GENE ACTION AND COMBINING ABILITY ANALYSIS OF DIALLEL CROSSES IN BREAD WHEAT UNDER MOISTURE STRESS AND NON-STRESS CONDITIONS

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Abstract: The present study was carried out during 2001/2002, 2002/2003 and 2003/2004 seasons at the Experimental Farm of Faculty of Agriculture, Assiut University. 15 F_1's obtained from a half diallel crossing system of six bread wheat parents were genetically analyzed to detect the type of gene action governing the heading date, yield and its attributes under favorable and stress conditions. A Randomized Complete Block Design with three replications was adopted for each experiment. Results showed that mean squares due to genotypes (i.e. parents and crosses) reached the significant level for all studied traits for both conditions as well as in the combined analysis. Stress condition reduced number of days to heading, plant height, spike length, yield and its components as compared with non-stress condition. The reductions in biological yield/plant from non-stress to stress as percentage were 19.98 and 29.19% for parents and F_1 generation, respectively. Also, the reductions in grain yield/plant were 35.05% for parents and 32.25% for F_1.

The calculated water stress susceptibility index (S) based on yield and its components revealed that the parental genotypes GIZA 160, SONORA 64, LENINGRADKA and SAKHA 8 were relatively stress tolerant for no. of grain/spike. The best crosses for grain yield/plant were (GIZA 160 x SONORA 64), (SONORA 64 x LENINGRADKA), (GIZA 160 x CHENAB 70) and (LENINGRADKA x CHENAB 70).

Estimates of GCA effects revealed that the parental genotypes SONORA 64 and SAKHA 8 seemed to be the best general combiners for earliness and LENINGRADKA for grain yield/plant and yield components under both conditions. The cross combinations (LENINGRADKA X SAKHA 8), (SAKHA 8 X CHENAB 70) and (SONORA 64 X LENINGRADKA) showed high SCA effects for the mentioned traits. The dominance gene effects accounted for the most part of the total variation for all traits except days to heading under favorable condition, resulting in $(H_1/D)^{1/2}$ more than one.

Heritability estimates in broad sense were high for the studied traits except spike length in favorable (0.40) and number of grains/spike (0.49) in stress conditions. Heritability values in narrow sense were low except for days to heading and ranged from 0.08 to 0.38.

Key words: Gene action, combining ability analysis, bread wheat, moisture stress, non-stress.

Introduction

Wheat has been considered the first strategic food crop for more than 7000 years in Egypt, covered about 2,605483 feddan to be with a total annual production of 7.18 million tons (FAO Statistics Year Book, 2004). This amount satisfies around 60% of the fast growing populations needs. Therefore increasing food demands have led to cultivate wheat under marginal conditions.

Drought is a major stress factor, which limits crop production in most areas of the world. Wheat production under rainfed or minimum irrigation conditions became an objective in Egypt as well as many areas in the world due to increasing limitations of water supply. Nielsen and Halvorson (1991), Kobata *et al.* (1992) and Kheiralla *et al.* (1997) concluded from their studies that water stress caused reduction in grain yield and its components. Sapra *et al.* (1991) reported that significant relationship was found between plant height and grain yield under drought environment, where cultivars that grew longer under stress had greater dry matter accumulation, as well as higher grain yield. Dencic *et al.* (2000) found that number of kernels/spike, 1000 kernel weight and grain yield were more sensitive to drought stress than plant height and number of spikelets/spike. Hoffmann and Burucs (2005) showed that number of productive tillers were reduced by about 20% because of water deficiency. Yield reduction was found to be between 11 and 44% and was mainly due to decrease of thousand grain weight.

Therefore, it is important to evaluate local and exotic germplasm in crossing programs aiming to improve grain yield and its attributes. Combining ability is frequently employed to identify the desirable parents for producing better recombinants. Moreover, estimating gene effects are very essential in order to apply the most effective breeding procedure for improvement. El-Hennawy (1991) reported that the variances associated with general and specific combining abilities in bread wheat were significant for grain yield/plant, 100-grain weight, number of spikes/plant and days to heading except specific combining ability for days to heading that was insignificant, indicating the importance of additive and non-additive gene effects in the inheritance of these characters. Non-additive type of gene effects were more affected by stress conditions than the additive (Dhanda and Sethi, 1996; Choudhry *et al.*, 1999; Ahmed, 2003; Solomon and Labuschagne, 2003).

The main aim of this undertaken study was to obtain information on the nature of the genetic system governing the inheritance of earliness, yield and its attributes in wheat under favorable and moisture stressed conditions.

Materials and Methods

The present study was carried out during the period from 2001 to 2004 at the Experimental Farm of Faculty of Agriculture, Assiut University. The genetic material used in this study as parents included six bread wheat cultivars (*Triticum aestivum* L.); P1, GIZA 160 (Egypt); P2, SONORA 64 (Mexico); P3, LENINGRADKA (Russia); P4, SAKHA 8 (Egypt); P5, SAKHA 69 (Egypt) and P6, CHENAB 70 (Pakistan). In the 2001/2002 season, the wheat cultivars were sown in three different dates; November 15th, November 25th and December 5th to avoid (overcome) differences in the flowering time. All possible crosses among parents excluding reciprocal were made to obtain a diallel series of fifteen crosses using hand emasculation and pollination.

In the 2002/2003 season, the same six parents were sown as in the previous season and they were crossed again to produce sufficient hybrid seeds from each cross.

In the 2003/2004 season, the parents and their F_1 hybrids were sown on November 20th. Two adjacent experiments were conducted. The first experiment (stress) was irrigated one time after 40 days from planting irrigation (i.e., two irrigations were given through the whole season). The second experiment (non-stress or favorable) was irrigated five times after planting irrigation. Each experiment was designed in a Randomized Complete Block Design with three replications. Each plot consisted of one-meter long row, which spaced 30 cm apart. Seeds were planted 5 cm apart. The recommended practices of wheat production were adopted throughout the growing season. The following traits were recorded on ten individual plant for the two experiments; Days to heading: number of days from planting to 50% of plants protruded heads from the flag leaf sheath basis; Plant height (cm): the distance from the base of the main culm to the tip of the spike; Spike length (cm): it was measured from the base of the main spike to its tip excluding awns; Number of spikes/plant: number of tillers with fertile spikes plus main stem spike as a random sample of guarded plants; Biological yield/plant (g): air dry plant weight/plant (excluding roots); Grain yield/plant (g): air dry grain yield/plant; Number of grains/spike: as an average of number of grains/ main spike; Weight of grains/spike: it was recorded as the weight of grains/main spike; 1000-grain weight (g): it was obtained as the weight of 1000 grains, from the bulk of the guarded plants and Harvest index/plant: the ratio between grain yield (economic) and biological yield.

Statistical analysis:

The separate analysis of variance and the combined between the two experiments were performed according to Gomez and Gomez (1984). The combined analysis was carried out whenever homogeneity of variance was detected. Least significant difference (LSD) was used for comparing means.

The drought susceptibility index (S) was calculated according to Fisher and Maurer (1978) as follows:

$S = (1 – Yd/Yp)/D$

Where; S = An index of drought susceptibility; Yd = Mean yield in stress experiment; Yp = Mean yield in favorable experiment; D = Drought intensity = {1- (mean Yd of all genotypes/mean Yp of all genotypes)}.

Combining ability analysis:

Estimates of general and specific combining ability variances and their effects were calculated using ordinary method for analysis of variance in a randomized block design. If the differences between genotypes were significant, further analysis for general and specific combining ability was made according to Griffing (1956), method 2 model 1. In addition, the genetic mechanism governing the inheritance of each trait was calculated according to Hayman (1958).

Results and Discussions

The analysis of variance for each of the two experiments (stress and non-stress) for all studied traits as well as the combined analysis in the parents and F_1 generation are presented in Table (1). The analysis revealed that significant differences existed among genotypes, parents, crosses and parents vs. crosses. The differences among both irrigation conditions and the interaction between genotype x irrigation were also significant for all the studied traits, indicating that the tested genotypes varied from one irrigation regime to another.

I- Mean Performance of parents and F_1's:

Mean performance of parents and their F_1's under favorable and stress conditions and their combined data are shown in Table (2). The parental genotype SONORA 64 (P2) followed by SAKHA 8 (P4) were the earliest under both irrigation conditions. The earliness in heading reached 8.71% under stress as compared to non-stress conditions for parents and their F_1's.

For grain yield/plant, the averages over all parents and F_1 hybrids were 17.13 and 20.37g under favorable condition, but they were reduced to 11.12 and 13.79g under stress condition, indicating a reduction of 35.05 and 32.25% in grain yield/plant, respectively. The reductions could be attributed to incomplete development of some grains per spike because of the lack of water in the soil . These results are in harmony with Nielsen and Halvorson (1991), Kobata *et al.* (1992), Kheiralla (1994), Dencic *et al.* (2000) and Hoffmann and Burucs (2005). It is worthy to mention that the genotype (LENINGRADKA), which had the highest length (117.76

cm) under water stress, had greatest biological yield (52.0 g) as well as highest grain yield (13.13 cm). Sapra *et al.* (1991) reported similar findings.

In general, it could be concluded that drought stress condition reduced days to heading, grain yield and its attributes as compared to non-stress.

II- Stress susceptibility index:

The drought susceptibility index "S" based on number of spikes/plant, number of grains/spike, 1000-grain weight and grain yield/plant for parents and their F_1 's are presented in Table (3).

Table(3): Drought susceptibility index (S) calculated for no. of spikes/plant, no. of grains/spike, 1000-grain weight and grain yield/plant.

Genotype	Number of spikes/plant	Number of grains/spike	1000-grain weight	Grain yield/plant
Giza 160 (P_1)	1.6	0.63	1.22	1.16
Sonora 64 (P_2)	1.03	0.86	0.05	1.01
Leningradka (P_3)	1.6	0.86	0.72	1.07
Sakha 8 (P_4)	1.09	0.93	0.33	1.22
Sakha 69 (P_5)	1.99	1.01	0.71	0.99
Chenab 70 (P_6)	1.00	1.38	0.68	1.14
P_1 x p_2	0.92	0.29	0.044	0.42
P_1 x P_3	0.74	1.9	2.53	0.71
P_1 x p_4	1.868	1.81	0.64	1.47
P_1 x p_5	1.868	0.67	1.92	1.29
P_1 x p_6	0.36	0.94	0.87	0.58
P_2 x p_3	1.03	0.1	0.06	0.58
P_2 x p_4	0.96	1.27	0.53	0.51
P_2 x p_5	1.29	0.15	0.38	1.06
P_2 x p_6	0.79	1.6	0.69	1.85
P_3 x P_4	1.868	0.63	0.72	1.7
P_3 x P_5	0.41	1.19	0.16	1.21
P_3 x p_6	1.23	0.99	1.11	0.6
P_4 x p_5	0.31	1.97	1.1	1.73
P_4 x p_6	0.258	0.08	2.78	1.32
P_5 x P_6	0.668	1.26	0.42	0.97

The previous index was used to estimate the relative stress injury (drought) because it is accounted as variation in yield potential and stress intensity. Higher values indicated higher degree of susceptibility and vice versa (Fischer and Maurer, 1978 and Farshadfar *et al.* 1995).

The application of such index indicated that the parental genotypes GIZA 160 , SONORA 64, LENINGRADKA and Sakha 8 were tolerant to the stress condition for number of grains/spike and SONORA 64, LENINGRADKA Sakha 8 and Sakha 69 for 1000 grain weight. Regarding grain yield/plant, the best crosses for drought tolerance were (GIZA 160 X SONORA 64), (GIZA 160 X LENINGRADKA), (GIZA 160 X CHENAB 70), (SONORA 64 X LENINGRADKA), (SONORA 64 X SAKHA 8) and (LENINGRADKA X CHENAB 70). Moreover, crosses (GIZA 160 X SONORA 64) and (GIZA 160 X CHENAB 70) had values less than unity for S across the four studied traits.

It is worthy to mention here that drought susceptibility index provides a measure of tolerance based on minimization of yield loss under stress rather than non-stress yield *per se*. Therefore, the stress tolerant genotypes as defined by S values, do not need to have a high yield potential. These genotypes should possess resistance mechanisms, which may need to be incorporated into germplasm with higher yield potential for development of high yielding stress tolerant cultivars.

III- Combining ability analysis:

Partitioning mean square of genotypes into general (GCA) and specific (SCA) combining ability for studied traits is presented in Table (4). Mean squares of both GCA and SCA were highly significant at both conditions and combined analysis. These results point out the role of both additive and non-additive effects in the inheritance of these traits. The ratio of GCA/SCA for days to heading was more than unity for in non water stress and in the combined analysis, revealing that the largest part of the total genetic variance associated with this trait is additive nature. Thus, superior genotypes could be identified from it's phenotypic expression and selection in early generations would be effective to improve this trait. Similar findings were obtained by Raghavaiah and Joshi (1986), and Majumdar and Bhowal (1988).

On the other hand, the ratio for the other studied traits was less than one in all cases, suggesting that non-additive gene effects accounted for the great part of the total variation for these traits and selection should be delayed to later generations. It is fairly evident that the ratio for mean square (irrigation x SCA)/(SCA) was higher than the ratio of mean square (irrigation x GCA)/(GCA), indicating that the non-additive type of gene effects were more affected by irrigation conditions than the additive

effect. These results are in harmony with Dhanda and Sethi (1996), Choudhry *et al.* (1999), Ahmed (2003) and Solomon and Labuschagne (2003).

The general (g_i) and specific (s_{ij}) combining ability effects of the six parental genotypes are presented in Table (5). Results showed that the parental genotypes SONORA 64 and SAKHA 8 were the best general combiner for earliness and LENINGRADKA for grain yield/plant and yield components under both conditions. The cross combinations (LENINGRADKA X SAKHA 8), (SAKHA 8 X CHENAB 70) and (SONORA 64 X LENINGRADKA) Showed high SCA effects for mentioned traits and could be used for future improvement of both conditions.

IV- Genetic components:

Estimates of the genetic components of variation and the derived ratios for the studied traits in the F_1 generation for both conditions are presented in Table (6).

The additive (D) component was significant or highly significant for all the studied traits at both conditions except grain yield/plant and harvest index, indicating the importance of the additive gene effects in the inheritance of these traits.

The dominance components (H_1 and H_2) were also significant and larger in magnitude than the additive components except for days to heading at favorable condition, resulting in $(H_1/D)^{1/2}$ more than one, and confirming the role of epistatic effect in the genetic control of these traits. The covariance of additive and dominance gene effect (F value) coupled with (KD/KR) which was more than one, indicated an excess of dominant alleles in the genetic constitution of parental genotypes for most studied traits at stress and non-stress conditions.

The average frequency of negative and positive genes ($H_2/4H_1$) was found to be smaller than 0.25 for all studied traits except days to heading (favorable), biological yield and harvest index (stress), suggesting unequal gene distribution of positive and negative alleles among parents.

It is worth to mention that the component H_1 was approximately equal to H_2 one, for harvest index under stress condition, indicating that increasing and decreasing alleles were equally distributed among parents. These findings confirm the result of $H_2/4H_1$.

Insignificant additive component (D) in spite of a highly significant GCA was obtained for grain yield/plant. The contradiction could be attributed to the greater role of both allelic and non-allelic interaction of genetic type on the expression of this trait. Consequently, selection for grain yield in the segregating generations will be useless. Thus to improve this trait, indirect selection for traits correlated with it should be

used. Similar results were obtained by Jatasra and Paroda (1980), Singh *et al*. (1986), Ashoush (1996) and Attia (1998).

Heritability estimates in broad sense were high for all the studied traits except spike length in favorable (0.40) and number of grains/spike (0.49) in stress condition. Heritability values in narrow sense were low except for days to heading and ranged from 0.08 to 0.38 indicating the high contribution of the non-additive effects. In this case, family selection could be more useful (Falconer, 1989).

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الفعل الجينى و تحليل القدرة على الإتلاف لهجن الدياليل في قمح الخبز تحت ظروف الجفاف و غير الجفاف

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أجريت هذه الدراسة بمزرعة كلية الزراعة جامعة أسيوط خلال مواسم الزراعة 2002/2001 ، 2003/2002 و 2004/2003 . وقد أستخدم لهذه الدراسة خمسة عشر هجينا تم الحصول عليها من التهجين بين ستة آباء متباينة وراثياً من قمح الخبز بطريقة الدياليل (بدون الهجن العكسية) ، و ذلك لدراسة طرز فعل الجين و النظام الوراثى المتحكم فى وراثة صفات التزهير والمحصول ومكوناته فى القمح تحت ظروف الرى العادية والجفاف . تم زراعة الآباء والجيل الأول فى تجربتين: الأولى رويت رى طبيعى و الثانية رويت رية واحدة بعد رية الزراعة (الاجهاد المائى) و ذلك باستخدام تصميم القطاعات كاملة العشوائية مع ثلاث مكررات . ويمكن تلخيص النتائج المتحصل عليها كما يلى :

أظهر التحليل الاحصائى فروقاً معنوية بين التراكيب الوراثية الآباء ، الهجن لكل الصفات التى تم دراستها فى كل من معاملتى الرى وكذلك التحليل المشترك لهما . أنقصت ظروف الجفاف عدد أيام التزهير وطول النبات وطول السنبلة والمحصول ومكوناته مقارنة بظروف الرى العادية و كان النقص فى المحصول البيولوجى 19.98 و 29.19% لكل من الآباء وهجن الجيل الأول مقارنة بظروف الرى العادية على التوالى . أيضاً بلغ النقص فى محصول الحبوب 35.05 للآباء و 32.25% للهجن . بحساب دليل الحساسية للإجهاد المائى كانت التراكيب الأبوية (Giza 160) P_1 و (Sonora 64) P_2 و (Leningradka) P_3 و(Sakha 8) P_4 أكثر تحملاً لنقص الماء وذلك لصفة عدد حبوب السنبلة . أفضل الهجن تحملا و ذلك لصفة محصول حبوب / نبات كانت الهجن الآتية : (Giza 160 X Sonora 64), (Sonora 64 x Leningradka), (Giza 160 X Chenab 70) and (Leningradka X Chenab 70).

أظهرت نتائج القدرة العامة والخاصة على الائتلاف معنوية لجميع الصفات المدروسة تحت ظروف التجربتين والتحليل المشترك ، و كانت التراكيب الأبوية (Sonora 64) P_2 و (Sakha 8) P_4 الافضل قدرة عامة على الإئتلاف بالنسبة للتزهير و ليننجرادكا لمحصول الحبوب ومكوناته بينما كانت الهجن(Leningradk x Sakha 8) و (Sakha 8 x Chenab 70) و (Leningradk x Sonora 64) لها قدرة خاصة على الائتلاف عالية للصفات السابقة . كان المكون الوراثى السيادى الأكثر أهمية لجميع الصفات تحت الدراسة ماعدا عدد أيام التزهير تحت ظروف الرى العادية وهذا نتيجة متوسط درجة السيادة $(H_1/D)^{½}$ حيث كان أكبر من الواحد الصحيح لكل الحالات السابقة . كما أن الأليلات الموجبة والسالبة غير متساوية التوزيع بين الآباء لجميع الصفات فيما عدا معامل الحصاد.

كانت قيم درجة التوريث بمعناها العريض عالية لجميع الصفات فيما عدا طول السنبلة تحت ظروف الرى العادى (0.40) وعدد الحبوب / السنبلة (0.49) تحت ظروف الجفاف . بينما كانت درجة التوريث الخاصة منخفضة ما عدا عدد الأيام حتى التزهير وتراوحت من 0.8 إلى 0.38 .