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# Germination and Seedling Growth of *Zea mays* L. as Affected by Different Concentrations of $Na_2so_4$ and $Cacl_2$

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### *Authors' contributions*

*This work was carried out in collaboration between both authors. Author OJI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OJI and OTA managed the analyses of the study. Author OTA managed the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** The study was carried out to investigate the effects of different concentrations of $Na_2SO_4$ and $CaCl_2$ on seed germination and seedling growth of *Zea mays*.

**Study Design:** The experiment was set up in a completely randomized design (CRD) with five replications.

**Place and Duration of the Study:** The study was conducted in botany laboratory at Department of Biological Sciences, Ondo State University of Science and Technology, Okitipupa, Ondo State, Nigeria, between September, 2016 and January, 2017.

**Methodology:** Seeds of the test crop were germinated on Whatman No. 1 filter paper, each with 10 ml of $CaCl_2$, $Na_2SO_4$, combinations of $Na_2SO_4$ and $CaCl_2$ salt solutions in different Petri dishes. The germination percentages, root length, shoot length, fresh and dry weights of the seedlings were determined according to conventional method.

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**Results:** The results showed that treatment with different salt solutions gave a significant ($P < 0.05$) inhibition in germination percentage and seedling growth. The germination and growth parameters decreased with increase in concentration of salt solutions. The test crop showed an increase in root length and shoot length when subjected to combinations of $Na_2SO_4$ and $CaCl_2$ compared to the $NaSO_4$ regime.

**Conclusion:** This study demonstrated that germination and seedling growth of salt treated *Zea mays* was significantly inhibited by $Na_2SO_4$ salinity stress. The inhibition of the germination and other growth parameters measured increased with increase in concentration of the salts.

*Keywords: Germination; salinity; seedling; Zea mays; salt solutions.*

## 1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the family of grass i.e. Poaceae. It is the third most important cereal crop after rice and wheat and is grown under a wide spectrum of soil and climatic conditions. Maize, which belongs to the plants with C4 metabolism, is also classified as moderately sensitive to salinity [1]. At present, about 20 % of the world's cultivated land and approximately half of all irrigated land and 2.1 % of the dry agriculture land is affected by salinity [2]. The increasing frequency of dry periods in many regions of the world and the problems associated with salinity in irrigated areas frequently result in the consecutive occurrence of drought and salinity on cultivated land [3]. In general, salt stress is directly related with drought stress due to the capacity of the dissolved solutes to retain water. The rapid increase in the world's population requires an expansion of crop areas to raise food production. Salinization is spreading more rapidly in irrigated lands because of inappropriate management of irrigation and drainage. Moreover, rain, cyclones and wind add NaCl to coastal agricultural lands [4]. Anthropogenically induced salinity occurs as a result of deforestation, use of chemicals, poor quality irrigation water and overgrazing [5]. As suggested by Souza et al. [6] a marked increase of germination inhibition is expected at higher NaCl concentrations in the substrate. Reduction in growth characters and yield are observed for maize grown under salinity [1].

Soil salinity in agriculture refers to the presence of high concentration of soluble salts in the soil moisture of the root zone. The most widely accepted definition of a saline soil has been adopted from FAO [7] as one that has an ECc of 4 dS m-1 or more and soils with ECc's exceeding 15 dS m-1 are considered strongly saline. Concentrations of soluble salts through their high osmotic pressures affect plant growth by restricting the uptake of water by the roots [8]. Although more frequent in arid lands, salt-affected soils are also present in areas where salinity is caused by poor quality of irrigation water and excessive fertilizer application. Saline soil induces physiological and metabolic disturbances in plants, affecting development, growth, yield, and quality of plants [9].

Hasegawa et al. [10] stated that when plants are challenged with salinity stress, an increase in the concentration of $Ca^{2+}$ often can ameliorate the inhibitory effects on growth. Salinity results in a reduction of $K^+$ and $Ca^{2+}$ content and an increased level of $Na^+$, $Cl^-$ and $SO_4^{2-}$, which forms its ionic effects [11]. A saline soil is usually the reservoir of a number of soluble salts such as $Ca_2^+$, $Mg_2^{+,}$ $Na^+$ and anions $SO4_2^-$ $Cl^-$, $HCO_3^-$ with exceptional amounts of $K^+$, $CO_3^{2-}$, and $NO_3^-$ [12].

Calcium is an essential nutrient for the growth and development of plants and it plays a fundamental role as a second messenger in many signal transduction pathways within the cell [13,14]. In addition, $Ca^{2+}$ helps in maintaining the integrity and structure of the membranes and cell wall, and its displacement by Na+ may occur in saline conditions, leading to altered plasma membrane integrity and to the leakage of intracellular solutes [15]. Salinity on plants might be alleviated by the addition of supplemental $Ca^{2+}$ in the growth medium. This is due, in part, to the ability of $Ca^{2+}$ in decreasing the influx of $Na^+$ and the efflux of $K^+$ through the inhibition of non-selective cations and outward rectifying $K^+$ channels, respectively [16]. In addition, $Ca^{2+}$ appears to alter root lipid composition [17] and to induce organic solute accumulation, such as proline and glycinebetaine [18] in salt-stressed plants. The objective of the study was to investigate the effects of different concentrations of $Na_2SO_4$ and $CaCl_2$ on seed germination and seedling growth of *Zea mays*.

## 2. MATERIALS AND METHODS

This study was conducted in botany laboratory at biological sciences department of Ondo State University of Science and Technology Okitipupa, Ondo State, Nigeria. The seeds of *Z. mays* were collected from IITA (International Institute of Tropical Agriculture) Ibadan. The experimental treatments consisted of different salinity levels (90 mM, 130 mM, 170 mM $CaCl_2$; 90 mM, 130 mM, 170 mM $Na_2SO_4$; mixtures of $CaCl_2$ and $Na_2SO_4$; control). The experiment was set up in a completely randomized design (CRD) with five replications.

The seeds of the test crop were selected randomly on the basis of uniformity of size and the seed were then soaked for five minutes separately in 5% sodium hypochlorite to prevent fungal infection. Thereafter, they were rinsed for about five minutes in running water. Ten of these seeds were placed in each of the clean oven dried Petri-dish which had been lined with a Whatman No 1 filter paper. The filter paper in each of the Petri-dishes allocated to the control was moistened with 10 ml of distilled water while that of the Petri-dishes allocated to the other treatments were moistened with 10 ml of the different concentrations of the salt solution.

The germination percentage, shoot length, root length, seedling fresh and dry weight of each plant were determined. Statistical analysis was performed using ANOVA ($P< 0.05$). Based on the ANOVA results, a Duncan's Multiple Range Test (DMRT) was performed, to test for significant differences among means.

## 3. RESULTS AND DISCUSSION

Seed germination of *Zea mays* was significantly affected by the salt solution. The control had the highest germination (100%) followed by that of 170 mM $Na_2SO_4$ + $CaCl_2$ (93%). On the other hand, the lowest seed germinations (60% and 63%) were found with the highest level of salinity used in the study i.e., 170 mM $Na_2SO_4$ and 170 mM $CaCl_2$ respectively (Table 1). The results also showed that germination of seeds significantly decrease with increase of each level of the salts. This finding was similar to the study of Radic et al. [19] who found the significant decrease in germinability at higher salinity levels. The reduction of seed germination could be as a result of the decrease of the water movement into the seeds during imbibitions. According to Ashraf et al. [20] plants take up high amounts of $Na^+$ while uptake of $K^+$ and $Ca^{2+}$ are significantly reduced under excessive saline conditions. These could lead to nutritional imbalance and ion toxicity which could be responsible for the reduction in the growth of the test crop by the application of the salt solutions.

The effect of $Na_2SO_4$ on the germination, root length and shoot length of the test crop was reduced by addition of $CaCl_2$ (Tables 3, 4, 5 and 6). For most plant species, supplemental $Ca^{2+}$ can reverse the adverse effects of salinity on growth and membrane permeability [21]. It is well known that $Ca^{2+}$ alleviates the adverse effects of salinity on many plant species [15]. Calcium alleviated the toxic effects of $Na^+$ and $Mg^{2+}$ on the germination of *Kalidium capsicum* [22,23] and *Hordeum vulgare* L. [24]. Tobe et al. [25] showed that $Ca^{2+}$ successfully alleviated the toxicity of various chloride and sulfate salts on the germination of *Kalidium capsicum*.

The control had the longest root (7.73 cm) which was statistically different from other treatments. The shortest root (0.87 cm) was determined 170 mM $Na_2SO_4$ whereas the root length in the 130 mM $CaCl_2$ treatment was 2.04 cm (Tables 1 and 2). The root length significantly decreased with the increasing salinity stress level (Table 1).

**Table 1. Effect of different concentrations of $Na_2SO_4$ on germination, growth and biomass accumulation of *Zea mays* L.**

| Treatments | % germination | Root length (cm) | Shoot length (cm) | Fresh weight (g) | Dry weight (g) |
|---|---|---|---|---|---|
| Control | 100±2.60a | 7.73±1.99a | 6.40±1.36a | 0.68±0.06a | 0.25±0.14ab |
| $Na_2SO4$ (90 mM) | 92±0.50a | 2.38±0.38b | 2.08±0.32b | 0.40±0.05b | 0.22±0.02b |
| $Na_2SO_4$ (130 mM) | 64±0.50b | 1.70±0.53b | 0.83±0.33c | 0.43±0.12b | 0.27±0.07a |
| $Na_2SO_4$ (170 mM) | 60±0.37b | 0.87±0.21b | 1.00±0.30c | 0.40±0.11b | 0.23±0.06b |

*Means followed by the same letters along the column are not significantly different according to Duncan test at 5% level; ± SE (Standard error)*

**Table 2. Effect of different concentrations of $CaCl_2$ on germination, growth and biomass accumulation of *Zea mays* L.**

| Treatments | % germination | Root length (cm) | Shoot length (cm) | Fresh weight (g) | Dry weight (g) |
|---|---|---|---|---|---|
| Control | 100±2.60a | 7.73±1.99a | 6.40±1.36a | 0.68±0.06a | 0.25±0.14b |
| CaCl2 (90 mM) | 88±.31b | 4.40±0.93b | 4.13±0.83b | 0.60±0.13a | 0.28±0.07b |
| CaCl2 (130 mM) | 92±0.63ab | 2.04±0.31b | 3.68±0.38c | 0.66±0.04a | 0.36±0.05a |
| CaCl2 (170 mM) | 63±0.31c | 2.8±0.76b | 2.53±0.68d | 0.40±0.10b | 0.27±0.07b |

*Means followed by the same letters along the column are not significantly different according to Duncan test at 5% level; ± SE (Standard error)*

**Table 3. Effect of combinations of $Na_2SO_4$ and $CaCl_2$ on germination, growth and biomass accumulation of *Zea mays* L.**

| Treatments | % germination | Root length (cm) | Shoot length (cm) | Fresh weight (g) | Dry weight (g) |
|---|---|---|---|---|---|
| Control | 100±2.60a | 7.73±1.99a | 6.40±1.36a | 0.68±0.06a | 0.25±0.14a |
| Na2SO4+ CaCl2 (90 mM) | 68±0.31b | 7.73±1.10a | 4.10±0.91b | 0.50±0.11b | 0.27±0.06a |
| Na2SO4+ CaCl2 (130 mM) | 61±0.37c | 4.4±0.38b | 3.67±0.34c | 0.40±0.05b | 0.20±0.05a |
| Na2SO4+ CaCl2 (170 mM) | 93±1.00a | 2.9±0.50c | 2.76±0.51d | 0.44±0.05b | 0.26±0.05a |

*Means followed by the same letters along the column are not significantly different according to Duncan test at 5% level± SE (Standard error)*

**Table 4. Effect of different concentrations of $Na_2SO_4$, $CaCl_2$ and $Na_2SO_4$ - $CaCl_2$ combinations on germination of *Zea mays* L.**

| | % Germination | | | Mean |
|---|---|---|---|---|
| Treatments | $Na_2SO_4$ | CaCl2 | $Na_2SO_4$+ CaCl2 | |
| Control | 100±2.60a | 100±2.60a | 100±2.60a | 100 ±2.60a |
| 90 mM | 92±0.50a | 88±.31b | 68±0.31c | 82.66 ± 1.14b |
| 130 mM | 64±0.50b | 92±0.63 a | 61±0.37c | 72.33 ±1.41c |
| 170 mM | 60±0.37c | 63±0.31b | 93±1.00a | 72.00 ± 1.78c |
| Mean | 79 ±1.30b | 86 ±1.00a | 81 ±0.44b | |

*Means followed by the same letters across the rows are not significantly different according to Duncan test at 5% level ± SE (Standard error)*

**Table 5. Effect of $Na_2SO_4$, $CaCl_2$ and $Na_2SO_4$ - $CaCl_2$ combinations on root length of *Zea mays* L.**

| | Root length | | | Mean |
|---|---|---|---|---|
| Treatments | $Na_2SO_4$ | CaCl2 | $Na_2SO_4$+ CaCl2 | |
| Control | 7.73±1.99a | 7.73±1.99a | 7.73±1.99a | 7.73 ± 1.99a |
| 90 mM | 2.38±0.38c | 4.40±0.93b | 7.73±1.10a | 4.84 ±0.33 b |
| 130 mM | 1.70±0.53c | 2.04±0.31b | 4.40±0.38a | 2.71 ± 0.10c |
| 170 mM | 0.87±0.21c | 2.80±0.76b | 2.90±0.50a | 2.19 ± 0.13c |
| Mean | 3.17 ±0.11 c | 4.24 ±0.17 b | 5.69 ± 0.29a | |

*Means followed by the same letters across the rows are not significantly different according to Duncan test at 5% level ± SE (Standard error)*

Bakht et al. [26] also found significant variation in root length of maize seedling due to salinity effect. The results suggested that increasing salinity level had a negative effect on the root length. The shoot length of the test crop was reduced by the application of $Na_2SO_4$ and $CaCl_2$.

**Table 6. Effect of $Na_2SO_4$, $CaCl_2$ and $Na_2SO_4$ – $CaCl_2$ combinations on shoot length of *Zea mays* L.**

| | Shoot length | | | Mean |
|---|---|---|---|---|
| **Treatments** | **$Na_2SO_4$** | **CaCl2** | **$Na_2SO_4$+ CaCl2** | |
| Control | 6.40±1.36a | 6.40±1.36a | 6.40±1.36a | 6.40±1.36 a |
| 90 mM | 2.08±0.32c | 4.13±0.83a | 4.10±0.91b | 3.44 ± 0.01b |
| 130 mM | 0.83±0.33b | 3.68±0.38a | 3.67±0.34a | 2.72±0.03 c |
| 170 mM | 1.00±0.30c | 2.53±0.68b | 2.76±0.51a | 2.10 ±0.15 d |
| Mean | 2.58 ±0.16 b | 4.19 ± 0.02a | 4.23 ±0.04 a | |

*Means followed by the same letters across the rows are not significantly different according to Duncan test at 5% level ± SE (Standard error)*

The length of the shoot was longest (6.40 cm) in the control. Also, the shortest shoot length (0.83 cm) was determined in 130 mM $Na_2SO_4$ (Table 1). This was consistent with the work of Akram et al. [27] who reported considerable variations in the root, shoot length and biomass of different maize hybrids at different salinity levels. Similarly, Radic et al. [19] reported that the shoot length of maize seedling was significantly reduced by salinity.

## 4. CONCLUSION

This study demonstrated that germination and seedling growth of salt treated *Zea mays* was significantly inhibited by salinity stress. The inhibition of the germination and other growth parameters measured increased with increase in concentration of the salts. Therefore, the salt has direct harmful effects on the germination and seedling growth *Zea mays.* These findings confirm that *Z. mays* growth is responsive to $CaCl_2$ as the salt can alleviate $Na^+$ toxicity.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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