

Effect of Salt Stress on the germination of Two Varieties of Durum Wheat (*Triticum durum* DESF)

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Abstract

Salinity is an abiotic factor that interferes with the growth and development of plants and their metabolism, and its toxic effect differs according to the level of its concentration and the stage of development of the plant.

To carry out this study, two varieties Bousselam and Simeto of durum wheat (*Triticum durum* Desf.) were germinated and watered with NaCl salt water at different increasing concentrations for a period of fifteen days to determine the effect of salt stress on their germination behaviour.

The results obtained from the different physiological parameters studied showed that salinity has a toxic effect on the germination of durum wheat which varies according to the salt concentration as well as the variety.

Keywords: - Durum wheat (*Triticum durum* Desf.), varieties, salinity, toxic effect, germination.

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Introduction

Plants being sessile in nature, are simultaneously subjected to various adverse conditions including salinity, drought, cold, heat, excess water and heavy metals that limit their development and growth [1] and [2].

Soil salinity is a major threat to global food security. Up to 22% of the world's irrigated land, which produces one-third of the world's food, is affected by salt [3].

Excessive application of mineral fertilizers and inadequate irrigation, combined with high evaporation in arid and semi-arid regions, inevitably lead to salinization of soils and water tables [4].

The accumulation of soluble salts in the soil leads to an increase in the osmotic pressure of the soil solution, which can limit water uptake by seeds or roots. Salt injury to plants is attributed to reduced water availability, toxicity of specific ions and nutrient imbalances caused by these ions [4]. Plant tolerance to salt is highly variable. However, crop performance under saline conditions depends on seed germination, seedling emergence, establishment and also tolerance to later growth stages [5].

Germination is one of the most fundamental and important phases of the plant growth cycle, determining plant establishment and crop yield [6]. It begins with the uptake of water by the seed (imbibition) and ends with the emergence of the embryonic axis, usually the radicle [7]. Germination is controlled by both internal and external factors [8].

Every year, salinity stress prevents the germination of a number of crop species, including cereals [9]. Durum wheat (*Triticum durum* Desf.) is an important crop in the Mediterranean basin and is deeply rooted in the history and tradition of this region [10].

Durum wheat plays an important role in agriculture around the world because of its importance as a food crop. However, production and yields are still too low to meet the needs of the population. In Algeria, this crop is grown on the highlands, which are semi-arid zones characterized by erratic rainfall and high temperatures. Among the constraints affecting durum wheat production are abiotic stresses. Salinity is one of these abiotic stresses, limiting plant growth and causing yield losses.

In this context, the aim of this work is to study the effect of salt stress on two durum wheat (*Triticum durum* Desf.) varieties during germination.

Materials and Methods

The two varieties studied, Bousselem and Simeto, were selected for their important agronomic characteristics in terms of productivity and their degree of resistance and adaptation to stress.

Four saline solutions were prepared using sodium chloride (NaCl) and distilled water as follows: 50 mM, 100 mM, 200 mM, 300 mM were prepared in addition to a control (0 mM) based on distilled water.

The seeds were first disinfected with sodium hypochlorite diluted to 6° for 5 minutes to eliminate any fungal contamination, then rinsed three times with distilled water. Germination was then carried out in sterile Petri dishes, the bottom of each dish being covered with two layers of filter paper.

250 grains of each variety were placed in petri dishes containing 10 grains of wheat each. There were 5 replicates for each concentration.

These were sprayed daily with 10 ml of saline solutions of different NaCl concentrations, including the control, which was sprayed with distilled water (0 gram per litre NaCl). Finally, the Petri dishes were placed in an oven at 25°C.

In order to determine the effect of salt stress on the germination behaviour of durum wheat, the following physiological parameters were studied:

Final germination rate: This parameter is the best way of identifying the salt concentration at the physiological limit of seed germination. It is expressed as the ratio of the number of germinated seeds to the total number of seeds. [11].

$$\text{Final germination rate\%} = \frac{\text{number of germinated seeds}}{\text{total number of germinated seeds}} \times 100$$

Germination kinetics

This is a parameter that allows a better understanding of the ecological significance of the germination behaviour of the two varieties studied, as well as of all the events that begin with the stage of water absorption by the seed and end with the elongation of the embryonic axis and the emergence of the radicle [12]. The number of germinated seeds was counted daily until the 15th day of the experiment [13].

Percentage phytotoxicity (P.P.)

The percentage toxicity of NaCl on the germination of the two selected durum wheat varieties was determined according to the law of [14]:

$$\text{Percentage phytotoxicity} = \frac{\text{control radicle length} - \text{test radicle length}}{\text{control radicle length}} \times 100$$

Results and discussion

The analysis of variance of the final germination shows that the NaCl concentrations applied to the Bousselam and Simeto varieties had a highly significant effect.

Figure 1 shows that the increase in salt concentration caused a reduction in the final germination rate; the reduction was significant, particularly at the highest level of salt concentration.

Indeed, when the stress is moderate (50, 100 mM), both varieties show a germination rate that is not significantly different from the control. However, when the stress intensity is high (200, 300 mM), both varieties are affected and show a germination rate different from that of the control. The Bousselam variety had a higher germination rate than the Simeto variety.

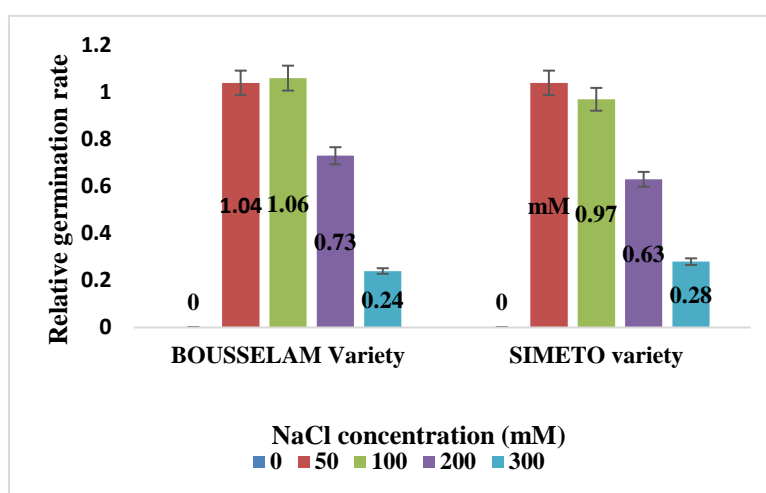


Figure 01: Final germination rate of two durum wheat varieties exposed to different concentrations of NaCl

According to the results obtained from the analysis of variance of the final germination rate of the Bousselam and Simeto varieties, it can be seen that the germination rate of the seeds decreases with increasing NaCl concentration. The effect of salinity on the germination of durum wheat grains was more pronounced at higher NaCl concentrations than in the controls, reflecting the inhibitory effect of salt on seed germination, including delayed germination. Inhibition was greater in grains exposed to concentrations of 200 (mM) and especially 300 (thousandth of a mole). Germination rates for the two cultivars were almost equal.

It can be said that wheat grains tolerate a threshold concentration of NaCl between 0 and 100, but concentrations above this value have an inhibitory effect and consequently reduce the rate and duration of germination.

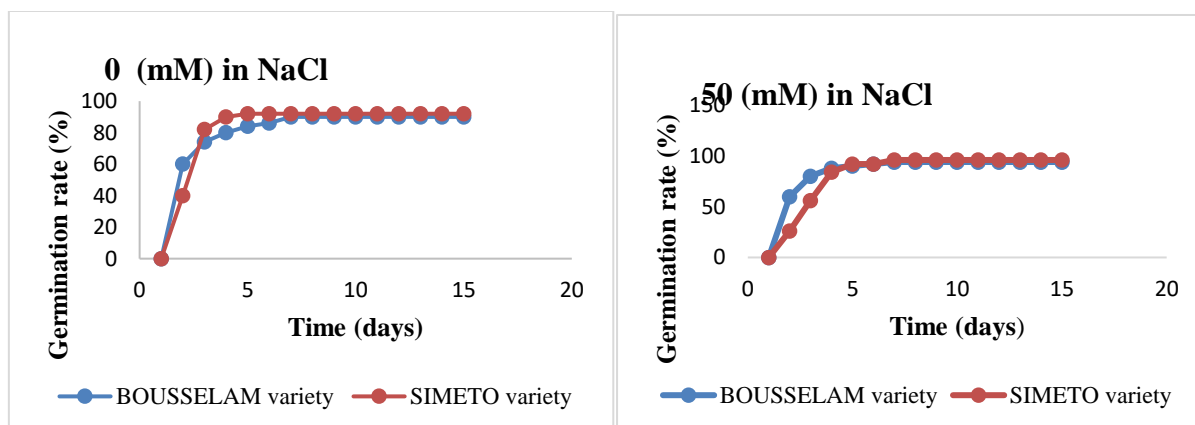
Effect of salt stress on durum wheat germination kinetics

The analysis of variance of this parameter shows that the salt stress applied to the two varieties has a very highly significant effect. The following figures show the germination of two durum wheat

varieties exposed to different NaCl concentrations over a period of 15 days. The results show that the germination rate curves for the stressed grains are below those of the control curves and decrease as the NaCl dose increases.

According to the germination curves obtained, we can distinguish 03 phases (Fig. 2):

- A latency phase during which the germination rate remains low because it is necessary for the first germinations to appear. The duration of this phase varies according to the NaCl concentration. It is short and even negligible in the control seeds and those sprayed with concentrations of 50 (mM) and 100 (mM). On the other hand, it becomes more or less long, especially in seeds exposed to concentrations of 200 (mM) and 300 (mM), for which this phase can last up to 05 days;
- An exponential phase, corresponding to a rapid increase in the germination rate, proportional to time, at least for control grains and grains exposed to concentrations of 50 (mM) and 100 (mM). However, it becomes very short for grains irrigated with concentrations of 200 (mM) and 300 (mM), which explains the reduced germination rate due to the inhibitory effect of salt on germination;
- A third phase, corresponding to a level representing the final germination percentage and reflecting the germination capacity of the two durum wheat varieties and for each concentration. It appears that this germination capacity decreases for the two varieties studied, but to different degrees depending on the stress applied.



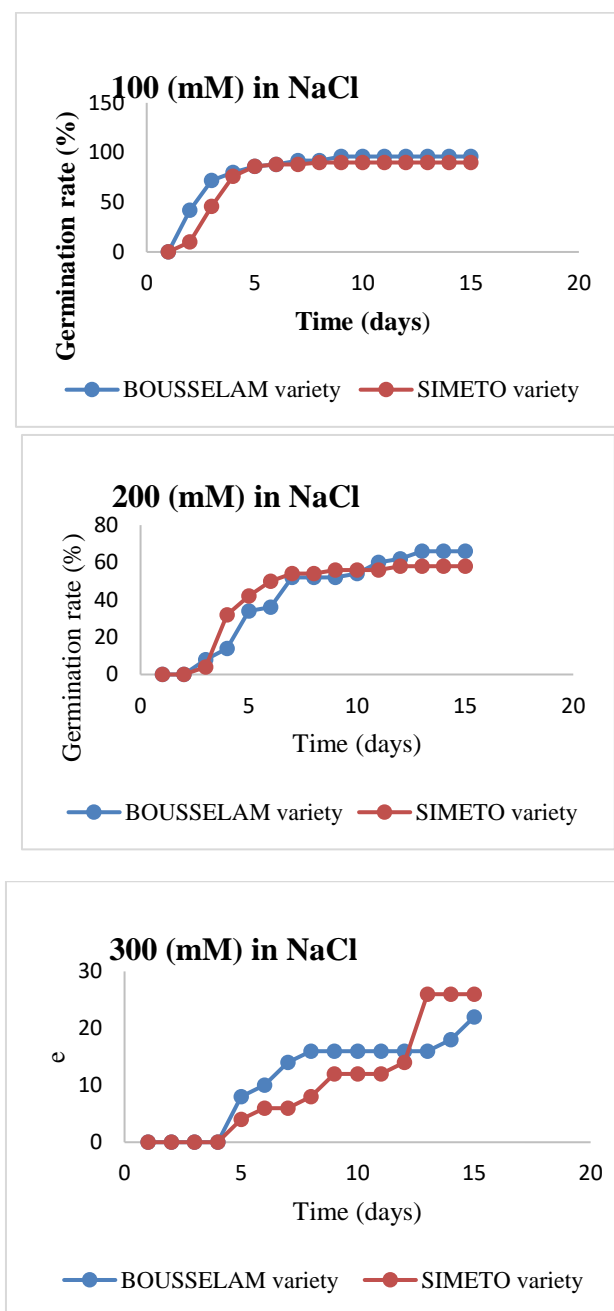


Figure 2: Germination kinetics of two durum wheat varieties exposed to different concentrations of NaCl

Effect of salt stress on the tolerance index (T.I.) of durum wheat

The analysis of variance of this parameter shows that the different NaCl concentrations applied to the Bousselam and Simeto varieties have a highly significant effect.

Figure 3 shows the effect of NaCl concentrations on the tolerance index of the Bousselam and Simeto varieties. Although the salt tolerance of the grains of both varieties is highly significant, the results obtained show that grain tolerance decreases with increasing NaCl concentration, with the maximum value recorded for grains irrigated with NaCl concentration 50 (mM). On the other

hand, grains irrigated with a concentration of 300 (mM) showed a low salt tolerance. For the variety Simeto, the salt tolerance at 300 (mM) concentration was almost zero. The variety Bousselam was more resistant to salt stress than the variety Simeto.

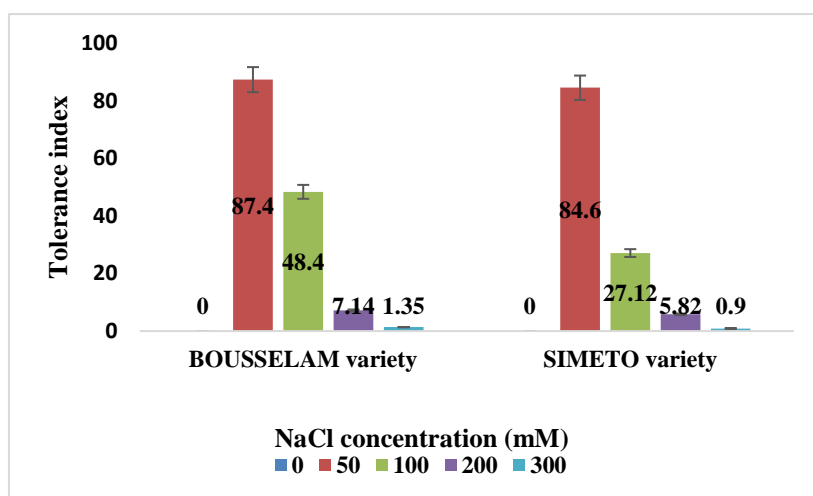


Figure 3: Tolerance index in two durum wheat varieties exposed to different NaCl concentrations

Discussion

It is clear that the germination stage of durum wheat is the first stage to be exposed to salt stress, and the response of the grain to salt during this stage can be used to predict the development of the whole plant and the quality of production.

The germination behaviour of the two durum wheat varieties *Triticum durum* Desf. Bousselam and Simeto to salt stress caused by increasing concentrations of NaCl was determined by studying physiological and morphological parameters such as final germination rate, germination kinetics, relative germination rate, coleorrhiza and coleoptile length and their ratio, tolerance index and phytotoxicity percentage. The results showed that the measured components of both varieties were significantly affected by salt concentrations.

According to the results obtained from the analysis of variance of the final germination rate of the Bousselam and Simeto varieties, it can be seen that the germination rate of the seeds decreases with increasing NaCl concentration. The effect of salinity on the germination of durum wheat grains was more pronounced at higher NaCl concentrations than in the controls, reflecting the inhibitory effect of salt on seed germination, including delayed germination. Inhibition was greater in grains exposed to concentrations of 200 (mM) and especially 300 (mM). Germination rates for the two cultivars were almost equal.

The results of the present study are confirmed by (Borlu et al., 2018), who also reported that salt stress at the germination stage of wheat is the most sensitive and ultimately reduces the percentage, rate and duration of germination. Reference [15] who applied different concentrations of NaCl on

the germination of Simeto variety grains, admitted that durum wheat grains showed a decrease in germination percentage when salt stress increased.

According to [11], soft wheat varieties are more resistant to salt stress and have higher germination rates than durum wheat varieties, even under the most severe conditions. Wheat is generally considered to be relatively more salt tolerant than barley and triticale.

In rice, germination was completely inhibited in all varieties at a salinity of 20 dS m⁻¹. The percentage of germination was inversely related to the salt concentration [16].

Reference [17] and [18] state that salinity significantly reduces seed germination due to its osmotic effects and the toxicity of minerals during germination metabolism. The first stage of germination is the uptake of water by the seed and the osmotic component of salinity has a strong inhibitory effect on the hydration of the embryo, cotyledon and endosperm.

Reference [19] speculate that the reduction in seed germination may be due to the loss of seed viability at higher salinity levels and the delay in seed germination due to salinity inhibited the physiological change of seeds to germinate.

A negative effect on germination was found in *Oryza sativa* [16], *Pennisetum glaucum* [20], *Zea mays* [21] and *Hordeum vulgare* [22]. The sensitivity of germination to salt stress varies according to different salinities and cultivars [22].

According to the results of the variation of the germination kinetics in the two varieties Bousselam and Simeto, the number of grains germinated per day decreased as a function of the NaCl concentration, which translates into a slowing down of the germination process in relation to the increase in salinity. There was also a long latency period before germination, starting at 100 (mM) for the Simeto variety and 200 (mM) for the Boussaleme variety, which suggests that the Boussaleme variety is more resistant to salt stress than the Simeto variety. The effect of NaCl on the germination behaviour of durum wheat is reflected in an increase in the latency time and a decrease in the germination speed and rate.

According to [24], this delay can be explained by the time needed for the seed to establish mechanisms that allow it to adjust its internal osmotic pressure. While [25] explained that this delay could be due to the alteration of enzymes and hormones present in the seed.

With regard to the results for the percentage of phytotoxicity, both varieties showed an increase as a function of the increase in NaCl concentration. It should be noted that both varieties were more affected at concentrations of 200 and 300 (mM), reflecting the toxic effect of sodium chloride on durum wheat root growth. The toxic effect of salt stress was much more evident in the Simeto variety than in the Bousselam variety.

The effects of salinity are manifested by direct toxicity due to the excessive accumulation of ions (Na⁺ and Cl⁻) in the tissues and an imbalance in mineral nutrition, mainly due to competition

between elements: sodium with potassium and with calcium, chloride with nitrate, with phosphate and with sulphate [31] and [32]. Salinity interferes with various physiological and metabolic processes and reduces plant growth and development [33].

Conclusion

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Salt stress affects the physiological and morphological appearance of plants. It is a limiting factor for durum wheat (*Triticum durum* Desf.) crops. In order to cope with this constraint, plants develop adaptation mechanisms that enable them to resist salinity.

From the results obtained, it can be seen that the effect of sodium chloride on the germination of the grains of the two durum wheat varieties is manifested by a physiological and morphological change. The effect varies according to the concentration of NaCl and the variety.

References

- [1] D. Santos, T. Benedito, A. Ferreira Ribas, S. Graciele Hülse de Souza, I. G. Frasson Budzinski and D.s Silva Domingues, “Physiological Responses to Drought, Salinity, and Heat Stress in Plants”, A Review Stresses 2, no. 1, 2022, pp 113-135, <https://doi.org/10.3390/stresses2010009>.
- [2] C. Uçarlı, “Effects of Salinity on Seed Germination and Early Seedling Stage”, Abiotic Stress in Plants, Oct. 2020, IntechOpen. DOI:10.5772/intechopen.93647.
- [3] S. C. Bhatla and M. A. Lal, “Plant physiology, development and metabolism”, Springer Singapore, 2018. pp. 1237.
- [4] R. A. James, R. Munns, S. Von Caemmerer, C. Trejo, C. Miller and T. J. P. Condon, “Photosynthetic capacity is related to the cellular and subcellular partitioning of Na^+ , K^+ and Cl^- in salt-affected barley and durum wheat”, Cell & Environment, 2006. 29, pp. 2185-2197.

- [5] A. Sourour, R. Neila, C. Zoubeir, B. Saddreddine, K. Feker, B. Themir, M. Mayada, B. Y. Mongi, "Effect of salt stress (sodium chloride) on germination and seedling growth of durum wheat (*Triticum durum* Desf.) genotypes", *International Journal of Biodiversity and Conservation*, 2014. 6, pp. 320-325.
- [6] P. Ahmad, M. Azooz and M. N. V. Prasad, "Ecophysiology and responses of plants under salt stress", *Springer Science & Business Media*, Nov. 2012, pp. 1-512.
- [7] J. D. Bewley and M. Black, "Seeds: physiology of development and germination", *Springer Science and Business Media*, 2013, Edi. 3, p. 391.
- [8] P. Ahmad, M. M. Azooz and M. N. V. Prasad, "Salt stress in plant, Signalling, omics and adaptations", Mar. 2014, pp. 1-509.
- [9] F. Martínez-Moreno, I. Solís, D. Noguero, A. Blanco, Í. Özberk, N. Nsarellah, E. Elias, I. Mylonas, J. M. Soriano, "Durum wheat in the Mediterranean Rim: Historical evolution and genetic resources", *Genetic Crop. and Evolution*, Mar. 2020, pp. 1-22.
- [10] M. Mrani Alaoui, L. El Jourmi, A. Ouarzane, S. Lazar, S. El Antri, M. Zahouily and A. Hmyene, "Effet du stress salin sur la germination et la croissance de six variétés marocaines de blé (Effect of salt stress on germination and growth of six Moroccan wheat varieties) ", *Journal of Material and Environmental Science*, 2013. 4 (6), pp. 997-1004.
- [11] L. Benidire, K. Daoui, Z. Fatemi, W. Achouak, L. Bouarab, K. Oufdou, "Effet du stress salin sur la germination et le développement des plantules de *Vicia faba* L.(Effect of salt stress on germination and seedling of *Vicia faba* L.) ", *Journal of Material and Environmental Science*, 2015, 6 (3), pp. 840-851.
- [12] H. Hajlaoui, M. Denden and M. Bouslama, "Etude de la variabilité intraspécifique de tolérance au stress salin du pois chiche (*Cicer arietinum* L.) au stade germination (Study of intraspecific variability in tolerance in salt stress of cheakpea (*Cicer arietinum* L.) at germination stage)", *Tropicultura*, 25, 3, pp. 168-173, 2007.
- [13] C.-H. Chou and H.-J. LIN, "Autointoxication mechanism of *Oryza sativa* I. Phytotoxic effects of decomposing rice residues in soil", *Journal of Chemical Ecology*, vol. 2, pp. 353-367, 1976.
- [14] R. Kouadria, M. Bouzouina, R. Azzouz and B. Lotmani, "Salinity stress resistance of durum wheat (*Triticum durum*) enhanced by fung", *International Journal of Bioscience*, vol. 12, No. 6, pp. 70-77, 2018.
- [15] M. Hakim, A. Juraimi, M. Begum, M. Hanafi, M. R. Ismail and A. Selamat, "Effect of salt stress on germination and early seedling growth of rice (*Oryza sativa* L.), *African Journal of Biotechnology*", vol. 9(13), pp. 1911-1918, 29 March, 2010.

- [16] A. Wahid, I. Ali, A. Baig and E. Rasul, "Short term incubation of sorghum caryopses in sodium chloride levels: changes in some pre-and post-germination physiological parameters", *Plant Science*, Elsevier, vol. 139, pp. 223-232, 1998.
- [17] A. Wahid, M. Farooq, S. Basra, E. Rasul and K. Siddique, "Germination of seeds and propagules under salt stress". *Handbook of plant and crop stress*, CRC Press, 3 pp. 321-337, 2010.
- [18] S. Gulzar and M. Ajmal Khan, *Annal of Botany*, "Seed germination of a halophytic grass *Aeluropus lagopoides*", 2001, 87, pp. 319-324, doi:10.1006/anbo.2000.1336
- [19] L. Radhouane, "Effet du stress salin sur la germination, la croissance et la production en grains chez quelques écotypes de mil (*Pennisetum glaucum* (L.) R. Br.) autochtones de Tunisie (Effect of salt stress on germination, growth and grain production in some native Tunisian millet (*Pennisetum glaucum* (L.) R. Br.) ecotypes)", *Sience Direct, C. R. Biologies*, 2008, 331, pp. 278-286.
- [20] E. Carpýcý, N. Celyk and G. Bayram, "Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars", *African Journal of Biotechnology*, 2009, vol. 8 (19), pp. 4918-4922.
- [21] A. Djerah and B. Oudjehih, "Effet du stress salin sur la germination de seize variétés d'orge (*Hordeum vulgare* L.) (Effect of salt stress on the germination of sixteen varieties of barley (*Hordeum vulgare* L.)", *Courier du savoir, Université Mohamed Khider-Biskra*, 2016, 20, pp. 47-56.
- [22] H. O. Borlu, V. Celiktas, S. Duzenli, A. Hossain and A. El Sabagh, "Germination and early seedling growth of five durum wheat cultivars (*Triticum durum* desf.) is affected by different levels of salinity", *Fresenius Environmental Bulletin*, 2018, vol. 27, 11, pp. 7746-7757.
- [23] D. Ben Miled, M. Bousaid and A. Adblkeffi, "Tolérance au sel d'espèces annuelles du genre *Medicago* au cours de la germination (Salt tolerance of annual species of genus *Medicago* during germination ", *Symposium on plants in arid environments, Djerba, Tunisia*, 8-10 sept. 1986, 586.
- [24] C. Daas-Ghrib, F. Gharbi, R. Kchaou, S. Rejeb, M. L. Khoudja and M. N. Rejeb, "Réponse de Trois Espèces d'Eucalyptus à la Salinité (*Eu. sargentii*, *Eu. gomphocephala* et *Eu. astringens*) (Response of Three Eucalyptus Species to Salinity (*Eu. sargentii*, *Eu. gomphocephala* and *Eu. astringens*)", *European Journal of Scientific Research*, 2011, vol. 53 No.1, pp.56-66.
- [25] M. Jamil and E.-S. Rha, "The effect of salinity (NaCl) on the germination and seedling of sugar beet (*Beta vulgaris* L.) and cabbage (*Brassica oleracea* L.) ", *J. P. R.* 2004, vol. 7, pp. 226-232.

- [26] R. Munns, Plant cell and environment, “Comparative physiology of salt and water stress”, 2002, vol. 25, pp. 239-250.
- [27] M. Rogers, C. Noble, G. Halloran, M. Nicolas, “The effect of NaCl on the germination and early seedling growth of white clover (*Trifolium repens* L.) populations selected for high and low salinity tolerance”, Seed Science and Technology, 1995, vol. 23, pp. 277-287.
- [28] H. Homayoun, M. Daliri and P. Mehrabi, “Study of PGA stress effect on wheat cultivars at germination stage”, Middle-East Journal of Scientific Research, Ireland - Pakistan – UAE, 2011, vol. 9 (1), pp. 71-74.
- [29] Y. El Goumi, M. Fakiri, O. Lamsaouri, M. Benchekroun, “Salt stress effect on seed germination and some physiological traits in three Moroccan barley (*Hordeum vulgare* L.) cultivars”, Journal of Material and Environmental Science, 2014, vol. 2 (5), pp. 625-632.
- [30] A. Soltani, M. Hajji and C. Grignon, “Recherche de facteurs limitant la nutrition en milieu salé” (Research into factors limiting nutrition in a salty environment), Agronomie, , 1990, 10, pp. 857-866.
- [31] A. Levigneron, F. Lopez, G. Vansuyt, P. Berthomieu, P. Fourcroy and F. Casse-Delbart, “Les plantes face au stress salin (Plants under salt stress)”, Cahiers Agricultures, France, 1995, 4 (4), pp. 263-273 (1).
- [32] Z. Rahnesan, F. Nasibi and A. Moghadam, “Effects of salinity stress on some growth, physiological, biochemical parameters and nutrients in two pistachio (*Pistacia vera* L.) rootstocks”, Journal of Plant Interactions, Jan. 2018, vol. 13, pp. 73-82.