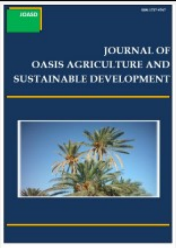
Journal of Oasis Agriculture and Sustainable Development
www.joasdjournal.org

RESEARCH ARTICLE



JOURNAL OF OASIS AGRICULTURE AND SUSTAINABLE DEVELOPMENT

www.joasdjournal.org

JOASD

p-ISSN: 2724 – 699X
e-ISSN: 2724-7007

The Impact of Salinity on the Productivity and Quality of Durum and bread Wheat

Nejla Turki[1], Tariq Shehzad[2], Safia El Bok*[3] & Okuno Kazutoshi[4]

[1]*Graduate School of Life and Environmental Sciences, University of Tsukuba, Presently Higher Institute of Applied Science and Technology Mahdia, Tunisia.*
[2]*Graduate School of Life and Environmental Sciences, University of Tsukuba, Presently Syngenta Crop Protection, LLC 9 Davis Drive Research Triangle Park, NC 27709, USA.*
[3]Laboratory of Biodiversity, Biotechnologies and Climate Change (LR11/ES09), Faculty of Sciences of Tunis, University of Tunis El-Manar, Tunis 2092.
[4]*Graduate School of Life and Environmental Sciences, University of Tsukuba, Presently Kayada 2069-6, Yachiyo 276-0043, Japan.*

Article info

Article history:
Received: 07 July 2024
Accepted: 31 July 2024

Keywords: Breadwheat, Durum wheat, Protein content, Salt tolerance.

***Corresponding author**
safia.elbok@fst.utm.tn

Conflict of Interest : The authors declare no conflict of interest.

Abstract

Salinity poses a significant challenge to the quality and productivity of crops. In the primary wheat cultivation areas worldwide, salinity negatively affects wheat growth, yield, and quality. To address this issue, the development of tolerant wheat varieties through selective breeding techniques is essential. The aim of this study was to assess the effects of salinity on grain yield, protein content, and thousand-kernel weight (TKW) among 55 different varieties and accessions of bread and durum wheat. The findings revealed that the application of salt treatment (100 mM NaCl solution) resulted in reduced growth and yield production in 45 bread and durum wheat varieties. However, 6 durum wheat varieties, 3 durum wheat accessions, and 1 common wheat accession showed insignificant susceptibility to salinity. These included Chryssodur from Greece, Saragolla, Silur, and Dakter from Italy, Sculptur from France, Karim from Tunisia, Algeria 70-2 from Algeria, Ethiopia 201 and Ethiopia 229 from Ethiopia, and the Morocco 85 accession of bread wheat from Morocco. The decline in grain yield could be attributed to salinity, which led to a decrease in photosynthetic capacity, resulting in reduced starch synthesis and accumulation in the grain. Furthermore, the study demonstrated that winter wheat exhibited greater tolerance to salt stress compared to spring wheat, and durum wheat displayed higher tolerance than common wheat. Additionally, salt accumulation was found to increase protein content in five varieties and one accession of durum wheat. This variation may be linked to the relatively stable nitrogen metabolism under salt stress, contributing to higher protein concentrations. TKW also decreased in all 10 varieties and accessions, irrespective of the species.

1. INTRODUCTION

Salinity negatively impacts soil fertility, leading to the implementation of various solutions to mitigate this problem, such as soil reclamation or the cultivation of tolerant plant species. However, soil reclamation is a costly process, making the selection of tolerant crop varieties the most practical solution when salinity levels are low. According to the FAO Land and Plant Nutrition Management Service, more than 6% of the world's land is affected by either salinity or sodicity. Additionally, the poor quality of water and inadequate drainage systems are the primary causes of these stresses. This issue becomes even more severe in regions with high evaporation rates, particularly in arid and semi-arid zones where saline soils are prevalent. As a result, land productivity has significantly decreased in numerous countries worldwide (Atlassi et al., 2009). The results of the study showed that there were significant differences in salt tolerance among the wheat genotypes tested. Some genotypes exhibited higher salt tolerance, as indicated by their ability to maintain higher grain yield, protein content, and TKW under saline conditions. These findings suggest that selecting and breeding wheat varieties with higher salt tolerance could be an effective strategy to mitigate the negative effects of salinity on crop productivity. In addition to genetic variation, the study also found that the duration and intensity of salt stress significantly influenced the response of wheat genotypes. Longer exposure to high salt concentrations resulted in greater reductions in grain yield, protein content, and TKW. This highlights the importance of considering the timing and severity of salt stress when developing strategies to improve crop tolerance to salinity.

2. MATERIAL AND METHODS

2.1. Plant materials

Fifty-five accessions of durum and bread wheat were utilized in this study. Out of these, 16 were classified as winter wheat, while the remaining 39 were categorized as spring wheat accessions. The experiments took place within the controlled environment of a glass house. The winter varieties were sown during winter season, whereas the spring accessions were sown in spring season. Each pot contained 10 seeds, and once the plants emerged, they were thinned down to 6 plants per pot.

2.2. Salt stress treatment

At different stages of development, a salt treatment was administered when the plant had 3 to 4 leaves, utilizing varying concentrations (0 and 100 mMol). Subsequently, the electrical conductivity (EC) was assessed by means of an EC meter.

2.3. Agronomic traits

2.3.1. Seedling stage parameters

The quantification of chlorophyll content was conducted 21 days subsequent to the application of salt treatment, employing the SPAD-502 Chlorophyll Meter. This instrument facilitates swift and non-invasive assessments of the chlorophyll content present in the leaves.

2.3.2. Tillering stage parameters

The number of tillers per plant and the number of leaves per tiller were assessed across various accessions and varieties under both controlled and treated conditions.

2.3.3. Maturity stage parameters

The calculation of the number of spikes and the number of seeds per spike was conducted in order to assess the impact of salinity on crop yield.

2.4. Quality analysis

The primary objectives of this study are to assess the impact of salt on grain quality using various parameters :

- The weight of 1000 kernels is considered significant in determining the yield of semolina. To determine the TKW, a manual count of 100 seeds is conducted after removing any broken kernels and foreign materials. The weight of 100 kernels is then multiplied by 10 to obtain the weight of 1000 kernels.
- The concentration of protein in micrograms per milliliter (ug/ml). To quantify the total protein content, all seeds are collected and milled. The BCA Protein Assay Kit is utilized for this purpose, with two replications performed. This assay is based on bicinchoninic acid (BCA) and is compatible with detergents. It enables the colorimetric detection and quantitation of total protein.

2.5. Data analysis

Statistical analysis was performed using JMP software. To compare means Values of different trais a student test was used.

3. RESULTS AND DISCUSSION

3.1. Evaluation of agronomic traits among durum and bread wheat at seedling stage

According to Fig. 1 and 2, the level of chlorophyll content varied among different accessions of durum and bread wheat. This variation is influenced by two primary factors: the genetic makeup of the plant and the concentration of NaCl. Most of the species examined in this study exhibited a wide range of tolerance to salt stress. For instance, the Nasr (V13) variety from Tunisia exhibited a high level of tolerance, whereas the Carioca (V6) variety from Italy showed low tolerance. There were also some species that displayed a moderate level of tolerance, such as the Sculptur (V3) variety from France. According to previous research, salinity has negative effects on plant species, including a reduction in the net photosynthetic rate, transpiration rate, and stomatal conductance.

However, it was observed that at low salinity levels, the chlorophyll content increased, while at high salinity levels, it degraded. This observation is consistent with the findings of Kamran et al. (2020). Statistical analysis, conducted using a student test, indicated that the decrease in chlorophyll content was significant in the sensitive genotypes compared to the highly tolerant ones. These results align with the conclusions drawn by Kumar et al. (2021) and are supported by the findings of numerous other researchers.

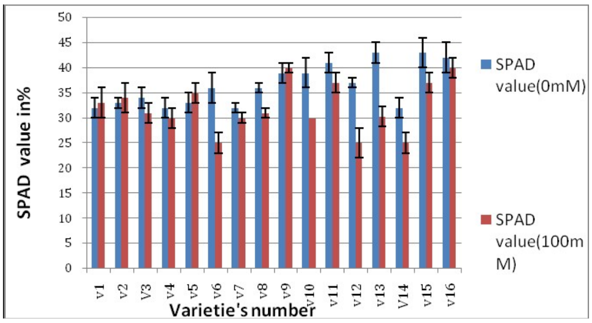


Fig. 1. Variation of chlorophyll content (Spad value) among durum wheat genotypes.

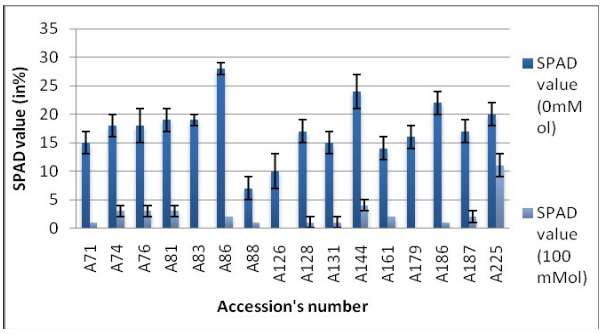


Fig. 2. Variation of chlorophyll content (Spad value) among bread wheat genotypes.

3.2. Evaluation of agronomic traits among durum and bread wheat at tillering stage

The impact of salt stress on tiller's number in different types of durum and common wheat is demonstrated in Fig. 3 and 4. From these figures, it can be inferred that in certain species, this characteristic significantly decreases with the severity of salt stress. This is evident in the varieties of durum wheat such as Nasr (V13) and Ismur (V16) (Fig. 3).

Regarding common wheat, Fig. 4 illustrates a decrease in tiller's number from 5 to 3 tillers. This is observed in the accessions Shiro Komugi (A74), Khaishu Komugi (A76), Sonalika (A83), Pakistan Zairaishu WB 27 (A86), Pakistan Zairaishu WB 115 (V88), Bhutan 40 (A126), Nepal Zairaishu (49 N 3) −3 (A128), Nepal Zairaishu (49 N 4) −2 (A131), and Morocco 85 (A225). Additionally, the accession Anahuac (A187) experiences a decrease from 5 to 2 tillers. In a similar context, Maas et al (1994) discovered that salt stress during tiller emergence can hinder their development and lead to their abortion in later stages.

Moreover, when salinity levels exceed 7.5 dSm−1 or 50mM NaCl, the majority of secondary tillers in moderately tolerant genotypes are eliminated, resulting in a significant reduction in their number. Furthermore, high-tillering wheat varieties exhibit higher grain yield in poor soil compared to low-tillering varieties. Conversely, low-tillering varieties in rich soil produce equal or greater yields than high-tillering ones. Therefore, enhancing salinity tolerance in wheat may necessitate an increase in tillering capacity (Islam and Sedgley, 1981).

3.3. Evaluation of agronomic traits among durum and bread wheat at maturity stage

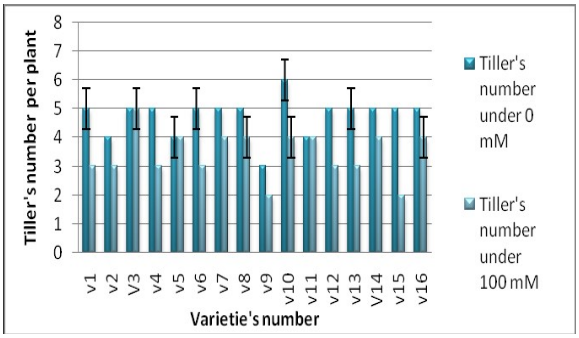


Fig. 3. Variation of number of tillers among durum wheat genotypes

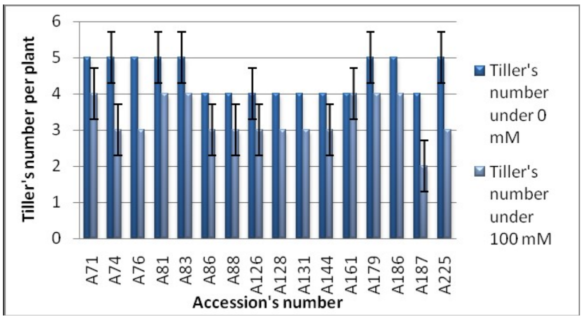


Fig. 4. Variation of number of tillers among bread wheat genotypes

In the maturity stage, the number of spikes in wheat plants was found to be significantly influenced by both the species of wheat (Fig. 5 and 6) and the different salt concentration treatments applied. This was indicated by a statistically significant p-value of less than 0.05 (Table1). Furthermore, it was observed that the number of spikes showed a strong correlation with the number of tillers in the plants. Based on the results of our study, it can be concluded that as the severity of salt stress increased, the number of seeds per spike also increased. This suggests that wheat plants respond to salt stress by producing more seeds in each spike. However, it should be noted that this conclusion is limited to tolerant accessions and varieties of wheat. In these tolerant plants, a significant reduction in

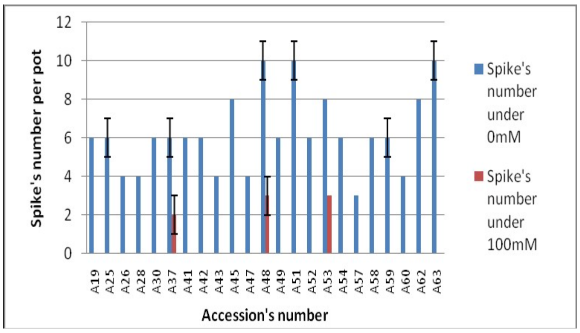


Fig. 5. Variation of number of spikes among durum wheat genotypes

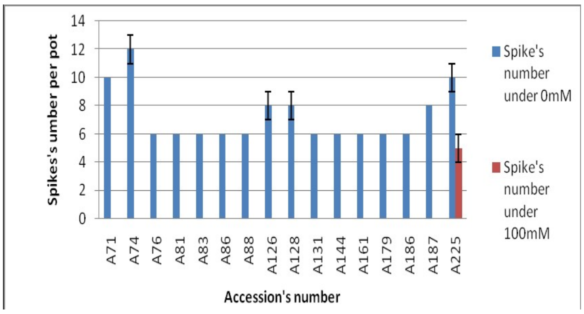


Fig. 6. Variation of number of spikes among bread wheat genotypes

Table 1. Comparison per pairs (Student test) between different concentrations of NaCl based on seed's number per spike

Salt level	Mean Value
0	14.654 a
100	1.745 b

Means not followed by same letter are significantly different (p<0.05).

the quantity of seeds per spike was observed under salt stress conditions. In fact, for the remaining samples that were not tolerant to salt stress, the number of seeds per spike was recorded as zero. This outcome can be explained by the fact that wheat plants subjected to salt stress during the apex vegetative stage experienced a shorter period of spikelet development. This resulted in a lower number of spikelets per spike, which in turn led to a reduction in the number of grains per spike (Akram et al., 2002, Zheng et al. 2009a). This finding suggests that the negative effects of salt stress on wheat reproductive development are more pronounced in non-tolerant varieties.

Overall, our study highlights the importance of considering both species and salt concentration treatments when assessing the number of spikes in wheat plants. It also emphasizes the strong correlation between the number of spikes and tillers, as well as the impact of salt stress on seed production in wheat.

3.4. Assesssment of quality paramters

3.4.1. Thousand kernel weight (TKW)

The findings of this study indicate that salt stress has a significant impact on the thousand kernel weight (TKW) of sensitive genotypes compared to tolerant ones. Fig. 7 supports this conclusion, as it demonstrates a substantial reduction in TKW across various genotypes. Additionally, the duration of grain development plays a crucial role in determining TKW, as longer durations result in heavier seeds. In our specific case, the stress conditions caused by higher salinity levels lead to a decrease in this developmental stage.

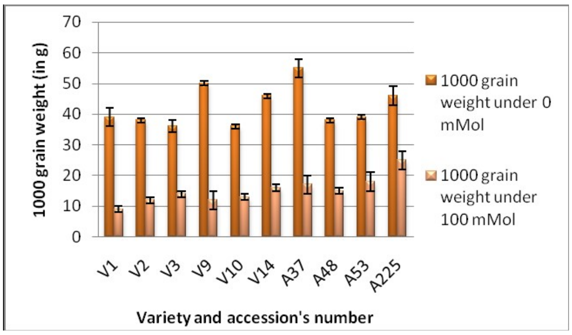


Fig. 7. Variation of Thousand kernel weight (TKW) in gunder salt stress.

In a study conducted by K.S Gill in 1979, it was observed that reduced grain yield under salt stress could be attributed to a decrease in the efficiency of grain filling per day, resulting in a longer duration for effective grain filling. Furthermore, disturbed starch-sugar balance was identified as another contributing factor.

Interestingly, TKW was found to be less sensitive to salinity compared to spikelet number, which was identified as the most sensitive yield component. These findings align with previous research conducted by Hendawy et al. (2005).

3.4.2. Protein content

The protein content of pasta and semolina is a key factor in determining their quality. In a study, Fig. 8 illustrates the impact of salt accumulation on the protein content of five different varieties and one accession of durum wheat. Among these varieties, V1, also known as Chryssodur from Greece, displayed the highest protein level at 500ug/ml. This indicates that Chryssodur has a superior protein content compared to the other varieties tested. On the other hand, the variety V10, named Silur from Italy, exhibited the lowest protein value at 180ug/ml. This suggests that Silur has a relatively lower protein content compared to the other varieties. These findings

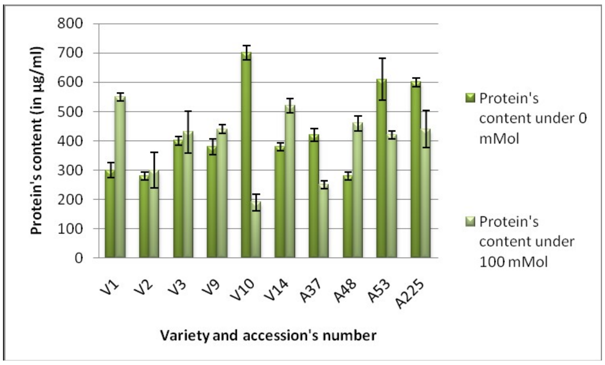


Fig. 8. Variation of protein concentration under salt stress.

highlight the importance of considering protein content when evaluating the quality of pasta and semolina, as it can vary significantly depending on the variety of durum wheat used.

The variation in protein content is closely associated with the genetic diversity observed among different genotypes within the same context. Zheng et al. (2009b) have highlighted in their research that the protein content of plant grain yield exhibits a negative correlation with salt stress, leading to a decline in this trait. Additionally, under saline conditions, plants tend to accumulate proteins, which serve as a storage form of nitrogen. These proteins are subsequently re-utilized when the stress subsides and may contribute to osmotic adjustment. In response to salt stress, plants may synthesize proteins de novo or have them present constitutively at low concentrations, which then increase upon exposure to salt stress (Ashraf and Harris, 2004).

4. CONCLUSION

This research offers significant findings regarding the genetic diversity and ability of different wheat genotypes to tolerate high salt levels. These findings emphasize the potential for developing and selecting crop varieties that can flourish in saline environments, based on their productivity and quality characteristics. By addressing the challenge of salinity and its detrimental effects on agricultural land, it becomes feasible to mitigate food scarcity and water scarcity issues, thereby making a valuable contribution to global food security.

REFERENCES

Akram, M., Hussain,M., Akhtar,S., and Rasul,E. (2002). Impact of NaCl Salinity on Yield Components of some wheat accessions/varieties. International Journal of Agriculture and Biology 1560–8530/04–1–156–158.

Ashraf, M. and Harris, P.J.C. (2004). Potential biochemical indicators of salinity tolerance in plants. Plant Sci., 166: 3-6.

Gill, K. S. (1979). Effect of soil salinity on grain filling and grain development in barley. Biologia Plantarium, 21(4):241-244.

Hendawy, S., EL. Hua, Y., Yakout, G.M., Awad, A .M., Hafiz, S.E and Schmidhalter, U. (2005). Evaluating salt tolerance of wheat genotypes using multiple parameters. Europ. J. Agronomy, 22:243–253.

Islam, T.M.T., and Sedgley, R.H. (1981). Evidence for a ‘uniculm effect’ in spring wheat (Triticum aestivum L.) in a Mediterranean environment. Euphytica 30:277-282

Kamran, M., Parveen, A., Ahmar, S., Malik, Z., Hussain, S., Chattha, M. S., et al. (2020). An Overview of hazardous impacts of soil salinity in crops, tolerance mechanisms, and amelioration through selenium supplementation. Int. J. Mol. Sci. 21 (1), 148. doi: 10.3390/ijms21010148.

Kumar, S., Li, G., Yang, J., Huang, X., Ji, Q., Liu, Z., Ke, W., Hou, H. (2021). Effect of Salt Stress on Growth, Physiological Parameters, and Ionic Concentration of Water Dropwort (Oenanthe javanica) Cultivars. Front Plant Sci. 21;12:660409. doi: 10.3389/fpls.2021.660409.

Maas, E.V., Lesch, S. M., Francois, L. E., and Grieve, C.M., (1994). Tiller Development in Salt-Stressed Wheat. Crop Science Vol. 34, No. 6, 1594-1600

Zheng, Y. H., Xu, X. B., Wang, M. Y., Zheng, X. H., Li, Z. J., Jiang, G. M. (2009a). Responses of salt-tolerant and intolerant wheat genotypes to sodium chloride: Photosynthesis,antioxidants activities, and yield. Photosynthetica 47, 87–94.

Zheng, Y.H., XU, X., Li, Z. and Yang .X. (2009b). Differential Responses of grain yield and quality to salinity between wheat cultivars. Seeds Sciences and Biotechnology, 3(2) :40-43.