (STI) of Corn (*Z. mays* L.) under sodium chloride-induced stress.

Table 13. *Strong Seed Index (SSI) of Corn (Z. mays* L.) *under Sodium Chloride-Induced Stress*

Salt Stress Level	GP	RL	SL	SSI
0	94.00	7.68	2.33	9.41
-5	98.00	4.74	0.76	5.39
-10	88.00	0.64	0.12	0.67
-15	44.00	0.18	0.05	0.10

(GP = Germination Percentage, RL = Root Length, SL= Shoot Length, SSI = Strong Seed Index)

The results (see Table 13) showed that the Strong Seed Index (SSI) measures how seeds perform under varying osmotic stress concentrations. At 0 bar, the Corn (*Z. mays* L.) showed the highest SSI of 9.41. At -5 bar, the SSI decreased to 5.39, which implied that the seed germination was not heavily affected by the mild salinity stress. At -10 and -15 bars, the SSI dropped significantly to 0.67 and 0.10, respectively, which implied that the high salinity stress impaired the germination and seedling growth of the Corn (*Z. mays* L.). The data revealed that SSI is inversely proportional to salinity intensity, and higher salinity stress reduces seed vigor in corn *(Z. mays* L.).

Table 12. *Salt Tolerance Index (STI) of Corn under Sodium Chloride-Induced Stress*

	Shoot			Root		
Salt Stress Level	TDWS	TDWC	STI%	TDWS	TDWC	STI%
-5	0.50	0.80	62.50	1.20	1.40	85.71
-10	0.10	0.80	12.50	0.20	1.40	14.29
-15	0.10	0.80	12.50	0.10	1.40	7.14

(TDWS = Total Dry Weight Sample, TDWC = Total Dry Weight Control, STI = Stress Tolerance Index)

In the Salt Tolerance Index (STI) (see Table 14), the data showed that the STI at -5 bar was 62.50% for shoots and 85.71% for roots, indicating a mild reduction in biomass and greater tolerance of Corn (Z. mays L.) to mild salinity. At -10 bar, the STI decreased to 12.5% for the shoot and 14.29% for the roots, indicating that salinity stress significantly affected shoot and root biomass. At -15 bar, the STI remains at 12.5% for the shoot while the STI for the roots decreased further to 7.14%, indicating that high salt stress inhibits growth.

The findings in the salinity stress confirm that Corn (*Z. mays* L.) is a moderately salt-tolerant crop. However, as salinity increases, the growth of Corn (Z. mays L.) is impaired, and osmoprotectants, such as proline, increase as an adaptive response (Naz et al., 2022). According to Hayat (2012), proline acts as a metal chelator, an antioxidative defense molecule, and a signaling molecule during stress, thereby maintaining cell turgor, stabilizing membranes to prevent electrolyte leakage, and keeping reactive oxygen species (ROS) within the normal range. The decreasing STI across stress levels indicates that high salinity reduces biomass in both shoots and roots, with roots more tolerant than shoots. This is confirmed by the study of Rizk et al. (2024), in which two maize genotypes (SC180 and SC168) exhibited a reduction in shoot length and root length by 13.6% under 150 nM NaCl, and it is associated with efficient Na+ regulation, maintenance of K+ levels, and a strong antioxidant defense system. These insights highlight the development of resilient corn varieties.

Conclusion

This study demonstrates that both sorbitol- and sodium chloride-induced stress affect germination and seedling development in corn (Z. mays L.). As the concentration of sorbitol and sodium chloride increases, there is a reduction in all seedling parameters such as the germination rate, germination percentage, the length of shoot and root, the fresh and dry weight of shoot and root, relative water content (RWC), and seed vigor. In addition, the findings revealed that Corn (*Z. mays* L.) is moderately salt-tolerant, but the early growth stage is sensitive to osmotic and salt stress, particularly in the shoot. The decline in different seedling parameters under osmotic and salinity stress highlights the vulnerability of Corn (*Z. mays* L.) to drought and salinity. This underscores the need to develop resilient corn varieties, especially in high-salinity or arid environments. Thus, future research may focus on enhancing Corn (*Z. mays* L.)'s adaptation to abiotic stress by genetically modifying genes involved in proline production as an adaptive response.

Contributions of Authors

The authors indicate equal contribution to each section. The authors reviewed and approved the final work.

Funding

The work received no specific grant from any funding agency.

Conflict of Interests

The authors declare no conflicts of interest regarding the publication of this paper.

Acknowledgment

The researcher would like to express sincere gratitude to the Almighty God for the wisdom, strength, guidance, and perseverance that made the completion of this study possible, especially amid the unprecedented challenges brought about by the onset of the COVID-19 pandemic. Heartfelt appreciation is also extended to Dr. Dorothy A. Antesa, the researcher's Plant Physiology teacher, for her invaluable guidance, expertise, encouragement, and unwavering support throughout this research. The researcher is likewise deeply grateful to Silway-8 National High School for generously providing the necessary laboratory apparatus and facilities used in this study. Sincere thanks are also extended to the researcher's PhD classmates for their encouragement, cooperation, shared knowledge, and moral support throughout this academic journey. Their companionship and mutual motivation played a significant role in sustaining perseverance during challenging times. This study was conducted during the onset of COVID-19, a period marked by uncertainty, restrictions, and major adjustments in the academic and research environment. Finally, the researcher extends heartfelt appreciation to all individuals who, in one way or another, offered assistance, encouragement, and motivation throughout this endeavor. Their contributions are deeply valued and will always be remembered.

References

Abdul-Baki, A., & Anderson, J. (1970). Viability and leaching of sugars from germinating barley1. Crop Science, 10(1), 31–34. https://doi.org/10.2135/cropsci1970.0011183x001000010012x

Agoot, L. (2023). DA tells farmers to grow drought-tolerant plants amid El Niño. Philippine News Agency. https://tinyurl.com/3pk3w5dv

Alghamdi, S.A. (2024). Drought and salinity effects on plant growth: A comprehensive review. SABRAO Journal of Breeding and Genetics, 56(6): 2331–2340. http://doi.org/10.54910/sabrao2024.56.6.14

Aslam, M.M., Waseem, M., Jakada, B.H., Okal, E.J., Lei, Z., Saqib, H.S.A., Yuan, W., Xu, W., & Zhang, Q. (2022). Mechanisms of Abscisic acid-mediated drought stress responses in plants. International Journal of Molecular Sciences, 23(3), 1084. https://doi.org/10.3390/ijms23031084

Chauhan, A., AbuAmarah, B., Kumar, A., Verma, J., Ghramh, H., Khan, K.A., & Ansari, M.J. (2019). Influence of Gibberellic acid and different salt concentrations on germination percentage and physiological parameters of Oat cultivars. Saudi Journal of Biological Sciences, 26(6), 1298–1304. https://doi.org/10.1016/j.sjbs.2019.04.014

Finch-Savage, W., & Bassel, G. (2015). Seed vigour and crop establishment: Extending performance beyond adaptation. Journal of Experimental Botany, 67(3), 567–591. https://doi.org/10.1093/jxb/erv490

Food and Agriculture Organization of the United Nations. (2024). FAO launches first major global assessment of salt-affected soils in 50 years. In the Food and Agriculture Organization of the United Nations. https://tinyurl.com/5fusdp9u

Harvey, F. (2024, December 11). Global food production at increased risk from excess salt in soil, UN report warns. The Guardian. https://tinyurl.com/mry9n7dx

Hayat, S., Hayat, Q., Alyemeni, M.N., Wani, A.S., Pichtel, J., & Ahmad, A. (2012). Role of proline under changing environments. Plant Signaling & Behavior, 7(11), 1456–1466. https://doi.org/10.4161/psb.21949

Henry, C., Bledsoe, S., Griffiths, C., Kollman, A., Paul, M., Sakr, S., & Lagrimini, L.M. (2015). Differential role for trehalose metabolism in Salt-Stressed Maize. PLANT PHYSIOLOGY, 169(2), 1072–1089. https://doi.org/10.1104/pp.15.00729

Institute of Environmental Science and Meteorology, University of the Philippines Diliman. (2020). Agricultural drought in the Philippines associated with the 2019 El Niño. Institute of Environmental Science and Meteorology, University of the Philippines Diliman. https://tinyurl.com/3yrmtt5h

Islam, M.S., Islam, M.R., Hasan, M.K., Hafeez, A.G., Chowdhury, M.K., Pramanik, M.H., Iqbal, M.A., Erman, M., Barutcular, C., Konuşkan, Ö., Dubey, A., Kumar, A., & Sabagh, A.E. (2024). Salinity stress in maize: Consequences, tolerance mechanisms, and management strategies. OBM Genetics, 08(02), 1–41. https://doi.org/10.21926/obm.genet.2402232

Lamaoui, M., Jemo, M., Datla, R., & Bekkaoui, F. (2018). Heat and drought stresses in crops and approaches for their mitigation. Frontiers in Chemistry, 6. https://doi.org/10.3389/fchem.2018.00026

Li, J., Zhao, M., Liu, L., Guo, X., Pei, Y., Wang, C., & Song, X. (2023). Exogenous sorbitol application confers drought tolerance to maize seedlings through up-regulating antioxidant system and endogenous sorbitol biosynthesis. Plants, 12(13), 2456. https://doi.org/10.3390/plants12132456

Lobell, D., Deines, J., & Di Tommaso, S. (2020). Changes in the drought sensitivity of US maize yields. Nature Food, 1(11), 729–735. https://doi.org/10.1038/s43016-020-00165-w

Lugojan, C., & Ciulca, S. (2011). Evaluation of relative water content in winter wheat. Journal of Horticulture, Forestry and Biotechnology, 15(2), 173–177. https://tinyurl.com/576bh4a9

Marschner, H. (1995). Mineral nutrition of higher plants. In Elsevier eBooks. https://doi.org/10.1016/b978-0-12-473542-2.x5000-7

Mogato, G.A.A. (2019). El Niño damage to agriculture now at P7.96 billion – DA. Rappler. https://tinyurl.com/mr2ns2nf

Naz, M., Akram, I., Saleem, M.A., Ilyas, Q., & Ilyas, N. (2022). Influences induced by salinity stress on germination, growth and proline contents of maize (Zea mays L.). https://tinyurl.com/ys2a2kx6

Ribba, T., Garrido-Vargas, F., & O'Brien, J.A. (2020). Auxin-mediated responses under salt stress: From developmental regulation to biotechnological applications. Journal of Experimental Botany, 71(13), 3843–3853. https://doi.org/10.1093/jxb/eraa241

Rizk, M., Assaha, D.V., Mekawy, A.M., Shalaby, N., Ramadan, E., El-Tahan, A., Ibrahim, O., Metwelly, H., Okla, M., Maridueña-Zavala, M.G., AbdElgawad, H., & Ueda, A. (2024). Comparative analysis of salinity tolerance mechanisms in two maize genotypes: Growth performance, ion regulation, and antioxidant responses. BMC Plant Biology, 24(1). https://doi.org/10.1186/s12870-024-05533-3

Sapes, G., & Sala, A. (2021). Relative water content consistently predicts drought mortality risk in seedling populations with different morphology, physiology, and times to death. Plant, Cell & Environment, 44(5), 1561–1574. https://doi.org/10.1111/pce.14149

Sumithra, K., Jutur, P.P., Carmel, B.D., & Reddy, A.R. (2006). Salinity-induced changes in two cultivars of *Vigna radiata*: Responses of antioxidative and proline metabolism. Plant Growth Regulation, 50(1), 11–22. https://doi.org/10.1007/s10725-006-9121-7

Uçarlı, C. (2021). Effects of salinity on seed germination and early seedling stage. IntechOpen. https://doi:10.5772/intechopen.93647