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Improving wheat production under drought conditions by using diallel crossing system. Drought Index (DI)

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Abstract. Two experiments were conducted to evaluate the seven parents and their twenty-one F_1 hybrids for some yield and its components for drought at two levels of soil moisture (60 and 40% depletion of the available soil moisture) in 2003/04 season. The results indicated that mean squares for genotypes, parents and crosses DI were significant for all traits. The parental line-606 (P_7) seemed to be good combiner for DI in 1000-kernel weight, straw, grain and biological yields/plant and could be considered as an excellent parent in breeding programs aimed to release a high yielding variety under drought conditions. The best combinations were the cross Giza 168 (P_4) × Sakha 93 (P_5) followed by cross Sham 6 (P_2) × Giza 168 (P_4) for straw, grain and biological yields and some of its components.

Keywords. Wheat – Drought index – Heterosis – Combining ability.

Amélioration de la production du blé en conditions de sécheresse grâce à l'utilisation du système de croisement diallélique. Indice de Sécheresse

Résumé. *Deux expériences ont été menées pour évaluer les sept parents et leurs vingt et un hybrides F_1 pour un certain rendement et ses composantes par rapport à un indice de sécheresse pour deux niveaux d'humidité du sol (60 et 40% de réduction d'humidité du sol disponible) pour la saison 2003/04. Les résultats ont indiqué que les carrés moyens pour les génotypes, les parents et les croisements DI ont été significatifs pour tous les caractères. La lignée parentale 606 (P_7) semblait être une bonne combinaison par rapport au DI pour le poids de 1000 grains, la paille, les rendements en grain et biologique/plante et pourrait être considérée comme parent excellent dans les programmes de sélection visant à mettre au point une variété à haut rendement en conditions de sécheresse. Les meilleures combinaisons ont été le croisement Giza 168 (P_4) × Sakha 93 (P_5), suivi du croisement Sham 6 (P_2) × Giza 168 (P_4) pour la paille, les rendements en grain et biologique et certaines de ses composantes.*

Mots-clés. *Blé – Indice de sécheresse – Hétérosis – Aptitude à la combinaison.*

I – Introduction

Increasing grain yield of cereal crops is considered one of the more important national goals in Egypt to face the needs of increment of Egyptian population. Wheat production in Egypt increased from 2.08 million ton in 1982/83 to 7.18 million ton in 2003/04 seasons (ARC, 2004). This increase was achieved by both increasing wheat area and improved cultural practices at newly reclaimed areas. It has become necessary to develop wheat lines adapted to drought regions.

The main objectives of the present investigation are to assess the variations amongst a few wheat genotypes and available crosses for Drought Index for some yield and its components traits, to estimate the magnitude of heterosis, general combining ability and specific combining ability for DI to determine suitable genotypes for drought resistance in wheat genotypes.

II – Material and methods

A diallel cross set involving the seven parents was made, to produce the F_1-generation. In 2003/04 growing season, two experiments were conducted, each experiment include the seven parents and their twenty-one F_1 hybrids. The first and the second experiments irrigated when the field capacity was 60 and 40% depletion of the available soil moisture, respectively.

Heterosis for each trait computed as parents *vs* hybrids sum of squares was obtained by partitioning the genotypes sum squares to its components. Procedure genotypes were subdivided to parents, crosses, and parents *vs* crosses. Heterosis was also determined according to Paschal and Wilcox (1975) for individual crosses as the percentage deviation of F_1 mean performance from the better parent mean (BP) for each experiment as well as the combined analysis. General and specific combining ability estimates were obtained by employing Griffing (1956) diallel cross analysis designated as a model-1 method-2.

Drought Index (DI) was calculated using formula given by Saulescu *et al*. (1995).

III – Results and discussion

1. Heterosis

Heterosis expressed as the percentage deviation of F_1 mean performance from better parent values for DI for yield and yield components is presented in Table 1. For DI of number of spikes/plant, the two crosses Giza-168 (P_4) × Sakha-93 (P_5) and Giza-168 (P_4) × Gemmiza-7 (P_6) expressed significant positive heterotic effects relative to the better parent. Five, eight, eight, two, eight and one parental combinations expressed significant positive heterotic effects relative to better-parent values for number of kernels/spike, 1000-kernel weight, straw yield/plant, grain yield/plant, biological yield/plant and harvest index, respectively. The best combinations was the cross Giza-168 (P_4) × Sakha-93 (P_5) followed by cross Sham-6 (P_2) × Giza-168 (P_4) for straw, grain and biological yields and some of its components. This superiority in the previous genotypes for DI heterosis may be due to high desirable for one or more of drought measurements.

2. General combining ability

Estimates of GCA effects ($\hat{g}_i$) for individual parent for each trait of DI are presented in Table 2. High positive values would be interesting for all measurements of DI in question from the breeder point of view. The parental variety Yacora Rojo (P_1) exhibited significant positive $\hat{g}_i$ effect of DI for 1000-kernel weight and straw yield/plant. It was around the average for the other traits of DI. The parental variety Sham-6 (P_2) and Gemmiza-7 (P_6) had a significant negative or insignificant $\hat{g}_i$ effect of DI for all the studied traits. The parental ICARDA-3 (P_3) seemed to be a good combiner of DI for no. of kernels/spike. On the contrary, it expressed either significant negative or insignificant $\hat{g}_i$ effects of DI for other drought measurements.

The parental variety Giza-168 (P_4) exhibited significant positive $\hat{g}_i$ effects of DI for 1000-kernel weight. However, it was around the average of $\hat{g}_i$ effects of DI for the other traits.

The parental variety Sakha-93 (P_5) expressed significant positive $\hat{g}_i$ effects of DI for no. of kernels/spike. On the contrary, it expressed either significant negative or insignificant $\hat{g}_i$ effects of DI for other traits.

The parental line-606 (P_7) seemed to be good combiner for DI in 1000-kernel weight, straw, grain and biological yields/plant. However, it was around the average of $\hat{g}_i$ effects of DI for the other traits. Therefore, line-606 (P_7) could be considered as an excellent parent in breeding programs aimed to release a high yielding variety under drought conditions.

Table 1. Percentage of heterosis of better parent for drought index (DI) of some yield and its components in the F_1 generation

Crosses†	No. of spikes/ plant	No. of kernels/ spike	1000-kernel weight (g)	Straw yield/ plant (g)	Grain yield/ plant (g)	Biological yield (g)	Harvest index
$P_1 \times P_2$	-13.656**	-19.318**	-3.545*	25.657**	-30.676**	8.707**	-36.325**
$P_1 \times P_3$	-21.183**	0.890	-31.257**	-28.661**	-42.568**	-33.547**	-13.411**
$P_1 \times P_4$	-22.903**	-3.041*	-10.956**	-17.397**	-33.514**	-24.456**	-11.932**
$P_1 \times P_5$	-17.097**	9.942**	-11.386**	6.133*	-19.054**	-3.457	-16.262**
$P_1 \times P_6$	-26.129**	1.430	-27.605**	-40.134**	-42.297**	-38.985**	-8.976**
$P_1 \times P_7$	1.505	-21.551**	-1.504	9.499**	-19.595**	8.759**	-29.778**
$P_2 \times P_3$	-7.092	-3.782**	-0.779	23.041**	-11.453	13.355**	-21.828**
$P_2 \times P_4$	3.181	8.977**	-2.138	33.111**	13.508*	26.897**	-10.761**
$P_2 \times P_5$	-6.815	-22.045**	10.273**	4.992	-17.824**	-2.241	-16.087**
$P_2 \times P_6$	-7.379	-9.241**	3.394*	-24.972**	-11.419	-23.639**	-9.891**
$P_2 \times P_7$	-3.931	2.727*	-7.005**	-31.420**	-8.108	-23.966**	0.109
$P_3 \times P_4$	6.501	-3.671**	2.013	46.390**	7.863	34.658**	-19.892**
$P_3 \times P_5$	0.000	1.224	2.208	7.373*	3.590	7.313**	-3.548
$P_3 \times P_6$	-2.128	-17.492**	-7.636**	-36.009**	-19.145**	-33.168**	-5.806
$P_3 \times P_7$	-10.173	0.000	7.488**	-10.960**	-0.954	11.071**	-34.301**
$P_4 \times P_5$	16.729**	20.643**	6.038**	56.807**	56.883**	63.167**	-27.531**
$P_4 \times P_6$	22.857**	-18.812**	11.515**	-9.365**	11.246	-6.683**	-0.467
$P_4 \times P_7$	-21.387**	-0.114	7.367**	-12.109**	-15.739**	-10.949**	-15.421**
$P_5 \times P_6$	-8.178	2.640*	-0.121	-17.614**	-0.865	-15.965**	-5.119
$P_5 \times P_7$	-3.931	-5.815**	15.580**	-9.916**	4.610	-4.501*	-4.778
$P_6 \times P_7$	-4.971	-6.711**	7.488**	-17.015**	-1.272	-9.976**	9.948*

†P_1 = Yacora Rojo; P_2 = Sham-6; P_3 = ICARDA-3; P_4 = Giza-168; P_5 = Sakha-93; P_6 = Gemmiza-7; P_7 = Line-606.
*Significant at $p < 0.05$; **Significant at $p < 0.01$.

Table 2. Estimates of general combining ability effects for drought index (DI) of some yield and yield components in parents

Parental variety or line†	No. of spikes/ plant	No. of kernels/ spike	1000-kernel weight (g)	Straw yield/plant (g)	Grain yield/plant (g)	Biological yield (g)	Harvest index
P_1	0.0061	-0.0125**	0.0069*	0.0182**	0.0006	0.0055	0.0044
P_2	-0.0193	-0.0120**	-0.0149**	-0.0373**	-0.0328**	-0.0383**	0.0089
P_3	0.0117	0.0197**	-0.0435**	-0.0388**	-0.0088	-0.0161**	0.0115
P_4	-0.0016	-0.0029	0.0083**	0.0028	0.0044	0.00002	-0.0117
P_5	0.0041	0.0080**	0.0016	-0.0221**	0.0123	-0.0122**	0.0106
P_6	-0.0184	0.0019	-0.0011	-0.0197**	-0.0132	-0.0193**	0.0104
P_7	0.0174	-0.0023	0.0428**	0.0968**	0.0375**	0.0804**	-0.0340**
LSD (0.05) g_i	–	0.0049	0.0058	0.0100	0.0151	0.0067	0.0134
LSD (0.05) g_i-g_j	–	0.0075	0.0088	0.0152	0.0231	0.0102	0.0205

†P_1 = Yacora Rojo; P_2 = Sham-6; P_3 = ICARDA-3; P_4 = Giza-168; P_5 = Sakha-93; P_6 = Gemmiza-7; P_7 = Line-606.
*Significant at $p < 0.05$; **Significant at $p < 0.01$.

The variances associated with general and specific combining ability were highly significant for DI in all traits except GCA for number of spikes/plant. Such results indicated that additive and non-additive types of gene action were important in the inheritance of DI for the exceptional traits (no. of spikes/plant); additive types of gene action seemed to be more important than non-additive gene action.

With the exception of DI for 1000-kernel weight, low GCA/SCA ratios of less than unity were detected for all traits indicating the predominance of non-additive gene action in the inheritance of DI of such traits. For the DI for 1000-kernel weight, high GCA/SCA ratio was obtained; revealing that the largest part of the total genetic variability associated with DI for this trait was a result of additive and additive-by-additive gene action. The results agree with the results reported by El-Borhamy (2000) and El-Gamal and El-Ghafar (2001).

3. Specific combining ability

Specific combining ability effects of the parental combinations computed for drought index for all the studied traits are presented in Table 3.

Table 3. Estimates of specific combining ability effects for drought index (DI) of some yield and yield components in F_1 generation

Crosses†	No. of spikes/ plant	No. of kernels/ spike	1000-kernel weight (g)	Straw yield/ plant (g)	Grain yield/ plant (g)	Biological yield (g)	Harvest index
$P_1 \times P_2$	0.0089	-0.1177**	0.0830**	0.2598**	-0.0201	0.1801**	-0.2142**
$P_1 \times P_3$	-0.0925**	0.0471**	-0.1463**	-0.1720**	-0.1325**	-0.1717**	-0.0003
$P_1 \times P_4$	-0.0949**	-0.0077	-0.0089	-0.1242**	-0.0783**	-0.1170**	0.0375
$P_1 \times P_5$	-0.0467	0.0924**	-0.0067	0.0891**	0.0200	0.0596**	-0.0260
$P_1 \times P_6$	-0.1081**	0.0808**	-0.1545**	-0.2240**	-0.1256**	-0.1946**	0.0436*
$P_1 \times P_7$	0.1127**	-0.1496**	0.0441**	0.1713**	-0.0090	0.1068**	-0.1094**
$P_2 \times P_3$	-0.0135	0.0052	-0.0003	0.1146**	-0.0057	0.0663**	-0.0972**
$P_2 \times P_4$	0.0250	0.1216**	-0.0386**	0.0714**	0.0677**	0.0734**	0.0203
$P_2 \times P_5$	-0.0405	-0.1624**	0.0387**	-0.0723**	-0.1071**	-0.0840**	-0.0520**
$P_2 \times P_6$	-0.0414	-0.0171*	0.0458**	-0.0331*	-0.0075	-0.0272**	0.0054
$P_2 \times P_7$	0.0258	0.0663**	-0.0812**	-0.1658**	0.0075	-0.1183**	0.1422**
$P_3 \times P_4$	0.0841**	-0.0034	0.0228**	0.2261**	0.0700**	0.1620**	-0.0590**
$P_3 \times P_5$	0.0228	0.0305**	0.0055	-0.0029	0.0364	0.0023	0.0706**
$P_3 \times P_6$	0.0277	-0.1239**	-0.0166	-0.1301**	-0.0703**	-0.1262**	0.0506*
$P_3 \times P_7$	-0.0590*	0.0296**	0.0673**	0.0325*	0.0286	0.1476**	-0.1703**
$P_4 \times P_5$	0.1321**	0.1192**	0.0097	0.1898**	0.1929**	0.2274**	-0.1655**
$P_4 \times P_6$	0.1587**	-0.1133**	0.0899**	0.0670**	0.0861**	0.0715**	0.0496*
$P_4 \times P_7$	-0.1436**	0.0293**	0.0148	-0.0208	-0.0771**	-0.0495**	-0.0344
$P_5 \times P_6$	-0.0520	0.0714**	0.0001	0.0177	0.0081	0.0095	0.0094
$P_5 \times P_7$	0.0018	-0.0319**	0.0898**	0.0258	0.0426	0.0155	0.0560**
$P_6 \times P_7$	0.0161	-0.0035	0.0256**	-0.0453**	0.0312	-0.0226*	0.0591**
LSD 5% (Sij)	0.0570	0.0143	0.0168	0.0290	0.0440	0.0194	0.0390
LSD 1% (Sij)	0.0758	0.0191	0.0223	0.0386	0.0585	0.0258	0.0518
LSD 5% (Sij-Sik)	0.0846	0.0213	0.0249	0.0431	0.0653	0.0288	0.0579
LSD 1% (Sij-Sik)	0.1126	0.0283	0.0331	0.0573	0.0869	0.0383	0.0770
LSD 5% (Sij-Skl)	0.0792	0.0199	0.0233	0.0403	0.0611	0.0269	0.0541
LSD 1% (Sij-Skl)	0.1053	0.0265	0.0310	0.0536	0.0813	0.0358	0.0720

†P_1 = Yacora Rojo; P_2 = Sham-6; P_3 = ICARDA-3; P_4 = Giza-168; P_5 = Sakha-93; P_6 = Gemmiza-7; P_7 = Line-606.
*Significant at $p < 0.05$; **Significant at $p < 0.01$.

For DI, four, ten, nine, nine, four, nine and seven crosses expressed significantly positive S_{ij} effects for no. of spikes/plant, no. of kernels/spike, 1000-kernel weight, straw, grain and biological yields/plant and harvest index, respectively. The most desirable S_{ij} effects for DI were recorded by two crosses Giza-168 (P_4) × Gemmiza-7 (P_6) and Giza-168 (P_4) × Sakha-93 (P_5) for no. of spikes/plant, two crosses Sham-6 (P_2) × Giza-168 (P_4) and Giza-168 (P_4) × Sakha-93 (P_5) for no. of kernels/spike, Giza-168 (P_4) × Gemmiza-7 (P_6) and Sakha-93 (P_5) × line-606 (P_7) for 1000-kernel weight, Yacora Rojo (P_1) × Sham-6 (P_2) and ICARDA-3 (P_3) × Giza-168 (P_4) for straw yield/plant, Giza-168 (P_4) × Sakha-93 (P_5) for grain yield/plant, Yacora Rojo (P_1) × Sham-6 (P_2) and Giza-168 (P_4) × Sakha-93 (P_5) for biological yield/plant and Sham-6 (P_2) × line-606 (P_7) for harvest index. It is interesting to note that the superiority of the previous crosses in DI was resulted from lower TR (El-Hosary *et al.*, 2009).

Stress tolerant genotypes, as defined by DI values, do not need to have a high yield potential since DI provides a measure of tolerance based on minimization of yield loss under stress rather than non-stress yield *per se*.

Genotypes identified as stress tolerant using DI should posses tolerance mechanisms, which may need to be incorporated into germplasm with higher yield potential, for development of high yielding stress tolerant cultivars.

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