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Screening bread wheat genotypes for drought tolerance: Germination, radical growth and mean performance of yield and its components

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Abstract. Seed germination decreased as osmotic potential became more negative. Inhibition of seed germination was greatest under the lowest osmotic potential, -1.5 MPa. Cumulative germination after ten days ranged from 52.6 to 97.9% for the control compared to 27.4 to 69.8% at -1.5 MPa indicating more pronounced differences among genotypes at the lower osmotic potentials. Accordingly, ten bread wheat genotypes were selected and significantly varied for all traits tested under different irrigation treatments in each location. A reduction percentage for different studied traits under water stress treatments relative to control treatment was detected and susceptibility index (S) was also calculated for each genotype under severe water stress treatment. The superior lines numbers 27, 13, 15 and 5 had the highest grain yield/plant under severe treatment in both locations. The higher yielding capability of these genotypes obtained under drought stress may be primarily due to its higher yield potential under non stress conditions and maximize production of number of spikes/plant and number of grains/spike under water stress conditions. The main effect of irrigation treatments was not significant for susceptibility index (S) of grain yield/plant under both environments tested, indicating that S was not affected by increasing water stress intensity. S values ranged from 0.924 for G1 to 1.54 for the local check variety G10.

Keywords. Bread wheat – Rainfed – Drought stress – Cumulative germination – Susceptibility index.

Plan de criblage de génotypes de blé tendre résistants à la sécheresse : Germination, croissance racinaire et performances moyennes de rendement avec leurs composantes

Résumé*. La germination des semences diminue à mesure que le potentiel osmotique devient plus négatif. L'inhibition de la germination des semences a été plus grande dans le cadre du plus faible potentiel osmotique, - 1,5 MPa. La germination cumulée après dix jours variait de 52,6% à 97,9% pour le témoin contre 27,4% à 69,8% à -1,5 MPa, indiquant des différences plus marquées entre les génotypes aux potentiels osmotiques inférieurs. En conséquence, dix génotypes de blé tendre ont été sélectionnés et ont été très différents pour tous les caractères testés sous différents traitements d'irrigation à chaque endroit. Un pourcentage de réduction pour différents caractères étudiés sous traitements de stress hydrique, par rapport au témoin sans traitement, a été détecté et l'indice de sensibilité a également été calculé pour chaque génotype sous traitement de stress hydrique sévère. Les lignes supérieures Nº 27, 13, 15 et 5 avaient le plus haut rendement en grains / plante sous traitements sévères dans les deux endroits. La capacité de rendement plus élevée de ces génotypes obtenus sous conditions de sécheresse peut être due principalement à leur potentiel de rendement plus élevé en conditions de non stress et à la maximisation de la production du nombre d'épis / plante et du nombre de grains / épi en conditions de stress hydrique. Le principal effet des traitements d'irrigation n'était pas significatif pour l'indice de sensibilité (S) du rendement en grains / plante sous les deux environnements testés, indiquant que (S) n'a pas été affectée par l'augmentation de la contrainte hydrique. Les valeurs de S vont de 0,924 pour G1 à 1,54 pour la variété locale testeur G10.*

Mots clés. *Blé tendre – Non irriguées – Stress hydrique – Germination cumulative – Indice de sensibilité.*

I – Introduction

Wheat (*Triticum aestivum* L.) is the world's most important crop. A crop of wheat is harvested somewhere in the world during every month of the year (Briggle, 1980). Greater importance of bread wheat can be expected as a main source of food for the increasing populations of the world. It has many natural advantages as food providing almost 20% of the total calories of man's nutrient requirements. The decreasing gap between production and consumption necessitates increasing wheat production in Egypt. Increasing of cereal crops is an important national goal to face the increasing food needs of Egyptian population. The main objectives of the present study are: (i) screening and selection for laboratory characteristics (germination experiment) related to drought resistance; and (ii) evaluating performance and degree of stress tolerance of the ten selected bread wheat genotypes tested under suitable and soil moisture deficit conditions.

II – Materials and methods

1. Laboratory experiments

The germination experiments were carried out in betray dishes with tightly fitting lids in a germination chamber. The material used in this study included 30 bread wheat genotypes collected from different sources: 7 local landraces from North and Mid Sinai, 22 selected introduced genotypes from ICARDA, and the local check (Sakha 69) which was used as comparing variety. Mannitol was used as an osmotic substrate to prepare aqueous solutions having 0.5, 1.0 and 1.5 atmospheres of osmotic potential. The concentrations of mannitol were calculated from the following formula:

$$P = g\ R\ T/mV$$

where P = osmotic potential in atmosphere; g = grams of mannitol; R = 0.0825 liter atmospheres per degree per mole; T = absolute temperature; m = molecular weight of mannitol; V = volume in liters. The radical lengths of 25 seedlings were measured at the end of ten days.

In order to characterize the rate of seed germination in different osmotic potentials, results were expressed in terms of a promptness index (PI).

$$PI = [nd1\ (7 - D1)] + - - + [nd6\ (7 - D5)]$$

where D = number of the day of observation, counting as 0 the day on which the test was begun, nd = number of seeds observed to germinate on day of observation D. A germination stress index (GSI), as described by Bouslama and Schapaugh (1984), was expressed in percent as follows:

$$\frac{\text{Promptness index of stressed seeds (PIS)}}{\text{Promptness index of control seeds (PIC)}} \times 100$$

The data were analyzed as a randomized complete block design with four replications according to Gómez and Gómez (1984).

2. Field experiments

The present investigation was executed at the Experimental Farms, Faculty of Agricultural and Environmental Sciences, Suez Canal University, at two locations (El Arish and Rafah). The material used in this experiment included 9 bread wheat genotypes that showed high tolerance to mannitol stress in a previous experiment and a local check (Sakha 69) used as comparative variety. Two field experiments were conducted in split blocks design with four replicates. Irrigation treatments were arranged in main plots and bread wheat genotypes were randomly distributed in sub-blocks. Each plot consisted of 5 rows. The row length was 2 m, row to row spacing was 0.2 m and plant to plant distance was 0.1 m except irrigation. Total rain during 2006/2007 growing season was 79.95 mm and 123.12 mm at Arish and Rafah locations, respectively. Four irrigation treatments were conducted in the investigated soils as follow: T1 – rainfall according to ordinary seasons; T2 – irrigation at 50% of FC; T3 – irrigation at 65% of FC; and T4 – irrigation at 80% of FC.

III – Results and discussion

Analysis of variance indicates differences between genotypes in cumulative germination, and radical length after ten days of germination at different levels of osmotic potential. The genotypes and treatments were significant at the 0.01 probability level for cumulative germination percentage and radical length. Also, genotype × treatments interaction was significant at the 0.01 probability level for cumulative germination percentage and radical length. The interaction genotypes × treatments × days was also highly significant for cumulative germination indicating that some genotypes germinated more quickly for specific treatments than others. Seed germination decreased as osmotic potential became more negative. Inhibition of seed germination was greatest under the osmotic potential, -1.5 MPa. Cumulative germination after ten days ranged from 52.6 to 97.9% for the control compared to 27.4 to 69.8% at -1.5 MPa indicating more pronounced differences among genotypes at the lower osmotic potentials (Fig. 1). The significance of the genotypes × treatments × days interaction indicates relative differences among genotypes are dependent on the time course of the experiment. Some genotypes germinated earlier than others at the lower osmotic potentials (-1.0 and -1.5 MPa) but had similar cumulative germination after ten days. The greatest differences in germination between genotypes within such osmotic potential (-1.0 MPa) were observed between L13 (30.1%) and L28 (75.7%). The germination stress index (GSI) was used to account differences in the rate of germination due to osmotic stress (Bouslama and Schapaugh, 1984). High values of GSI indicate a high rate of germination. The rate of germination has indicated by GSI was inversely related to moisture stress. The highest GSI average over treatments was 81.9% for line 28 and the lowest 43.8% for line 13. Radical length also decreased as osmotic potential become more negative. In regard to the average of all osmotic potentials treatments among the genotypes tested, it clearly observed that line 1 followed by line 4 and line 10 are the best genotypes. According to these parameters (germination and radical length under the different osmotic potentials) lines 29, 28, 27, 26, 17, 15, 5, 4 and 18 were screened and symboled as G1, G2, G3, G4, G5, G6, G7, G8 and G9, respectively. The local variety, Sakha 69, was used as comparative genotype (G10) in the field experiments located at Arish and Rafah farms of Suez Canal University.

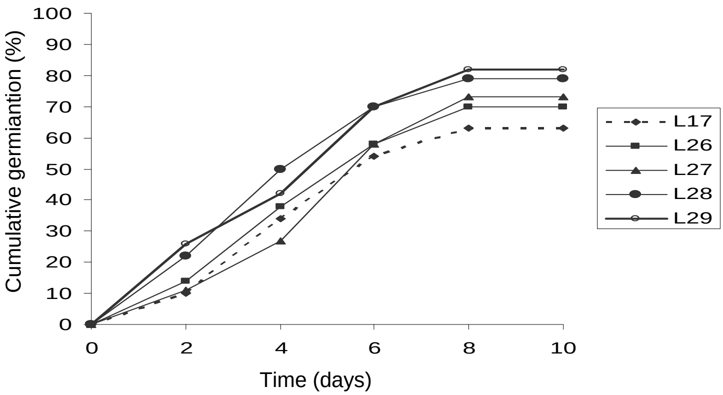

Fig. 1. Cumulative germination percentages of the best five bread wheat genotypes as a function of time in different osmotic potentials, values are average of the four replicates.

1. Grain yield, its components and susceptibility index

Data of grain yield/plant and its components, i.e. number of spikes/plant, number of grains/main spike and 1000-grain weight were measured for the ten bread wheat genotypes under 4 water regimes. Grain yield/plant and its components were reduced significantly by moderate and severe soil moisture deficit treatments in both locations. Severe water stress had greater reduction in all components than moderate stress. Reduction was as much as in grain yield/plant over the 3 water stress treatments of both locations relative to the control treatment. number of spikes/plant was the most affected yield component by water stress (34.9 and 32.6% average of reduction) under Arish and Rafah conditions, respectively. Hence it is considered the main component, which caused greater reduction in grain yield/plant under water stress treatments.

The least affected component by water stress was number of grains/main spike which averaged 8.57% reduction under Arish environment followed by 1000-grain weight (7.87%) at Rafah location suggesting that these two components are less sensitive to drought stress as compared to the no. of spikes/plant. Fischer and Maurer (1978), Guttieri *et al.* (2001) and Zhang *et al.* (2006) observed that grain number/spike was reduced more relative to other yield components as stress severity increased. Ehdaie *et al.* (1988) reported that number of grains/spike was the most affected yield component. Thompson and Chse (1992) displayed that reduced grain yield under moisture stress was a result of reduction in number of spikes/m^2, grains number/spike and individual grain weight. For number of spikes/plant, the exotic lines, G7 followed by G5, G2 and G1 gave the highest mean performance at Arish location while, G5 and G1 had the highest means for this trait at Rafah environment under severe stress treatment. Sakha 69 and G2 under Arish and Rafah conditions, respectively recorded the lowest means under severe stress for this trait. For 1000-grain weight the highest means were recorded by the exotic line G2 which gave average weight over the four treatments 33.53 and 35.53 g followed by G6 which gave 33.01 and 35 g under Arish and Rafah conditions, respectively. On the other hand, Sakha 69 recorded the lowest means for this trait which ranged from 29.55 g as average over the four treatments at Arish location to 31.55 g under Rafah conditions.

From the above results, it should be mentioned that the genotypes which exhibited low reduction in grain yield/plant and/or its components under water stress conditions in both locations will be considered as more drought tolerant for one or more of these traits than the other genotypes evaluated in this study and vice versa. Furthermore, the yield components performed as tolerant ones can be used as simple screening method for evaluating the response of numerous bread wheat genotypes to drought stress. Significant variation existing between the contrasting irrigation regimes and among genotypes under each irrigation treatments showed the presence of much variation among these variables in grain yield/plant and its components.

A drought susceptibility index (S) which provides a measure of stress tolerance based on minimization of yield loss under stress as compared to optimum conditions, rather than on yield level under stress per se, which has been used to characterize relative drought tolerance of wheat genotypes (Fischer and Maurer, 1978; Clarke *et al.*, 1984), is used in the present study. Bruckner and Frohberg (1987) and Sharma and Thakur (2004) suggested that the stress-susceptibility index should be calculated separately in different stress environments.

Application of grain yield/plant based on well watered and T1 stress treatment, at Rafah location, indicated that S values ranged from 0.90 for G1 to 1.4 for the local check variety G10. Low stress susceptibility value (S < 1) is synonymous with higher stress tolerance (Fischer and Maurer, 1978). This main parameter was true for G1, G2, G5 and G9 (the three Syrian lines nos. 5, 13 and 15 as well as line no. 27) which shared the highest potential under severe stress under the two experimental sites. Hence, these genotypes would be in the breeder point of view.

For supplemental file including all the tables make a contact with the author.

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