

Effect of Salinity on Grain Yield and Quality of Wheat and Genetic Relationships among Durum and Common Wheat

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Abstract: Salinity is a big constraint to crop quality and production. In the major wheat growing region of the world, wheat growth, yield and quality are affected by salinity. To solve this problem it is necessary to breed tolerant varieties through selection and breeding techniques. The objective of the present study was to determine the salinity impact on grain yield, protein content and thousand kernel weight (TKW) among 55 varieties and accessions of common and durum wheat (16 winter wheat varieties and 39 spring wheat accessions). The results showed that salt treatment (100 mM of NaCl solution) depressed growth and yield production in 45 common and durum wheat varieties. While 6 varieties of durum wheat, 3 accessions of durum wheat and 1 accession of common wheat were insignificantly affected by salinity. Among them were 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 finally the Morocco 85 accession of common wheat from Morocco. The decrease in grain yield might be caused by the salinity, which induced reduction of photosynthetic capacity leading to less starch synthesis and accumulation in the grain. In addition the results showed that winter wheat is more tolerant to salt stress than spring wheat and that durum type of wheat showed more tolerance than common wheat. Moreover it appeared that salt accumulation increased protein content in five varieties and one accession of durum wheat. This variation maybe related to the relatively stable nitrogen metabolism under salt stress, which might contribute to the higher protein concentration. TKW also decreased in all 10 varieties and accessions regardless of the species. Also the variation in response to salt of the varieties and accessions was closely related to genetic diversity among these species. Indeed Simple Sequence Repeat (SSR) markers showed the presence of two groups, African-European complex and African-Asian complex of wheat.

Key Words: Bread wheat, Durum wheat, Protein content, Salt tolerance, SSR markers

1. Introduction

Food shortage and water deficit are the greatest problem discussed nowadays, and it is linked to both with population growth and water allocation to different sectors, such as domestic, agronomic and industrial uses. According to the FAO Land and Plant Nutrition Management Service, over 6% of the world's land is affected by either salinity or sodicity. Moreover the low water quality and the poor drainage systems are the greatest causes of these stresses, and this problem is more acute with higher evaporation, especially in arid and semi arid zones, where saline soils are widespread that induced the decreasing of land productivity in many countries over the world (Atlassi *et al.*, 2009). Furthermore salinity affects soil fertility and due to these situations some solutions were taken to reduce this problem through soil reclamation or growing tolerant species; however, soil reclamation is a very expensive process, and then the selection of tolerant varieties of crops is still the most practical solutions when salinity is low.

Besides, a genotypic difference within and between plant

species was noted related to the response of plants to salt stress (Saudi *et al.*, 2003).

In this study, genetic variation and salt tolerance of wheat genotypes were investigated as result of treatment with a nutrient solution of NaCl. In addition, the effect of salinity on grain yield, protein content and thousand kernel weight (TKW) were determined. Moreover, genetic diversity among two wheat species was studied by using Simple Sequence Repeat (SSR) markers

2. Materials and Methods

2.1. Plant material

A total of 55 varieties and accessions of durum and common wheat were used in this experiment where 16 were winter wheat and 39 were spring wheat accessions. The experiments were conducted at the glass house. Winter varieties were sowed on December, 2009 however spring accessions were sowed on April, 2010. The experiments were carried out in pots as 10 seeds per pot. After emergence, all accessions are thinned on 6 plants per pot.

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2.2. Salt stress induction

3 to 4 leaves salt treatment was applied during different ontogenetic stages under various concentrations (0 and 100 mMol). Electrical Conductivity (EC) was measured by using EC meter.

2.3. Different traits

2.3.1. At seedling stages

Chlorophyll content was measured 21 days after salt treatment by using SPAD-502 Chlorophyll Meter which provides rapid and non destructive measurements of leaf chlorophyll content.

2.3.2. At tillering stage

In this stage tiller's number were taken among accessions and varieties under control conditions compared to untouched treatment and also leaves number per tiller were determined.

2.3.3. At maturity stage

Spikes number and seeds number per spike: these traits were calculated to evaluate the salinity effect on yield.

2.3.4. Quality analysis

Thousand kernel weight (TKW) in g: the high weight of 1000 kernel is considered relevant to semolina yield. The weight was determined with manual count of 100 seeds after removing handpicking broken kernels and others impurities. The weight of 100 kernels was multiplied by 10 to have the 1000 kernels weight.

Protein's concentration (in $\mu\text{g/ml}$): total protein was quantified by using BCA protein Assay Kit.

2.4. Genetic relationships among durum and common wheat

2.4.1. DNA extraction

High quality genomic DNA was extracted from leaves (stage 4-5 leaves) using the cetyl-trimethyl-ammonium bromide (CTAB). The DNA concentration was adjusted to 20 ng/ μl . SSR markers Wmc and Gwm markers were used to detect polymorphism among 55 varieties and accessions of durum and common wheat

2.4.2. Statistical analysis

Statistical analysis was performed using JMP software. To compare means values student test was used. Levels not connected by same letters are significantly different. To show the relationships between different genotypes, a clustering dendrogram was drawn using NTSYS software.

3. Results and discussion

3.1. Seedling stage

All genotypes were watered until stage 3 to 4 leaves; Under standard growth conditions, salt treatment was applied under two concentrations (0 and 100 mMol). In seedling stage,

chlorophyll content changed with two main factors: genotypes and NaCl concentration. Most of species ranged from highly tolerant to salt stress as for Nasr (V13) variety from Tunisia to low tolerant, such as variety: Carioca (V6) from Italy. Some species are medium tolerant to salt stress such as variety Sculptur (V3) from France. According to some researchers, salinity reduces net photosynthetic rate, transpiration rate, and stomatal conductance in plant species, increases chlorophyll content at low salinity and degrades chlorophyll at high salinity (Ashraf, 2004). Our statistical analysis (student test) mentioned that the decrease of chlorophyll content is significant in sensitive genotypes compared to high tolerant. These findings are in agreement with results of many researchers, who made similar conclusion (Khan *et al.*, 2009).

3.2. Tillering stage

In some species the number of tillers decreased strongly with the acuteness of salt stress load that is the case for V13 and V16 varieties concerning winter type for V45 and V51 varieties concerning spring type. Concerning common wheat, tiller's number decreased from 5 to 3 tillers per plant which is the case of the varieties V74, V76, V83, V86, V88, V126, V128, V131 and V225; and it decreased from 5 to 2 tillers in the case of the variety V187. However in the case of durum wheat, the number of tillers under salt stress ranged from 3 (in the case of the varieties: V1, V2, V6, V12 and V14) to 8 (in the case of V9). In the same concept, Nicolas *et al.* (1994) found that salt stress during tiller emergence can inhibit their formation and can cause their abortion at later stages. Furthermore, when salinity levels are greater than 7.5 dSm^{-1} or 50 mM NaCl, most of the secondary tillers of moderately tolerant genotypes were eliminated, and their number was greatly reduced (Hendawy *et al.*, 2005).

Statistical analysis of the data revealed that tiller's number was significantly ($P < 0.05$) affected by NaCl concentration's; wheat genotypes as we have described showed a considerable decreasing in tiller's number among sensitive genotypes then among tolerant ones. Concerning leave's number per tiller, statistical analysis revealed that this trait was not significantly ($P < 0.05$) affected by various species and NaCl concentrations.

3.3. Maturity stage

In maturity stage, number of spikes was significantly ($P < 0.05$) affected both between species and by different salt concentration treatment.

Furthermore, this trait was highly correlated with the number of tillers. Based on the results revealed in our work, we can conclude that seed's number per spike increased with the acuteness of salt stress. Furthermore, seed's number per spike was calculated only among tolerant accessions and

varieties, where we notified a great reduction of this trait however, for the remaining this value was equal to Zero.

These results was explained by the way that NaCl stressed wheat during apex vegetative stage, had a shorter spikelet development stage that, resulted in fewer spikelets per spike which led to the reducing of the number of grains per spikes (Akram *et al.*, 2002).

3.3. Quality analysis

The results of this study mentioned that thousand kernel weight (TKW) is so much affected by salt stress among sensitive genotypes than tolerant ones. In our work, we concluded that TKW was strongly reduced among different genotypes. Furthermore, according to Wardlow *et al.* (1980), this trait is related essentially to the duration of grain development. In this concept, Gill (1979) showed in his work on barley that reduced grain yield under salt stress could be due to reduced efficiency per day to fill the grains and consequent more effective days and also due to disturbed starch-sugar balance.

Concerning protein content, this trait was very important to evaluate pasta and semolina quality. In this work, salt accumulation increased protein content in five varieties and one accession of durum wheat. The highest level of protein was indetified for the variety “Chryssodur” from Greece by 500 µg/ml. However, the lowest value was notified by the variety “Silur” from Italy by 180 µg/ml.

This variation of protein content was related to genetic diversity among different genotypes, in the same concept,

3.4. Genetic relationships among durum and common wheat

A total of 67 bands (alleles) on 55 genotypes (selected basely from different continents like Africa, Europe and Asia) were obtained by using 160 SSR markers as showed by **Table 1**; we selected 10 high quality polymorphic primer pairs from two sources and these primers were used for genotyping. The number of alleles ranged from 7 to 11 and the primer “GWM131” detected the highest number of alleles.

4. Conclusion

In this study, salinity induced variations in grain yield and quality were larger among sensitive genotypes then salt tolerant ones. These results suggested that breeding and the use of salt-tolerant wheat cultivars might be the most promising strategies for harvesting higher grain yield of best quality under saline conditions. Finally, results showed that winter wheat was more tolerant to salt stress then spring wheat and that durum wheat showed more tolerance than the common wheat and this variation was strongly related to the genetic diversity

Table 1. Number of screened SSR loci and number of alleles detected in durum and common wheat

Source of SSR	Not Polymorphic	Polymorphic	Number of alleles
WMC	100	4	28
GWM	60	6	39
Total	160	10	67

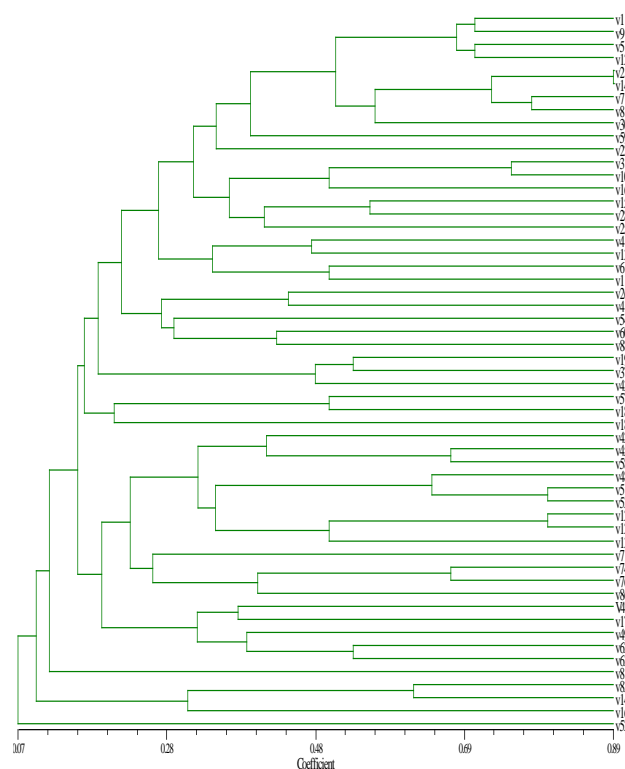


Fig. 1. Dendrogram of 55 wheat genotypes showing the genetic similarity based on 67 alleles detected by 10 SSRs using UPGMA cluster analysis

among these genotypes. In this concept appears the role of e-SSR markers in detecting polymorphism among different genotypes of wheat that become useful for assaying molecular genetic diversity.

In this study, many cases of null alleles were observed and according to some researchers Null alleles are common in wheat (Eujay *et al.*, 2001). To estimate genetic distance more accurately, combined analysis were carried out using all the SSR bands together. A clustering dendrogram (**Figure 1**) was drawn to show the relationships between different genotypes. Two main groups (A and B) were observed where the first one showed the clustering of genotypes of Africa and Europe and the second one included genotypes from Africa and Asia. We can conclude from this separation that African genotypes shared some alleles (similarity) with European and Asian genotypes. But European and Asian genotypes didn't show any similarity. The coefficient of similarity ranged generally from 0.26 to 0.81. Among winter wheat, this coefficient

ranged from 0.48 to 0.79 however among spring wheat, it ranged from 0.26 to 0.81. Also the similarity coefficient varied among the same species where it ranged from 0.27 until 0.8 in the case of durum wheat while it ranged from 0.27 until 0.81 in the case of common wheat. Based on this separation, we can conclude that African genotypes shared some alleles (similarity) with European and Asian genotypes. But European and Asian genotypes didn't show any similarity. Also in this study, winter wheat genotypes were selected in the first group where it was absent in the second one, however spring wheat genotypes was observed in both of these groups. To summarize these results, we can conclude that this separation between all genotypes was based essentially on geographical criteria otherwise it was difficult to separate between durum and common wheat.

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