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Variation in Response to Salt Stress at Seedling and Maturity Stages among Durum Wheat Varieties

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Abstract: Salinity is a significant constraint for crop quality and production, affecting wheat growth, yield and quality in the major wheat growing regions of the world. To counter this, it is necessary to develop tolerant varieties through selection and breeding techniques. The objective of this study was to investigate variation in response to salt stress among 119 worldwide landraces and improved varieties of durum wheat at seedling and maturity stages. The results showed that at seedling stage 100 mM NaCl decreased chlorophyll content, leaf length, number of tillers per plant, number of leaves per plant, shoot length and shoot fresh and dry weights, while at maturity stage plant height, the number of fertile spikes per plant and the number of seeds per spike were affected by 100 mM NaCl. The shoot fresh and dry weights were the most affected traits at seedling stage; however the number of fertile spikes and the number of seeds per spike were the most affected traits at maturity stage. These results reflected the importance of these traits for the assessment of salt tolerance in durum wheat varieties. On the basis of salt tolerance/susceptibility scale, most of tolerant varieties were originated from North African countries such as: Morocco, Egypt, Algeria and Tunisia and East African countries such as Ethiopia and Eritrea. Thirty-six highly tolerant and 16 highly susceptible varieties were evaluated in the saline area in the field. Results showed that tolerant varieties could grow and develop biomass under saline conditions. In contrast, susceptible varieties could not even emerge in the stressed condition.

Key Words: Durum wheat, Maturity stage, Salt stress, Seedling stage

1. Introduction

Wheat is the most widely growing cereal crop and occupies 17% of the total cultivated land in the world. It is the staple food for 35 percent of the world's population, and provides more calories and protein in the world's diet than any other crop. Salt stress appears to be one of the constraints for wheat production: more than 800 million hectares of land worldwide, or more than 6% of the world's total land area (FAO, 2008), are salt affected, severely impairing the agricultural production in many countries. Durum wheat is more sensitive to salt stress than bread wheat. Screening wheat for salt tolerance at the seedling and maturity stages has been performed by a number of different researchers (Akram *et al*., 2002; Khayatnezhad and Gholamine, 2011); however, achieving genetic increases in yield under salt stress has consistently proven a difficult challenge for plant breeders (Khayatnezhad *et al*., 2010). Further screening for salt tolerance and its validation in salt affected fields are still needed to better understand the mechanism of tolerance and to improve salt tolerance in wheat. The present study was conducted to identify some promising parental lines and morphological parameters, and to select tolerant and susceptible varieties at the seedling and maturity stages, with particular focus on their use for future breeding programs in durum wheat.

2. Materials and Methods

2.1. Plant materials

In order to study the effects of salinity stress at the seedling and maturity stages in durum wheat, two types of experiments were conducted using a completely randomized complete block design with two replications. In these experiments, 119 worldwide landraces and improved varieties of durum wheat were evaluated at two levels of salinity (0 and 100 mM NaCl).

The third experiment was conducted in the field using 52 varieties of durum wheat selected based on their high performance in tolerance/susceptibility to salt stress (36 were highly tolerant and 16 highly susceptible). In this experiment, we used a completely randomized design with three replications.

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2.2. Experiment at seedling stage

The seedling stage experiment was conducted in a glasshouse using perforated pots filled with soil. Salt was applied at the 3-leaf stage. Forty days later all plants were harvested and fresh and dry weights of shoots after drying all plants in oven for 72 hours at 70°C were recorded. Before harvesting, several traits were measured such as chlorophyll content using SPAD meter, number of tillers, number of leaves per tiller, shoot length and leaf length.

2.3. Experiment at maturity stage

The experiment was also conducted using perforated pots filled with soil. Salt was applied at booting stage and before this stage all plants were irrigated with tap water. During this experiment, different traits were measured such as plant height, the number of fertile spikes and the number of seeds per spike.

2.4. Field experiment

The experiments were carried out during the 2011-2012 growing season (1 year) in saline field of Seliana (region: Krib) in Tunisia (semi-arid). The surface layer (0-30 cm depth) of the soil had a silty clay loam texture. The electrical conductivity (EC) of the soil was around 8 dS m^{-1}. In this region, the mean of annual precipitation and temperature were given as 420 mm and 18°C, respectively.

Seeds of 52 varieties of durum wheat were sown in this soil and the traits recorded are the number of tillers per plant, number of leaves per plant, number of spikes per plant, number of seeds per spike, days from planting to heading, days from planting to flowering, plant height and 1000 grain weight.

2.5. Statistical analysis

The data were analyzed separately using ANOVA provided by JMP software, version 9 (SAS Institute Inc. 2010). Correlation analyses were conducted using Pearson correlation coefficient (r) to determine the relationship among all traits.

3. Results and Discussion

3.1. Salt effect on durum wheat at the seedling and maturity stages (Glasshouse experiments)

Salt stress induced a significant variation in plant growth during the experimental period. Under salt stress conditions, considerable reductions in various agronomic traits were observed in all varieties. At seedling stage, the chlorophyll content varied from 10.75% to 33.25%, with an average of 20% (**Fig. 1**). This trait was highly affected by salt stress with 35% reduction as compared with the control. High accumulation of sodium in plant tissues has been reported as an influential factor in the reduction of photosynthetic pigments and the rate of photosynthesis (Sairam *et al*., 2002; Ashraf, 2004). The oldest leaves showed chlorosis, and fell to the ground, as a result of a prolonged period of salt stress (Hernandez *et al*., 1995; Gadallah, 1999; Agastian *et al*., 2000), which affects the decrease of chlorophyll content in leaves.

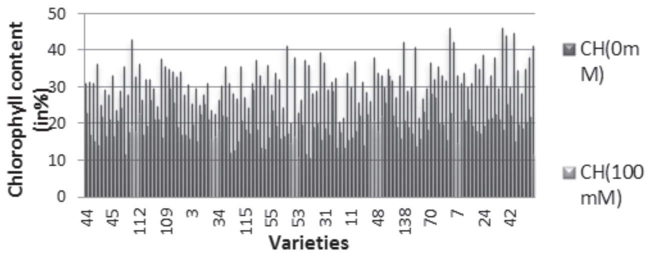

Fig. 1. Evaluation of chlorophyll content (CH) under salt stress.

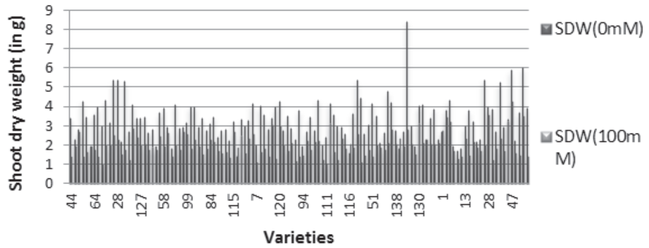

Fig. 2. Evaluation of shoot dry weight (SDW) under salt stress.

Shoot fresh and dry weights were the most affected traits with 48 and 42% reductions compared with the control respectively (**Fig. 2**). The reduction of these traits was previously reported by Singh *et al*. (1994) who found that alt stress reduces leaf area photosynthetic ability and dry matter accumulation. The number of tillers ranged from 3 to 12 with 6 on average, while under control conditions the average was 8. The reduction of the number of tillers in wheat under salt stress have been previously reported by El-Hendawy (2005) and Goudarzi *et al*. (2008). The number of leaves and the leaf length were less affected by salt stress with a reduction of 19 and 22%, respectively, as compared with the control.

The shoot fresh and dry weights were important for the assessment of salt tolerance in wheat because a positive correlation existed between these traits and yield related parameters. However, further verification is still needed to control the effect of salt stress at later stages.

The evaluation of final grain yield and of growth parameters determining grain yield is critical to breeding programs. The final yield of wheat is determined by the number of spikes per plant and various yield components, such as the fertile spikelet number, grain number, and grain weight. For instance, in this study the number of fertile spikes, ranging from 0 to 8, was highly affected by salt stress with 57% reduction as compared with the control. The reduction of this trait was reported by several studies such as Maas and Grieve (1990), Grieve *et al*. (1993) and Francois *et al*. (1994) who demonstrated that salt significantly reduced the number of spikelet primordia on the main spike.

The plant height was significantly ($p < 0.05$) decreased by salt stress. Under salt stress conditions, the mean values of this trait ranged from 43.5 to 103 cm with an average of 71cm. The reduction of plant height under salt stress conditions was also reported by Khan *et al*. (2007). The number of seeds was decreased to 56% as compared with the control. According to Francois *et al*. (1994) a reduction in floret viability seriously affected the total number of kernels per spike and this effect was more pronounced in susceptible than in tolerant varieties. The number of fertile spikes can be considered as one of the main traits to evaluate salt tolerance in wheat because only tolerant varieties could produce fertile spikes, while the susceptible ones produced sterile spikes. On the basis of tolerance/susceptibility scale, we designated varieties with a reduction of less than 25% in number of fertile spikes as a highly tolerant variety. Most of the varieties belonging to this group were originated from African counties such as Ethiopia, Egypt, Algeria, Morocco and Tunisia. However, further experiments in the field are required to confirm the stability of these varieties under salt stress conditions. Therefore, 52 varieties were selected for this field experiment based on the higher performance of tolerance/susceptibility to salt stress (36 selected as highly tolerant to salt and 16 as highly susceptible).

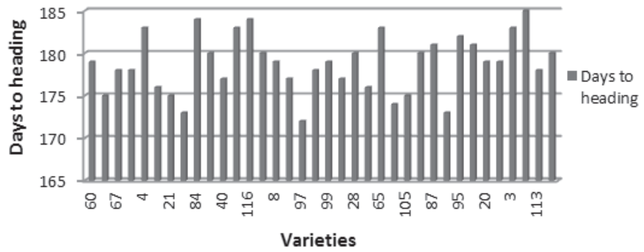

Fig. 3. Evaluation of days to heading under salt stress.

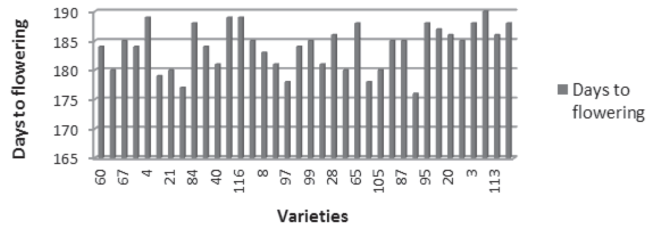

Fig. 4. Evaluation of days to flowering under salt stress.

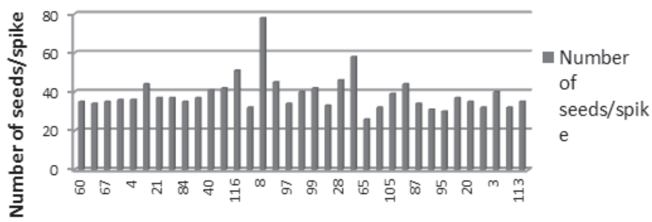

Fig. 5. Evaluation of the number of seeds per spike under salt stress.

3.2. Field experiment

In the previous experiments we demonstrated the importance of some traits such as shoot fresh and dry weights, number of fertile spikes and the number of seeds per spike for the evaluation of salt tolerance at seedling and maturity stages. Here, we will focus mainly on traits at maturity stage to check the stability of yield parameters under salt conditions, since improving the grain yield of wheat under salt stress is consistently the main target in plant breeding.

In this experiment, highly susceptible varieties originated mainly from Asian countries could not germinate. In contrast, the tolerant ones could grow and reach final stage of development.

The number of tillers ranged from 3 to 8 with 5 on the average and was highly associated with yield parameters. The plant height showed a significant ($p < 0.05$) correlation with yield components. Under salt stress conditions, this trait ranged from 65 to 110 cm with an average of 84.

Days to heading and days to flowering were recorded in this experiment in order to evaluate the effect of salt stress on the days to maturity. Results showed that the number of days to heading varied from 172 to 185 with an average of 179 days (**Fig. 3**), while the days to flowering ranged from 176 to 189 days with an average of 184 days (**Fig. 4**). Some varieties such as Trigo (97) from Peru had the lowest number of days to heading and this could be considered as a mechanism for tolerance to stress where plants matured fast to complete their life cycle.

Under saline field conditions, the number of spikes within tolerant genotypes ranged from 3 to 8 with an average of 5.3.The varieties durum 36-6 from Ethiopia (80) and Hercules from Canada (6) had the highest number of spikes under salt stress.

The number of seeds per spike ranged from 26 to 78 with an average of 39 (**Fig. 5**). The variety ELS 6404-126-3 (8) from Eritrea (East Africa) had the highest number of seeds per spike under saline field conditions. This variety is a candidate gene pool for improvement of salt tolerance in durum wheat.

Thousand kernel weight (TKW) was also recorded in this study and the mean value of this trait ranged from 18 to 60 with an average of 34. The variety Malta 2 (58) from Malta has the highest value of TKW under salt stress conditions which reflects the importance of this variety for the improvement of yield in durum wheat.

In this experiment, yield related traits such as the number of spikes, the number of seeds per spike and TKW were correlated with each other and with various other traits. Due to this correlation, these traits can be used as selection criteria for the assessment of salinity tolerance in durum wheat varieties under saline field conditions. Many scientists had classified crop species on the basis of grain yield under stress conditions (Sadiq *et al*., 1994; Jafari-Shabestari *et al*., 1995; Anderson *et al*., 1996). Ayers and Wescot (1976) reported that wheat yield decreased by 50 percent at soil saturation extracts of 13 dS/m. Durum wheat has a higher sensitivity to salt than bread wheat. The threshold at which grain yield starts to decrease with an increase in soil salt is 5.9 dS/m for durum wheat and 8.6 dS/m for bread wheat. Furthermore, the yield in durum wheat was decreased at a higher rate with increase in salt content in soil than bread wheat (Maas and Grieve, 1986; Acevedo *et al*., 2003).

4. Conclusion

The focus of this study was to select the varieties which exhibit less reduction of yield components under salt stress conditions. All the 36 varieties selected from the previous experiment in the glasshouse showed their ability to grown in saline field conditions and produce grain yield. However, some varieties which had the lowest reduction in several traits under stress conditions can be used for the improvement of salt tolerance in durum wheat. The variety Malta2 (58) from Malta is one of the important varieties in salt tolerance to be used in future breeding of durum wheat.

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