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EVALUATION OF SALINITY TOLERANCE BY LEAF SYNTHESIS OF NATURAL OSMOPROTECTANTS IN DURUM WHEAT (*TRITICUM DURUM* DESF.) AT A JUVENILE STAGE

ZIAT Nour El Houda[1*], BRINIS Amir[1], AYADI Sawsen[2], AMARA Hajer[2] and BRINIS Louhichi[1]

1.Badji Mokhtar University of Annaba, Faculty of Sciences, Department of Biology, Plant Breeding Laboratory, P.O. Box 12, 23000, Annaba, Algeria
2.University of Carthage, National Agronomic Institute of Tunisia, Department of Agronomy and Biotechnology, Genetic and Plant Breeding Laboratory, 43 Avenue Charles Nicole, 1082 Tunis, Tunisia

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Abstract

Description of the subject: The climatic characteristics of cereal-growing areas in Algeria mean that the cultivation of durum wheat (*Triticum durum* Desf.) is exposed to various unfavorable environmental stresses, mainly in regions with arid and semi-arid climates, including the phenomenon of salt stress, which poses a serious threat to agricultural performance and food security.

Objective: In response to this major concern, the present contribution aims to explore the different biochemical abilities of durum wheat to adapt to salt stress.

Methods: The study focused on three durum wheat varieties grown in Algeria (Citra, Oued Zenati and GTA Dur) at the juvenile stage, for the identification of biochemical markers of salinity tolerance, namely the content of proline, soluble sugars, total proteins and total phenolic compounds. Salinity was induced by the application of increasing concentrations of the order of (0 $g.l^{-1}$, 9 $g.l^{-1}$, 12 $g.l^{-1}$ and 15 $g.l^{-1}$ NaCl).

Results: The results obtained demonstrate that under high saline power, a very significant increase in the activities of organic osmolytes compared to the control. The accumulation of the latter increases with increasing salt concentration, in the three durum wheat genotypes and for all parameters studied.

Conclusion: Therefore, we notice that osmo-regulation/osmo-protection is one of the effective manifestations for tolerance to the salinity stress. In this context, the improvement of genotypes tolerant to high thresholds of soil salinity constitutes a sustainable solution for the development and adaptation of cereal cultivation.

Keywords : Biochemical markers, osmo-protection, salinity, tolerance, *Triticum durum*.

ÉVALUATION DE LA TOLÉRANCE À LA SALINITÉ PAR LA SYNTHÈSE FOLIAIRE DES OSMOPRETECTEURS NATURELS CHEZ LE BLÉ DUR (*TRITICUM DURUM* DESF.) À UN STADE JUVÉNILE

Résumé

Description du sujet : Les caractéristiques climatiques des zones céréalières en Algérie, font que la culture du blé dur (*Triticum durum* Desf.) se trouve exposée aux différents stress environnementaux défavorables, principalement dans des régions à climat arides et semi-arides, dont le phénomène de la contrainte saline, qui représente une grave menace pour le rendement agricole et la sécurité alimentaire.

Objectifs : Pour répondre à cette préoccupation majeure, s'inscrit la présente contribution, qui vise pour objectif, d'explorer les différentes aptitudes biochimiques d'adaptation au stress salin chez le blé dur.

Méthodes : L'étude a portée sur trois variétés de blé dur cultivées en Algérie (Citra, Oued Zenati et GTA Dur) au stade juvénile, pour l'identification des marqueurs biochimiques de tolérance à la salinité, à savoir la teneur en proline, sucres solubles, protéines totales et composés phénolique totaux. La salinité a été induite par l'application de concentrations croissantes de sel de l'ordre de (0 $g.l^{-1}$, 9 $g.l^{-1}$, 12 $g.l^{-1}$ and 15 $g.l^{-1}$ NaCl).

Résultats : Les résultats obtenus démontrent que sous une forte puissance saline, une augmentation significative des activités des osmolytes organiques par rapport au témoin. L'accumulation de ces derniers augmente au fur et à mesure avec l'augmentation de la concentration saline, chez les trois génotypes de blé dur et pour tous les paramètres étudiés.

Conclusion : De ce fait, nous remarquons que l'osmo-régulation/l'osmo-protection est l'une des manifestations efficaces pour la tolérance à la contrainte salinité. Dans ce contexte, l'amélioration des génotypes tolérants à des seuils élevés de salinité des sols constitue une solution durable pour le développement et l'adaptation de la culture céréalière.

Mots clés : Marqueurs biochimique, osmo-protection, salinité, tolérance, *Triticum durum.*

*Auteur correspondant: ZIAT Nour El Houda, E-mail: malak23nourhouda@gmail.com

INTRODUCTION

The Cereals and their derivatives occupy a privileged place in the agricultural system, and constitute the most important food resource of humanity and animals on a global scale [1]. From an economic point of view, Wheat is considered the most cultivated cereal in the world [2] and constitutes the staple food for the majority of the inhabitants of the planet [3]. According to [4], currently the wheat crop represents 220.11 million hectares and 749.46 million tons. In Algeria, cereal products, in particular wheat, occupy a strategic place in the food system and in the national economy [5]. According to Chaise et *al*. [6], The edapho-climatic characteristics of cereal production areas in Algeria mean that wheat cultivation is generally vulnerable to several harmful environmental constraints in particular, the salinization of cultivated soils, which can occur according to four essential processes, namely; the rise of salt from the water tables by capillarity, the use of salt water for crop irrigation, salt sedimentation caused by rain and solutes transported by the wind [7 and 8]. It is considered to be one of the most widespread environmental stresses that considerably limit and affect the development and productivity of plants, following soil degradation in several regions of the world [9 and 10]. In addition, about a third of irrigated areas in the world suffer from salinity problems [11] and the globe loses 10 hectares of cultivable areas per minute, including 3 hectares due to this constraint [12]. In response to salt stress, plants adopt multiple mechanisms, which they combine to be able to adapt to stresses [13], and depend on their genotypes, salt density, growing conditions and the stage of development of the plant [14]. In addition, the introduction of tolerant plants is an often recommended alternative strategy [15]. In this context, the essential objective of this contribution is to evaluate the biochemical behavior of some durum wheat varieties, with the aim of highlighting the adaptive strategies of seedlings at a juvenile stage, based on the evaluation of some osmoprotection markers associated with salt tolerance, which can be used as selection criteria and improvement of the best tolerant genotypes in durum wheat in the face of salt stress.

MATERIALS AND METHODS

1. Plant material

Durum wheat (*Triticum durum* Desf.) From the *Poaceae* family, being the most widely cultivated cereal in the world, we have chosen it as biological material to conduct our study. The work focused on three varieties of durum wheat grown in Algeria namely; (V1: Cirta), (V2: Oued zenati) and (V3: Gta dur) (Table 1), durum wheat seeds were generously provided by the Technical Institute of Field Cultures (ITGC), El Khroub station, Constantine – Algeria. The experiments are carried out at the Genetic and Plant Breeding Laboratory, National Agronomic Institute of Tunisia (INAT), Department of Agronomy and Biotechnology, Tunis, Tunisia.

2. Conduct of the test

The test was carried out in 36 plastic pots 25 cm in diameter and 20 cm in height (12 pots for each variety); in a completely randomised experiment with increasing concentrations of NaCl (C_0, C_1, C_2, C_3) and three replicates (R_1, R_2, R_3) for each concentration, in favourable ambient conditions of temperature and humidity. The pots containing a layer of fine gravel were filled with a mixture of sand and potting soil (organic matter in proportions of 1/3 potting soil and 2/3 sand). We have previously ensured a good state of hygiene for the seeds of the durum wheat varieties studied throughout our work, are chosen carefully before use, they must be healthy and have no visible abnormalities. The selected seeds of each variety are pre-soaked in lukewarm water for 4 hours, then sterilized for 2 to 3 minutes in diluted sodium hypochlorite, then they are thoroughly rinsed with distilled water. After potting, irrigations of 250 ml of tap water are applied to all the pots, which corresponds to the field capacity. At the four-leaf stage, the prepared saline solutions are carried out for 15 days by performing two irrigations per week. The four salt concentrations used are: *(i)* Concentration 1 (C_0): control (without addition of NaCl), *(ii)* Concentration 2 (C_1): salinity based on NaCl at (9 $g.l^{-1}$), *(iii)* Concentration 3 (C_2): salinity based on NaCl at (12 $g.l^{-1}$), *(iv)* Concentration 4 (C_3): salinity based on NaCl at (15 $g.l^{-1}$).

Table 1 : Characteristics and origins of the durum wheat varieties studied [16 ; 17; 18].

Variety	Origin	Morphological characteristics	Technological characteristics
(V1) Cirta	Algeria (Constantine)	Plant with white spike, strong tillering. Dull yellow grain, small and elongated.	- Semi–early variety. - Tolerant to cold. - Drought tolerant. - Quite resistant to lodging. - Quite resistant to speckling and mitadinage. - Average PMG. - Crossbody quality: average. - Productivity: good.
(V2) Oued zenati	Algeria (Guelma)	A compact, white-spiked plant with black, long beards. Amber grain, large and slightly elongated, with high straw (1.30 m in favorable conditions) and full, with broad, drooping leaves, medium tillering.	- Late variety. -Tolerant to septoria. - Susceptible to brown rust and fusarium. - Quite resistant to speckling and mitadinage. - High PMG. - Crossbody quality: good. - Productivity: average.
(V3) Gta dur	CIMMYT (Mexico) *Gaviotadurm*	Plant with white spike, compact, medium straw, strong tillering.	- Early variety. - Resistant to cold. - Drought resistant. - Moderately resistant to lodging. - Resistant to fusarium, tolerant to brown rust. - Crossbody quality: good. - Productivity: good.

3. Laboratory analyzes

These mechanisms were chosen because of their explanatory utility for adaptation to environmental stresses, especially salinity.

3.1. Determination of proline

The method used to determine proline accumulation is that of Monneveux & Nemmar [19], which consists of taking 100 mg of the plant material, then adding 2 ml of 40% methanol, the whole being heated to 85°C in a water bath for 60 min. After cooling, 1 ml of extract is taken and 1 ml of acetic acid (CH_3COOH) is added; 25 mg of ninhydrin ($C_6H_6O_4$) and 1 ml of a mixture containing: 120 ml of distilled water; 300 ml of acetic acid; 80 ml of orthophosphoric acid. The solutions are boiled for 30 minutes at 100°C, they turn red; after cooling, 5ml of toluene is added, after stirring two phases separate: a lower phase without proline and an upper phase which contains proline, the latter is then recovered and dehydrated by the addition of $NaSO_4$. Calibrating the device, the optical density is determined using a spectrophotometer at a wavelength of 528 nm.

3.2. Determination of total protein

The total protein content is determined by the Bradford method [20], based on the Coomassie Brilliant Blue reagent (G250) to proteins at basic and aromatic residues. 100 mg of plant material are ground in a mortar with 5 ml of distilled water until a green solution is obtained. The solution obtained is filtered through Wattman paper, then the filtrate is poured into a test tube with 5 ml of distilled water (the level of distilled water is 10 ml). This is the solution to analyze. 2 ml of Bradford's reagent are added to 0.2 mL of the solution to be analyzed. Then the tubes are vortexed. After 5 min, the absorbance is then measured with a spectrophotometer at a wavelength of 595 nm, using Bovine Serum Albumin (BSA) as the standard.

3.3. Determination of soluble sugars

Total soluble sugars are determined according to Shields & Burnett [21], using the anthrone method in sulphuric medium to determine the amount of total reducing and hydrolysable carbohydrates. This method involves the extraction of a 100 mg sample weight (FM). 3 ml of 80% ethanol is added and left at room temperature for 48 hours. The ethanol is then evaporated and 20 ml of distilled water is added. 2 ml of extract is taken and 4 ml of anthrone is added. The reading is taken with a spectrophotometer at a wavelength of 585 nm after calibration of the apparatus.

3.4. Determination of total phenolic compounds

The determination of phenolitic compounds was carried out with reference to the protocol of Singleton et *al*. [22]. 500 mg of plant material was cold-ground in 2 ml of methanol at 80% concentration. The resulting grind was centrifuged at 1000 rpm for 10 min. A volume of 100 µl of the supernatant was taken and transferred to 15 ml Falcon tubes to which 1750µl of sterile distilled water, 250 µl of Folin-Ciocalteau reagent, and 50 µl of sodium carbonate Na_2CO_3 (20%) were added. The reaction mixture was then incubated in a water bath at 40°C for 30 min. After calibrating the apparatus, the optical density was determined at 760 nm.

4. Statistical analysis of data

Using the specific MINITAB version 16 software for statistical analysis and processing of data, we used the following statistical tests, to assess the significance of the different means, for each variable and for each of the four concentrations used.

The analysis of variance test (ANOVA) with a criterion or a classification factor, consists in comparing the means, between them, of the four concentrations of NaCl and this for each of the characteristics and for each durum wheat genotype studied. , using data from simple and independent random samples. The TUKEY test was used to determine groups of means or homogeneous concentrations for each characteristic and each variety of durum wheat.

RESULTS

The results obtained from the analysis of variance with two ANOVA classification criteria, presented in (Table 2), relating to the different increasing concentrations of salinity for each variety, show that there is a positive correlation between the average doses of NaCl applied C1 (9 g L^{-1}), C2 (12 g L^{-1}) and C3 (15 g L^{-1}), compared to the control C0, for the three durum wheat varieties tested (Cirta, Oued zenati and Gta dur) and for all the parameters studied (proline, soluble sugars, total proteins and total phenolic compounds).

Table 2: Results of the analysis of variance (ANOVA) with two classification criteria applied for the comparison, between the different concentrations, on the three varieties of durum wheat for all the parameters studied.

Variables	Variety	Source of variation	Ddl	SCE	CM	F_{obs}	*p*
Proline	V1	Traitements	3	2077.43	692.48	230.75	0.000***
	V2	Traitements	3	602.11	200.70	186.03	0.000***
	V3	Traitements	3	1623.90	541.30	182.29	0.000***
Total proteins	V1	Traitements	3	50.379	16.793	5.23	0.027*
	V2	Traitements	3	334.66	111.55	33.43	0.000***
	V3	Traitements	3	297.973	99.324	12.25	0.002**
Soluble sugars	V1	Traitements	3	1239.29	413.10	46.88	0.000***
	V2	Traitements	3	5445.6	1,815.2	38.31	0.000***
	V3	Traitements	3	2032.50	677.50	21.90	0.000***
Total phenolic compounds	V1	Traitements	3	48.480	16.160	31.53	0.000***
	V2	Traitements	3	54.147	18.049	18.14	0.001**
	V3	Traitements	3	6.7757	2.2586	5.33	0.026*

Ddl: the number of degree of freedom, SCS: the sum of squared differences, CM: the middle square, F_{obs}: the observed value of the variable F FISHER, P: the probability. V1: Cirta, V2: Oued zenati, V3: Gta dur. *: Significant difference compared to the control ($p \leq 0.05$). **: Highly significant difference compared to the control ($p \leq 0.01$). ***: Very highly difference compared to the control ($p \leq 0.001$).

1. Proline

The proline content extracted from leaves of durum wheat seedlings is shown in (Fig. 1). It is considered as a perfect indicator, widely used for the understanding of the tolerance state of plants to saline stress. A very highly significant ($p \leq 0.001$) positive correlation of the salt effect on proline content was displayed by the analysis of variance for all studied durum wheat cultivars (Table 2). This accumulation is low in the control lots, compared to the salt-stressed lots, which reach maximum values of 45.35, 31.30 and 42.47 µg.g^{-1} FM for the most severe NaCl concentration (15 g.l^{-1}) respectively in the three varieties. The Cirta variety represents the highest levels in plants treated with saline concentrations, whereas the Oued Zenati variety records the lowest amounts of proline in stressed seedlings, especially at the C1 level (20 µg.g^{-1} FM).

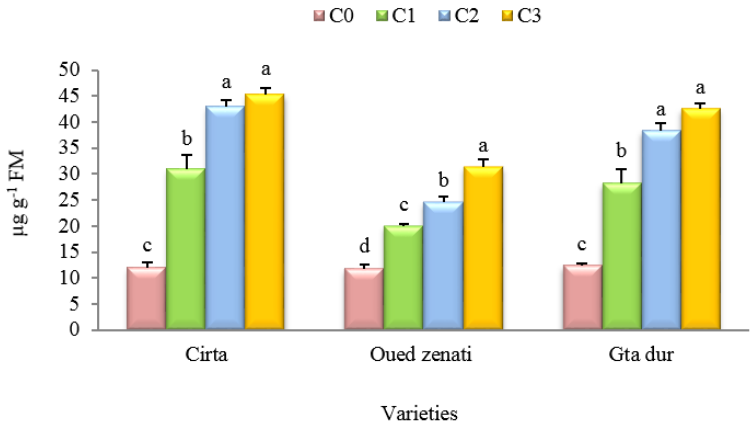

Figure 1: Effect of the different concentrations of NaCl on the proline content in the three varieties of durum wheat at the juvenile stage.
C_0: control, C_1: 9 g.l^{-1}, C_2: 12 g.l^{-1}, C_3: 15 g.l^{-1}, FM: fresh material.

2. Total Proteins

The results reported in (Fig. 2), show a remarkable accumulation of total proteins following the intensification of salinity in the culture medium. The analysis of variance with two classification criteria (table 2), reveals the existence of a very highly significant difference (p=0.000) as a function of increasing NaCl concentrations in the oued zenati variety, which records the highest levels, especially for the most restrictive concentration C3 (29.33µg.g^{-1} FM). Thus, in the Gta dur cultivar moderate doses of salt cause a highly significant (p = 0.002) increase from 11.09 µg.g-1 in controls to 21.78 µg.g^{-1} in the highest C3 dose. However, this increase becomes significant for the cirta variety (p=0.027) and varies from 12.71, 15.62 up to 17.31 µg.g^{-1} FM for the C1, C2 and C3 doses respectively, compared to the control lots (12.37 µg.g^{-1} FM).

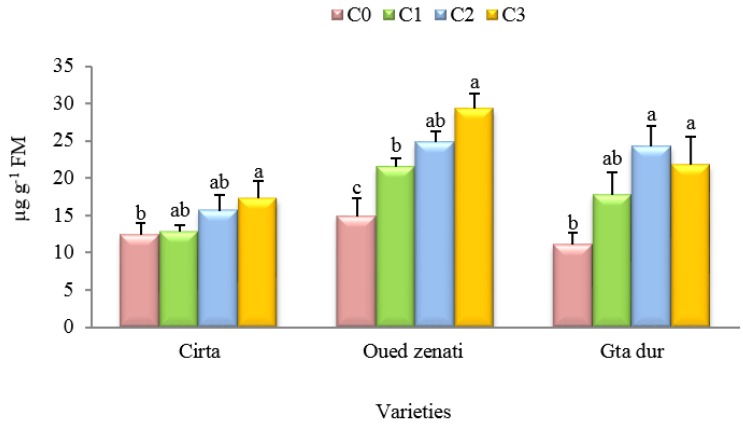

Figure 2 : Effect of the different concentrations of NaCl on the total protein content in the three varieties of durum wheat at the juvenile stage.
C_0: control, C_1: 9 g.l^{-1}, C_2: 12 g.l^{-1}, C_3: 15 g.l^{-1}, FM: fresh material.

3. Soluble sugars

The results presented in (Fig. 3), show the leaf soluble sugar content as a function of stress severity.The analysis of variance reported in (Table 2), reveals a very highly significant positive correlation (p≤0.001) on leaf soluble sugar content according to the different salinity treatments used (9 g.l^{-1}, 12 g.l^{-1} and 15 g.l^{-1}). This sharp increase pass from 21, 26.25 and 20.08 µg.g^{-1} FM in control seedlings to 48.66, 81.5 and 56.08 µg.g^{-1} FM in stressed seedlings respectively for the three genotypes. The oued zenati variety recorded the highest levels especially for the high concentrations C2 (64.91µg.g^{-1} FM) and C3 (81.5µg.g^{-1} FM).

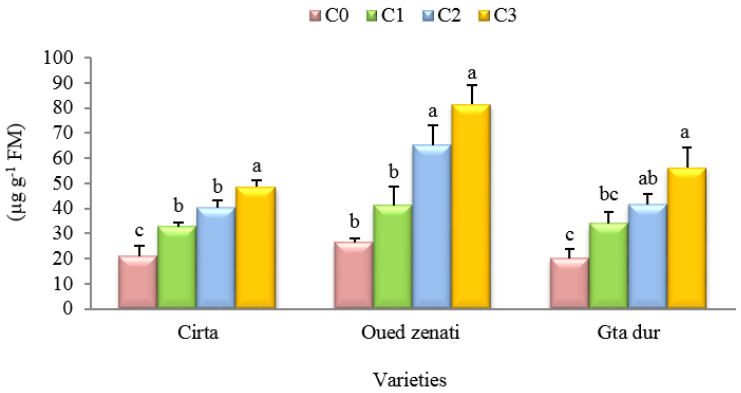

Figure 3 : Effect of the different concentrations of NaCl on the soluble sugars content in the three varieties of durum wheat at the juvenile stage

C_0: control, C_1: 9 g.l^{-1}, C_2: 12 g.l^{-1}, C_3: 15 g.l^{-1}, FM: fresh material.

4. Total phenolic compounds

The results obtained (Fig. 4) show that the different concentrations of NaCl (9, 12 and 15 g.l^{-1}) have a positive effect on the accumulation of total phenolic compounds which are considered as stress adaptation metabolites in plants. According to the analysis of variance (Table 2), the effect of salinity was found to be statically very highly significant ($p \leq 0.001$) for the two varieties cirta and oued zenati, varying from 2.12 and 2.08 mg.g^{-1} FM respectively in the controls to 7.35 mg.g^{-1} FM for the C2 dose in the cirta genotype and 7.18 mg.g^{-1} FM in the oued zenati genotype for the high C3 dose. While, for the variety Gta dur, a slight significant increase (p=0.026) in phenolic compound content is recorded in salt-fed plants which increases to 5.19 mg.g^{-1} FM for the concentration 15 g.l^{-1}.

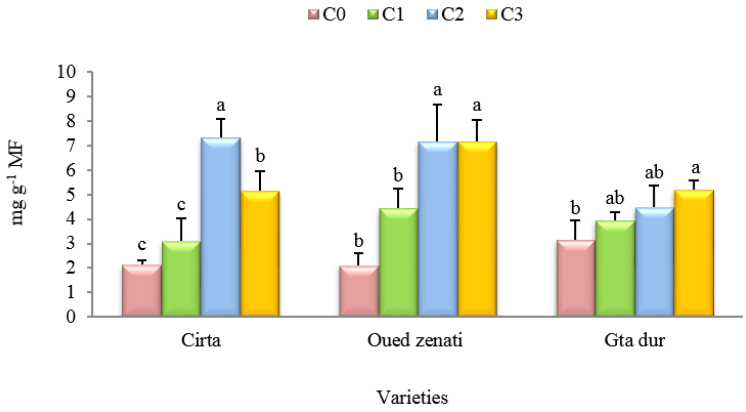

Figure 4: Effect of the different concentrations of NaCl on the total phenolic compounds content in the three varieties of durum wheat at the juvenile stage.

C_0: control, C_1: 9 g.l^{-1}, C_2: 12 g.l^{-1}, C_3: 15 g.l^{-1}, FM: fresh material.

DISCUSSION

Our study targets the evaluation of the biochemical reflexes of seedlings of three selected durum wheat genotypes in the face of salt stress. In the light of the results obtained and supported by the statistical analysis, it can be seen that, at the level of the leaves, the different salinity thresholds cause the gradual increase of natural compatible solutes (proline, soluble sugars, total proteins and total phenolic compounds) in all varieties in our trial at the juvenile stage. These large foliar increases in the amount of osmoprotectants correlate positively with the concentrations of NaCl applied (Fig.1, 2, 3 and 4).

It can be seen that the phenomenon of osmoprotection is considered to be an important tool for screening the protection and tolerance in plants against abiotic stresses in general, salinity in particular. In general, it is noted that the three durum wheat genotypes studied used the same defense mechanisms against salt stress with different degrees. This explains the adaptive capacities adopted by these plants and which may have classified them as tolerant species based on these responses. One of the strategies for adapting to salt stress consists of synthesizing osmoregulatory compounds [23], mainly compatible organic solutes to counteract the effect of salt [24].

This synthesis of osmoticum under salinity could be useful for osmoprotection, membrane balance [25], adjustment of osmotic pressure and maintenance of the potential for cell turgor [26], as well as the activation of antioxidant systems [27].

First, proline is an amino acid used as a selection element in the face of stress in general [28]. Accumulation of proline in leaf tissue is an adaptive measure [29]. According to [30], it is one of the main non-enzymatic antioxidants for preventing salinity inhibitory impacts on plants. In addition, proline has been suggested as a stabilizer of proteins and macromolecular complexes, scavenger of free radicals and moderator of cellular redox potential [31]. In addition, proline levels increase rapidly in many plants to maintain the osmotic adjustment between the cytoplasm and the vacuole [32]. The results obtained from our study reveal that under salinity conditions, the leaves of durum wheat seedlings responded by accumulating high levels of proline. The results of Djebar et *al.* [33], illustrate that the salinity causes a rise in the level of proline three times more in the stressed durum wheat seeds compared to the control seeds. These are also confirmed by the results of [34], which shows that the proline content increases with increasing salt dose in two genotypes of soft wheat. According to Abd El-Baki et *al.* [35], the effect of different levels of NaCl used, leads to an increase in the proline content in the shoots and roots of bean plants. Also, the work of Abbad et *al.* [36], shows that the NaCl salt causes the accumulation of large amounts of proline in both aerial and root parts in seedlings of (*Solanum lycopersicum* L.). Several other studies are consistent with our study, and approve the stimulation of proline in species subjected to salt stress such as Atlas pistachio tree [37] and the rice [38].

On the other hand, soluble sugars are involved in the defense mechanisms against several types of stress [39 and 40]. According to Lepengue et *al*. [41], the salt stress alters cell compartmentalisation in favor of the accumulation of soluble sugars. In addition, sugars play several essential roles in stressed plants. They prevent dehydration of plasma membranes [42], also, they act as molecular signals for the regulation of different genes [43]. According to Hacini & Brinis [44], genotypes that have accumulated high levels of sugars are thought to be the most tolerant to stress. Indeed, our results which bring an ascending accumulation of soluble sugars associated with salinity, are also corroborated by the work of Benderradji [45], on soft wheat, which shows that the accumulation of soluble sugars increases under the influence of salinity for the salinity/variety reaction. According to Brahimi Rahimi [46], the leaves of all varieties of *Triticum aestivum* L under salt stress accumulate more sugars than controls. This has also been reported by Mona et *al*. [47], which shows that the salt stress caused an increase in the amount of soluble sugars in bean seedlings. In addition, the results obtained by Chebbi et *al*. [48], illustrate that salt stress causes a very high accumulation of soluble sugars in the leaves and roots of fenugreek (*T. foenum-graecum* L.). Also, the work of Gharabi [49], on *Olea-europea* clearly shows a significant increase in the levels of soluble sugars under the effect of salinity. In addition, these results are also confirmed by the research of Noiraud et *al*. [50], carried out on celery (*Apium graveolens* L.), [51] on lentils (*Lens culinaris* L.*)* and [52] on okra (*Abelmoschus esculentus* L.).

Furthermore, soluble protein synthesis is well documented for abiotic stresses especially salt stress [53]. According to Jangpromma et *al*. [54], the alteration of metabolism during stress in plants leads to a change in protein expression. This accumulation is associated with the onset of phosphorylation as well as protein kinases (MAPKs) involved in signal transduction and induction of plant protection responses [55], moreover, it plays the role of an osmotic regulator to salinity [56]. The results obtained by Ben Kaddour [57], indicate that the significant accumulation of proteins in the leaves of durum wheat is influenced by the different doses of NaCl compared to controls, which is supported by the results obtained from our work. Also, Brinis [58], deduced that total proteins are considered as a criterion of tolerance to salinity in *Atriplex canescens*. According to Mohamed et *al*. [59], under salinity the shoots and roots of *Vigna unguiculata* L. accumulate high levels of total soluble proteins in comparison with the control. These results are in agreement with the work of Ouis [60], who demonstrates that the contents of soluble sugars increase with treatment by salinity in the leaves and roots of *Abelmoschus esculentus* plants. In addition, these results are in agreement with the experience of Agastian et *al*. [61], on mulberry trees.

Regarding phenolic compounds, it has been described that the accumulation of these has been caused in plants in response to various biotic and abiotic stresses [62].

They exhibit several antioxidant properties necessary to stop the actions of free radicals [63] and keep a low cellular ROS content, which reflects the resistance of plants to salinity [64]. In addition, they have a membrane stabilization capacity associated with phospholipids and essential membrane proteins [65]. Our results show that salinity positively increased the content of total phenolic compounds in the three durum wheat varieties studied. This was also mentioned by Lepengue et *al.* [66], who demonstrated a remarkable foliar increase in phenolic compounds in roselle (*Hibiscus sabdariffa* L.) plants treated with salt. Also, Faghire [67], suggests that the accumulation of phenolic compounds in beans may participate in the protection of the plant against salt stress. Another explanation has been put forward by Acila & Allioui [68], which results from a very significant content of total phenolic compounds in the leaves of two varieties of radish exposed to soil salinity. In addition, Mousa [69], explains that the salt constraint causes the synthesis of phenolic compounds in the Mushroom (*Pleurotus ostreatus*). The same results are also reported in barley [70] and maize [71].

CONCLUSION

This contribution is conducted to analyse some biochemical manifestations to the stress implied by the saline constraint, which allowed to appreciate the adaptive aptitudes and which translates into the accumulation of natural organic solutes, in three genotypes of durum wheat Triticum durum grown in Algeria. Salt stress elicits a variety of responses that result from alterations in cell metabolism. On the one hand, Understanding, verifying and confirming adaptation parameters in wheat are considered fundamental steps in the search for and selection of the most tolerant varieties to salt stress. On the other hand, the improvement and stability of productivity in regions with arid and semi-arid climates. In this context, the selection of tolerant genotypes assisted by biochemical aspects stands out as an essential alternative.

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