



Salinity Stress Effect on the Germination of Three Cereals: Maize (*Zea mays*), Millet (*Pennisetum glaucum*) and Rice (*Oriza sativa*)

Sanogo Souleymane^{1*}, Camara Brahima¹, Kone Tchoa², Tuo Seydou¹, Kamara Adjata¹, Kone Daouda¹ and Zouzou Michel¹

¹*UFR Biosciences, Laboratoire de Physiologie Végétale, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire.*

²*Unité de Formation et de Recherche Sciences de la Nature, Laboratoire de Biologie et Amélioration des Productions Végétales, Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.*

Authors' contributions

This work was done in collaboration among all the four authors. Author SS designed the study, performed the analysis and wrote the first draft of the manuscript. Authors CB, KT and TS supervised the study and analysed the data. All the authors managed the literature search writing of the final manuscript, All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2020/v32i430273

Editor(s):

(1) Dr. Abigail Ogbonna, University of Jos, Nigeria.

Reviewers:

(1) Badar-uz-Zaman, National Agriculture Research Centre, Pakistan.

(2) Aparecida Leonir da Silva, Universidade de São Paulo, Brazil.

(3) ABA-Toumou Lucie, University of Bangui, Central African Republic.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/55629>

Received 20 January 2020

Accepted 26 March 2020

Published 13 May 2020

Review Article

ABSTRACT

In Africa, cereals are major staple foods for the majority of the population. The cereal crop is not immune to the problem of salinity, which could threaten 10% of its world harvest. This work was undertaken to study the comparative effect of salinity on germination of three cereals, maize (*Zea mays*), millet (*Pennisetum glaucum*) and rice (*Oriza sativa*). The seeds were germinated in Petri dishes containing a range of NaCl solution (0 g/l, 5 g/l, 10 g/l, 15 g/l and 25 g/l) in the dark and at room temperature. The harmful effect of salt varies depending on the concentration of NaCl and the type of cereal. It is low on the germination rate of seeds up to a concentration of 10 g/l NaCl. From this dose onwards, this rate is reduced by 44% for millet, 20% for rice and 10% for maize. The average germination time between 0 g/l and 10 g/l NaCl is low and increases strongly between 10

*Corresponding author: E-mail: sanogosousa@yahoo.fr;

g/l and 15 g/l and reaches 37 days (millet) and 20 days (rice). Corn root growth is less affected by salinity (1.2 cm) at 15 g/l NaCl compared to more sensitive rice and millet (0 cm). The height of the epicotyl between 0 g/l and 25 g/l NaCl increased from 11.8 to 3.6 cm (corn), from 0.5 to 0 cm (rice) and from 4.3 to 0.3 cm (millet). The combination of the parameters studied shows that all three cereals are able to tolerate NaCl concentrations of 10 g/l. Rice is the most sensitive to salinity while maize is more tolerant than millet.

Keywords: Concentration; cereals; NaCl; salinity.

1. INTRODUCTION

Salinization is an important process of soil degradation. It can be natural or induced by agricultural activities such as irrigation [1] or the use of certain types of fertilizers [2,3]. It poses a real threat to global food security because it lowers crop yields and can cause irreparable land degradation. Indeed, every minute, three hectares of arable land are deteriorated in an often irreversible manner due to soil salinization [4]. This phenomenon is increasing rapidly worldwide and affects one-fifth of irrigated land. Moreover, in the space of two decades, the total area of irrigated land damaged by salt has increased from 40 million hectares to more than 62 million hectares [4]. Today, 20% of irrigated land is now producing less because of salt. Productivity losses vary by region from 15 to 70 per cent [4]. At the economic level, these losses in productivity and yield from degraded soils have been estimated at \$23.7 billion per year [4]. Soil salinity is one of the main abiotic stresses limiting crop growth [5].

Faced with this situation, some agronomists advocate the use of plant technologies. First by selecting better adapted varieties. The response of plant species to salt depends on several variables such as salt concentration, species, variety, but also on growing conditions and the stage of development of the plant [6]. Knowledge of the tolerance to salinity at the time of germination reveals a good tolerance of the species to salinity [7]. Cereals are by far the world's most important food resource for both human consumption and livestock feed [8]. In Africa, cereals such as sorghum, millet, wheat, maize and rice are major staple foods for the majority of the population [9]–10% of the world's cereal harvest is threatened by salinity [10]. The search for cereals that behave satisfactorily on saline soils would make it possible to extend their cultivation and to identify tolerance factors with regard to this constraint.

The present study is part of the improvement studies on cereal crops grown in Côte d'Ivoire. It

aims to determine the effects of sodium chloride (NaCl) on the germination of three cereals (maize, millet and rice). The germination tests were carried out under different concentrations of NaCl.

2. MATERIALS AND METHODS

2.1 Plant Material

This study focused on three cereals: maize (*Zea mays*), millet (*Pennisetum glaucum*) and rice (*Oriza sativa*) commonly used in Côte d'Ivoire.

2.2 Experimental Design

The purpose of this work was to determine the effects of different concentrations of sodium chloride (NaCl) on seed germination in the three cereals. For each cereal, 200 seeds were disinfected by washing with sodium hypochlorite (bleach) for 3 min and then rinsed thoroughly with distilled water to remove the bleach [11]. The seeds were germinated in Petri dishes lined with filter paper soaked with 10 mL of various solutions. For the control (T0) distilled water was added and for the treatments different concentrations of NaCl solution were used: T1: 5 g/l, T2: 10 g/l, T3: 15 g/l and T4: 25 g/l. The cans–Petri dishes were placed in the dark in an incubator set at a temperature of 25°C. Germination is indicated by the exit of the radicle from the seed coat which is at least 2 mm long. For the test, there were four replicates and five treatments. 20 Petri dishes containing 10 seeds each were prepared, 40 seeds for each treatment. Watering and measurements were carried out daily until the sixth day after sowing.

2.3 Data Collection

2.3.1 Final germination rate (FGR)

Final germination rate presents the physiological limit of seed germination. It is expressed according to the formula below:[12]

$$FGR = \frac{\text{Number of seeds germinated}}{\text{Total number of seed}} \quad [12]$$

2.3.2 Germination kinetics

Kinetic of germination represents the number of seeds germinated daily until the 8th day of the experiment [13].

2.3.3 Germination rate

The germination rate can be expressed by the average germination time (T50) (the time at which 50% of the germinated seeds is reached) Median time (T50) = $T1 + (0.5 - G1 / G2 - G1) \times (T2 - T1)$ [12].

With: G1 = cumulative percentage of germinated seeds whose value is closest to 50% by lower value.

G2 = Cumulative percentage of germinated seeds which is closest to 50% of the highest value.

2.3.4 Mean daily germination or MDG (Mean Daily Germination)

According to Osborne et al [14],

$$MDG = \frac{\text{Percentage of final germination}}{\text{Number of days to final germination}}$$

2.3.5 Lengths of root and epicotyl

The length of the primary root and the length of the epicotyl were measured using a graduated ruler.

2.4 Statistical Analysis

The data were processed using STATISTICA 7.0 software. The analysis of variance was performed by the File test at $\alpha = 5\%$ using Excel 2010 and the means were compared using the Newman and Keuls method.

3. RESULTS

3.1 Salinity Effect on the Final Rate and Germination Kinetics

3.1.1 Germination rate

The results show that germination rates of cereal seeds decrease as the NaCl concentration increases (Fig. 1). Germination rates were higher with the control (0 g/l NaCl) for all cereals, 100% for maize, 70% for millet and 37% for rice. Rates were lower at the maximum concentration of 25

g/l NaCl with 33% for maize, 23% for millet and 0% for rice. Moreover, maize seeds germinated more (between 33% and 100%) than rice seeds with the lowest proportions (between 0% and 37%) for all treatments. In addition, the depressant effect of salinisation is weak on seed germination up to a concentration of 10 g/l of NaCl. From this dose onwards, the reduction in germination rate is greater for millet 44% followed by rice 20% compared to 10% for maize.

3.1.2 Effect of salinity on germination kinetics

Fig. 2 shows the germination evolution of three cereals as a function of time for four concentrations of NaCl. The germination curves show three phases:

- a latency phase, during which the germination rate remains low. The duration of this phase varies according to the NaCl concentration. It is nil for maize and millet whatever the NaCl concentration. This latency phase is longer with rice (at least two days).

- a substantially linear phase, corresponding to a rapid increase in the germination rate which evolves in proportion to time. This phase is more marked between the first and second day and with treatments of 0 and 15 g/l of NaCl. It is lower for millet and accelerated with maize;

- a third phase corresponding to a stage representing the final percentage of germination and reflecting the germination capacity of the cereals and for each concentration.

The germination rate of the cereals decreases as the NaCl concentration increases. Germination kinetics shows that an increasing salt concentration causes a delay in germination. (Fig. 2).

3.2 Effect of Salinity on Germination Rate and Average Daily Germination Rate

3.2.1 Effect of salinity on average germination time (T 50) or germination speed

Examination of the results in Fig. 3 shows that between 0 g/l and 10 g/l of NaCl, the average germination time (T50) is low (between 1 and 5 days), but increases slightly for maize (1 day at 0 g/l and 2 days at 10 g/l) but decreases for rice (5 days at 0 g/l and 3 days at 10 g/l). In addition, the T50 for rice was higher than for other cereals. At salt concentrations between 10 and 15 g/l, the

average germination time increased sharply for millet (37 days) and rice (20 days). The variation in germination rate in maize was small despite the application of high doses of NaCl. A decrease in T50 was noted from the 25 g/l concentration for rice and millet (Fig. 3).

3.2.2 Effects of salinity on the average daily germination rate (ADG)

The results showed that the daily germination averages decreased with increasing NaCl

concentration for all cereals. Germination rates were higher with the control (0 g/l NaCl) for all cereals: 35% for maize, 17% for millet and 7% for rice. Levels were lower at the maximum concentration of 25 g/l NaCl with 10% for maize, 0% for millet and 0% for rice. However, the highest levels were recorded with maize (35%) while rice levels remained below 10% (Fig. 4). On the other hand, the decrease of the MDG according to NaCl concentrations is lower for maize with 10% than for millet and rice with 0% to 25 g/l NaCl (Fig. 4).

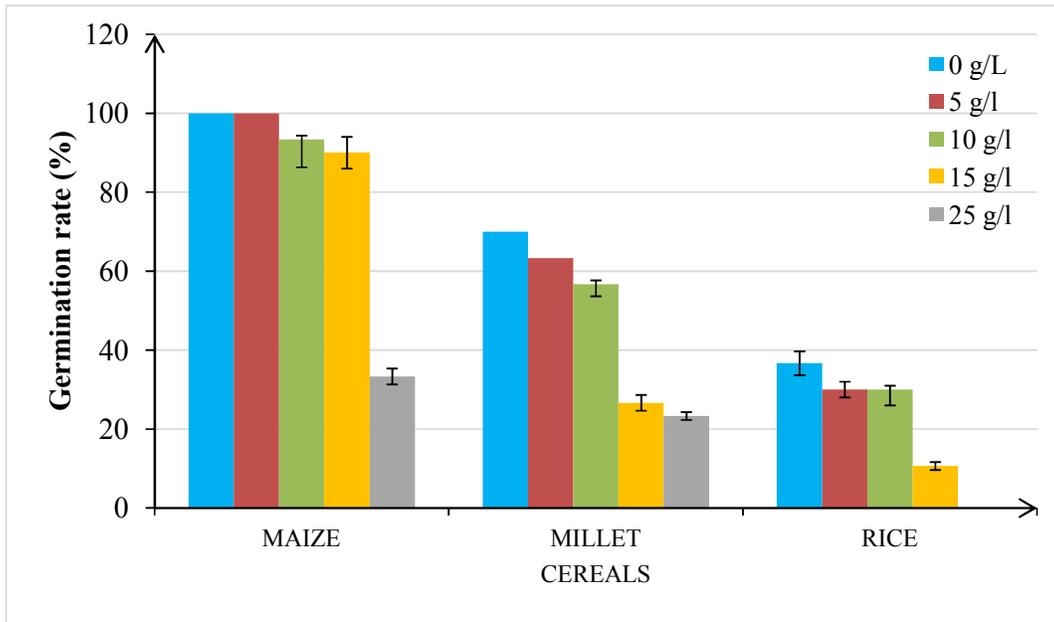
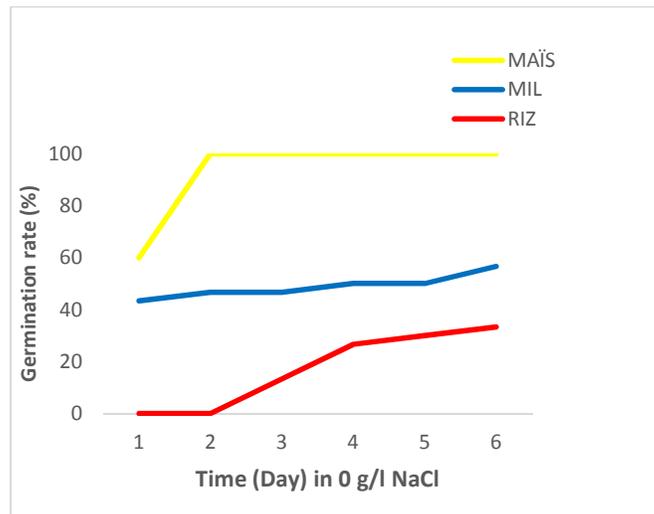


Fig. 1. Variation of the germination rate, of the different cereals seeds, according to the concentration of NaCl



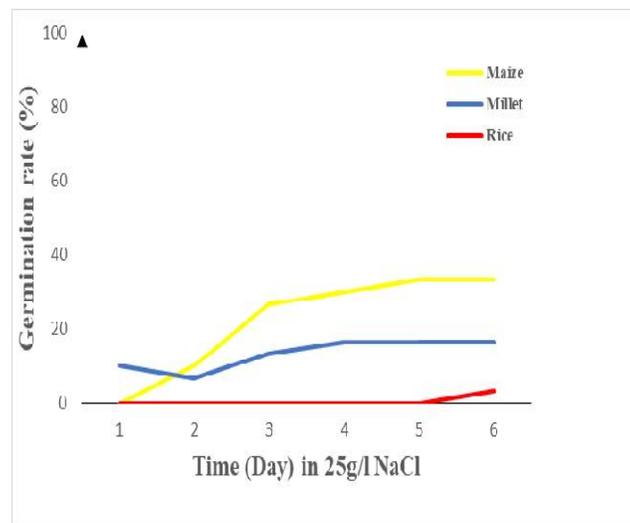
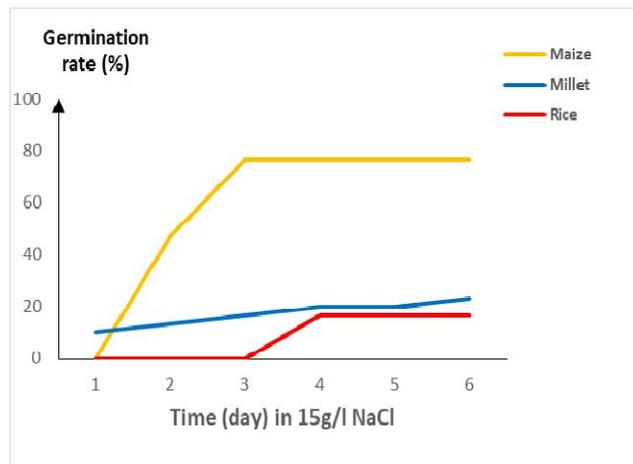
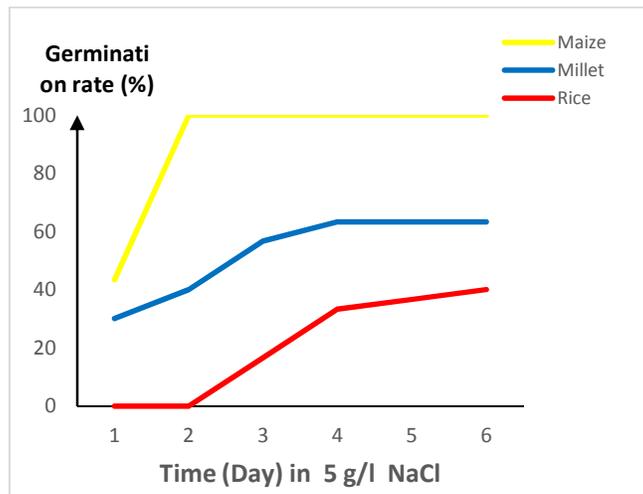


Fig. 2. Effects of different concentrations of NaCl on the kinetics of germination of maize, millet and rice

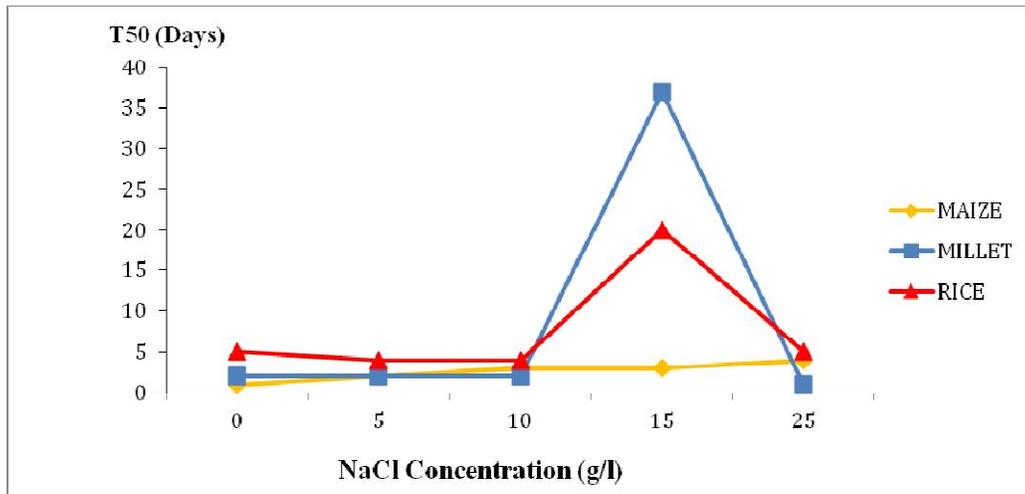


Fig. 3. Effects of different concentrations of NaCl on mean germination time T50 of grains of maize, millet and rice

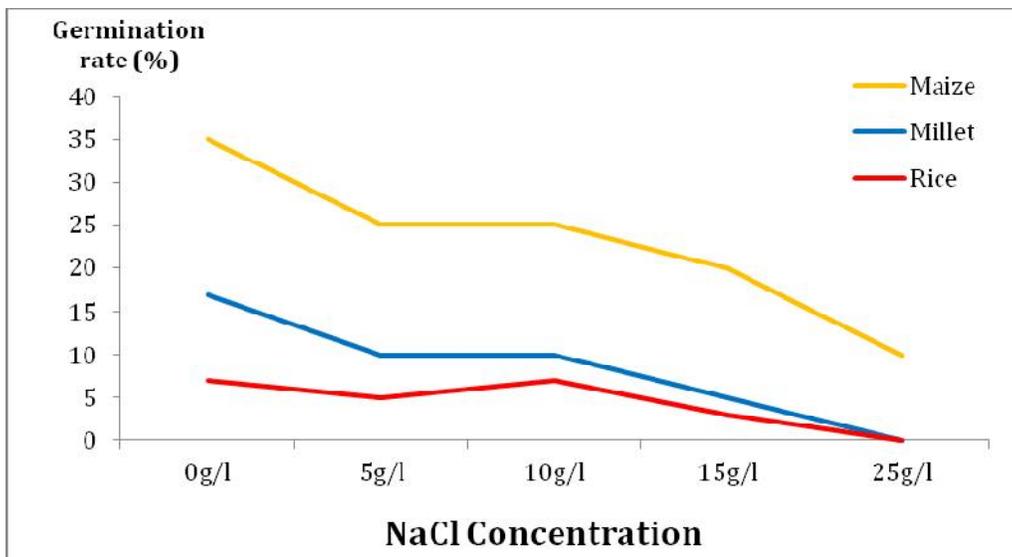


Fig. 4. Effects of different concentrations of NaCl on the daily average germination of of maize, millet and rice

3.3 Effect of Salinity on Root and Epicotyl Length

3.3.1 Effects on root growth

The results of the study of the root system of seeds subjected to different concentrations of NaCl are shown in Fig. 5. Root length decreased with increasing NaCl concentration. In addition, the depressant effect of salinity on root development was not the same for all cereals. Indeed, the longest root was 8.9 cm and obtained with maize on salt-free medium

(control), it decreased in the presence of NaCl to reach a value of 3.6 cm per 10 g/l NaCl and 1.2 cm per 25 g/l NaCl (maximum dose). For millet, root length decreased from 7.4 cm (0 g/l NaCl) to 3.7 cm per 10 g/l NaCl and 0 cm per 15 g/l NaCl. The shortest route lengths were for rice with 3.7 cm (0 g/l NaCl), 0.3 cm (10 g/l NaCl) and then 0 cm per 15 g/l NaCl (Fig. 5).

3.3.2 Effects on epicotyl growth

Salt affected the growth of epicotyl. Height was higher for corn followed by millet regardless of

treatment. The length of the epicotyl was reduced as the NaCl concentration increased. The reduction was greatest with maize (11.8 to 4.3 cm) and rice (0.5 to 0 cm) between the salt-free control and the 15 g/l dose of NaCl. The

variation was small with millet (4.3 to 1.8 cm). However, maize showed an epicotyl height of 3.5 cm at the maximum salt concentration of 25 g/l compared to 0.3 cm for millet and 0 cm for rice (Fig. 6).

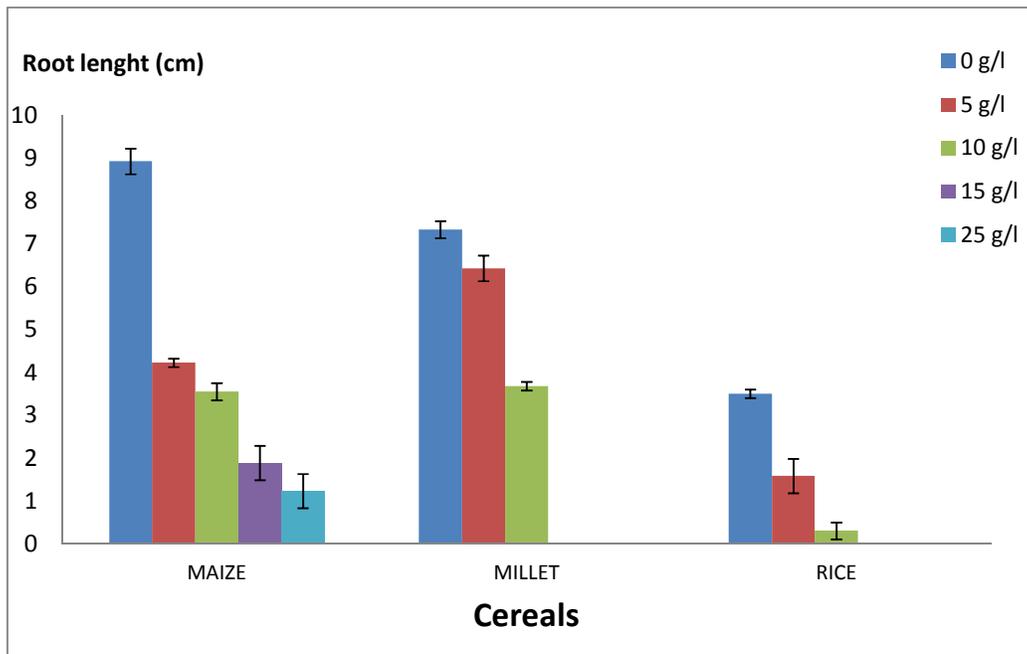


Fig. 5. Variation of t length of root of maize, millet and rice as a function of NaCl concentrations

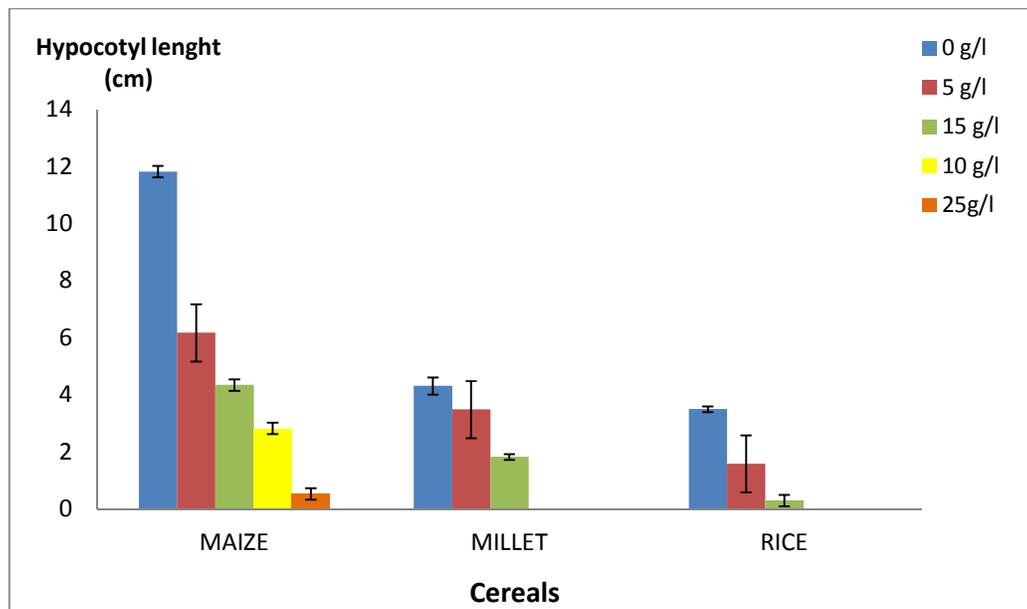


Fig. 6. Variation of length of epicotyl of of maize, millet and rice as a function of different NaCl concentrations

4. DISCUSSION

The study of the effect of salinity on the germination of three cereals was based on the analysis of a number of parameters.

4.1 Final Germination Rate

The results show that germination rates of cereal seeds decrease as the NaCl concentration increases. On the other hand, germination rates were higher for maize than for rice with the lowest proportions for all treatments. In addition, the depressant effect of salinisation affects cereal seed germination less than from a concentration of 10 g/l of NaCl. The higher NaCl contents affect less the germination of maize with a rate of 33% at the maximum concentration of 25 g/l of NaCl, a medium that did not allow the seeds of rice and millet to germinate. These results attest to the depressing effect of salinity on seed germination and are consistent with those of Ben et al. [15]; Rachidai et al. [16] who worked on wheat and Camara et al. [11] on legumes.

4.2 Germination Kinetics

Increasing concentrations of NaCl slow the germination of seeds in the cereals tested. High salt levels had less impact on the germination kinetics of millet than other cereals. Rice is more sensitive to salinity, which slows down seed germination. Salt has a depressant effect on the mobilization of seed reserves, which delays germination. These results are comparable to those reported by Taffouo et al. [17] and Benidire et al. [18] who worked on legumes.

4.3 Germination Rate and Average Daily Germination Rate

The results show that for all cereals tested, the average daily germination rate as well as the germination speed decreases with increasing salinity. However, maize seeds had the highest rates of these parameters. The decrease in the average daily germination rate is explained by the low energy required to use the seed's reserves. Indeed, high doses of NaCl cause a reduction in the availability of water in the medium, which can delay or prevent the absorption of water necessary to trigger the enzymatic reactivations that mobilize the reserves for germination [19, 20].

4.4 Variation in Root and Epicotyl Lengths

4.4.1 Root length

Salt affects root development. The length of the roots is reduced as the salt concentration increases. The depressive effect of salt is more marked at a concentration of 15 g/l for all cereals, which, however, do not show the same response to the salt doses applied. An absence of root growth (0 cm) is noted for rice and millet at 15 g/l of NaCl, unlike maize, which is less sensitive to this salt concentration with a length of 1.2 cm. Salinity slows down and even inhibits root growth. These results are in line with those of Saadallah et al. [21] who observed in beans a fall in root growth associated with an increase in the nodule number/root dry matter unit ratio. Allah [22] and Mallek-Maalej et al. [23] demonstrated the depressing effect of salt on the development of tomato and cultivated cereal seed germination, respectively. According to Benidire et al. [18], high salinity concentrations have a negative effect on the length growth of seedlings and reduce both the size and density of absorbent hairs. Salinity modifies the anatomical structure of the root and leads to a decrease in the number of cells per xylem cluster and the number of cortical parenchyma layers [18].

4.4.2 Length of the epicotyls

Epicotyl length is higher for corn followed by millet regardless of treatment. The development of epicotyl is reduced with the addition of NaCl and this reduction was even more important with the high salt concentration. Furthermore, the adverse effect of salinity is more significant at a dose of 15 g/l of NaCl. Thus, the growth of epicotyl is nil for rice, while the reduction is more than half for maize and millet. Bouda and Haddioui [24] state that the effect of NaCl on germination varies with the species, as the final germination rate and seedling growth differ significantly between the species studied. Rice is the most sensitive of the cereals tested to excess salt. These results could be explained by the small size of rice roots. Plant growth depends on several factors, including the availability of water and nutrients absorbed by the roots. Under the effect of salt, the absorption capacity of these roots is reduced, resulting in a reduction in the growth of young plants. Other studies on wheat and barley by Termaat et al. [25] revealed that

the reduction in growth of aerial organs is thought to be due to salinity on the production of root growth regulators, such as abscisic acid and cytokinins. However, maize has an epicotyl height of 3.5 cm at the maximum salt concentration of 25 g/l compared with 0.3 cm for millet. Maize grows under conditions of high salt content and is more tolerant to salinity than the other cereals tested. It has been established that the tolerance of cereals to salt stress varies significantly with genotype, stage of development, duration of exposure and severity of stress [26,27]. Similarly, El Mekkaoui [28,29] showed in eleven varieties of durum wheat that a concentration of 100 mM NaCl is sufficient to detect differences in tolerance. In bean varieties subjected to different salt concentrations, Benidire et al. [18] found varieties that were more tolerant to saline stress.

5. CONCLUSION

This analysis shows that salinity reduces the germination rate and growth of all three cereals. The depressant effect of salt also depends on the concentration and type of grain. The concentration of 10 g/l of NaCl was found to be the tolerance threshold. Maize is more tolerant, whereas rice is the most sensitive to salinity. These experiments should be continued to confirm these results obtained at the germination and seedling stages.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Mouhouche B, Boulassel A. Contribution to better control of irrigation water losses and salinization of soils in arid zones. *Agronomic research - INRA (Algeria)*. 1999; 4:15-23. French
- Bartels D, Nelson DE. Approaches to improve stress tolerance using molecular genetics. *Plant Cell Environ*. 1994;17:659-667.
- Quadir M, Coster JD. Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agricultures. *Science of the Total Environment*. 2004;323:1-19.
- Anonymous. Soil salinization is a real threat to global food security. [Accessed 5/11/11/2019] Available: <https://www.agrimaroc.ma/salinisation-sols-vraie-menace/>. French
- Munns R, Testy M. Mechanism of salinity tolerance. *Ann. Rev. Plant Biol*. 2008;59: 651-681.
- Bartels D, Sunkar R. Drought and salt tolerance in plants. *Crit. Rev. Plant Sci*. 2005;24:23-58.
- Jaouadi B, Abdelmalek B, Fodil D, Ferradji FZ, Rekik H. Purification and characterization of a thermostable keratinolytic serine alkaline proteinase from *Streptomyces* sp. strain AB1 with high stability in organic solvents. *Bioresour Technol*. 2010;101:8361-8369.
- Diouf J. Cereals, a major challenge for food security; 2019. [Accessed 12/10/2019] Available: <https://www.latribune.fr/opinions/20090610trib000386196/les-cereales-major-issue-of-food-safety.html>. French
- Harold M, Tabo R. Cereal crops: Rice, maize, millet, sorghum and wheat Africa Rice Center, Benin. 2015;1:38. French
- FAO, 2002. Salt in the earth: A danger for food production. [Accessed 5/11/2019] Available: <http://www.fao.org/worldfoodsumm/french/newsroom/focus/focus1>
- Camara B, Sanogo S, Chérif M, Tuo S, Koné N, M'bo K, Koné D. Effect of saline stress on seed germination of three leguminous species (*Phaseolus vulgaris* L., *Glycine max* L., and *Vigna unguiculate* L.). *Asian Journal of Advances in Agricultural Research*. 2018;8(1):1-8.
- Como D. Obstacles to Germination. *Plant Physiology Monographs*. Paris, Masson and Cie. 1970;1:62. French
- Hajlaoui H, Denden M, Bouslama M. Study of the intraspecific variability of tolerance to salt stress of chickpea (*Cicer arietinum* L.) at the germination stage. *Tropicultura*. 2007;25(3):168-173. French
- Osborne JM, Fox JED, Mercer S. Germination response under elevated salinities of six semi-arid blue bush species (Western Australia). In: Lieth H. & Al Masoom A. (Eds), *Towards the Rational Use of High Salinity Plants*. 1993;1:323-338.
- Ben Naceur M, Rahmoune C, Sdiri H, Meddahi ML, Selmi M. Effect of salt stress on the germination, growth and grain production of some Maghrebian varieties of wheat. *Science, Planetary Changes and Drought*. 2001;12:167-174. French

16. Rachidai A, Driouich A, Ouassou A, El Hadrami I. Effect of salt stress on the germination of durum wheat (*Triticum durum* Desf). *Rev. Improved. Prod. Agr.* 1994;6:209-228. French
17. Taffouo VD, Kenne M, Fokam TR, Fotso WO, Fonkou T, Mvondo Z, Amougou A. Variation in the response to salt stress in five legume species. *African Agronomy.* 2004;16(1):33-44. French
18. Benidire K, Daoui Z, Fatemi A, Achouak W, Bouarab L, Oufdou K. Effect of salt stress on the germination and development of seedlings of *Vicia faba* L. *J. Mater. About. Sci.* 2015;6(3):840-851. French
19. Levigneron A, Lopez F, Vansuyt G, Berthmieu P, Fourcroy P. Plants face salt stress. *Agricultures Notebooks.* 1995;4(4): 263-273. French
20. Niu X, Bressan RA, Hasegawa PM, Pardo JM. Ion homeostasis in NaCl stress environments. *Plant Physiol.* 1995;109(3): 735-742.
21. Saadallah K, Drevon JJ, Abdelly C. Nodulation and nodular growth in beans (*Phaseolus vulgaris*) under saline stress, *Agronomy.* 2001;21:627-634. French
22. Allah CR. Grown tomato under saline conditions. In: Allah C. R., ed. *Plant Salinity. Research, New Challenges.* 1999; 201-1203.
23. Mallek-Maalej E, Boulasnem F, Ben Salem M. Effect of salinity on the germination of cereal seeds cultivated in Tunisia. *Agriculture Notebooks.* 2004;12:153-156. French
24. Bouda S, Haddioui A. Effect of salt stress on the germination of some species of the genus *Atriplex*. *Nature & Technology.* 2011;5:72-79. French
25. Termaat A, Passora JB, Munns R. Shoot turgor does not limit shoot growth of NaCl affected wheat and barley. *Plant Physiol.* 1985;77:869-872.
26. Schachtman DP, Munns R. Sodium accumulation in leaves of *Triticum* species that differ in salt tolerance. *Austr. J. Plant Physiol.* 1992;19(3):333-339.
27. R'him Thouraya, Tili Imen, Hnan Imen, Iahy Riadh, Benali Ahlem, Jebari Hager. Effect of salt stress on the physiological and metabolic behavior of three varieties of pepper (*Capsicum annum* L.). *Journal of Applied Biosciences.* 2013;66:5060-5069. French
28. El Mekkaoui M. Contribution to the study of salt tolerance in durum wheat (*Triticum durum* Desf.) And barley (*Hordeum vulgare* L.). Diploma of DAA-Agricultural engineer, Montpellier. 1987;1:98. French
29. El Mekkaoui M. Study of the mechanisms of tolerance to salinity in durum wheat (*T. durum* Desf.) And barley (*H. vulgare* L.): research of early selection tests. Doctoral thesis in Agronomic Sciences, USTL-Montpellier. 1990;1:191. French

© 2020 Sanogo et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

*The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/55629>*