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COMBINING ABILITY ANALYSIS AND HETEROSIS IN RELATION TO SALINITY AND DROUGHT STRESSES FOR YIELD AND ITS ATTRIBUTES OF BREAD WHEAT

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ABSTRACT

Half diallel cross among six parental bread wheat divergent genotypes were evaluated under rainfed and saline stresses. Type and relative amounts of genetic variance components that interacted with environments were detected. Highly significant differences between environments were recorded for all traits under consideration i.e. mean squares for genotypes, parental lines or varieties, F_1 hybrids and parents vs. hybrids were significant for all traits in both locations as well as the combined analysis except parents vs. hybrids at Maryout and the combined analysis for number of grains / spike. The collected data revealed that predominance of additive gene effects in the genetic control of all traits except plant height under Siwa conditions and combined analysis. Combining ability x environment interaction revealed that the GCA (additive and additive x additive genetic effects) was more distorted by environmental fluctuations than specific combining ability (SCA) effects for all traits except number of spikes / plant and 1000-grain weight.

Mean performances of the parental genotypes and its derived F_1 crosses at both locations showed that P_1 x P_5 and P_2 x P_3 under rainfed and P_1 x P_4 and P_3 x P_4 under Siwa saline conditions were the superior combination for grain yield and most of its components. For grain yield / plant; eleven, fifteen and thirteen crosses expressed significant positive heterotic effects relative to mid parent in Maryout, Siwa and the combined analysis, respectively. While, six, five and six crosses from the previous hybrids exhibited significant positive heterotic effects relative to better parent in the same order. The best crosses were P_1 x P_5, P_2 x P_3, P_2 x P_5, P_3 x P_5 and P_3 x P_6 over both locations.

With regard to yielding capacity, P_4 was the best combiner under saline environment as well as the combined data. Also, P_4 had a significant g_i effects for two or more of the yield attributes under each of the two stress types tested. Such parental genotype (P_4) was developed under similar aimed conditions through the previous segregating generations among Desert Research Center breeding program. For grain yield / plant, six, three, and five crosses gave significant positive S_{ij} effects in Maryout, Siwa and the combined analysis, respectively. The best crosses were P_1 x P_5 and P_4 x P_5 in both locations and combined analysis and P_3 x P_5 in Maryout and the combined analysis.

Insignificant associations between parental means and their g_i effects where detected in all cases revealing that it is not necessarily that good combiner must have a good index of intrinsic performance.

Keywords: Combining ability, Heterotic effects, Additive and non-additive, Saline stress, Rainfed conditions, Relative importance.

INTRODUCTION

It is logical to imagine that crops growing under stress environments exploit various strategies at the whole plant as well as the cell level that allow them to overcome the stress conditions. Soil salinity in semiarid regions of the world is major detrimental factor for crop production. Salinity tolerance is considered a polygenic trait but much of this complexity is due to lack of knowledge, which need to be resolved by coordinated physiological genetic and crop breeding researchers (Tal, 1985). In dry areas of Egypt, the seasonal precipitation is the most limiting factor affecting yield that is the final product of large number of biochemical and physiological processes under genetic control of the individual genotype. Plant breeders continue to search for ways to increase the efficiency of selection for grain yield under stress conditions such as rainfed and salinity by detecting a working knowledge of the inheritance of various economic traits.

Wheat is the world' s leading grain crop. Wheat breeders are always looking for means and sources of genetic improvements in grain yield and its components. Genetic diversity is the main tool for the breeders to have better recombinants by creating heritable variability upon which selection can be practiced. Knowledge of genetic relationship among individuals or populations is essential to breeders for planning crosses to gain better selections for high yield and developing new promising lines.

Crossing of wheat genotypes possessing desired characteristics has so far been the most effective way to achieve progress. Diallel cross technique is a good tool for identification of hybrid combinations that have the potentiality of producing maximum improvement and identifying superior lines among the progeny in early segregating generations.

Scope of previously studies is limited if they are not carried out over environments as the combining ability and inheritance of quantitative characters may vary over environments. Information on the relative importance of general and specific combining ability are important in the development of efficient wheat breeding programs particularly under the stress conditions. Genetically, GCA is associated with additive genes, while SCA is attributed primarily to non-additive, dominance and epistasis. It is very essential that the breeder should evaluate the potentialities and eventually combining ability has proved to be of considerable use in crop improvement. It will enable to restrict the choice of fewer but efficient and productive basic core material that will serve as a source material for fashioning productive cultivates required for specific needs. In this regard, several studies have been reported in wheat El-Marakby *et.al.* (1993), Mann and Sharma (1995), Afiah *et.al* (1997), Afiah and Abdel-Sattar (1998), Afiah (1999), Afiah *et.al*. (2000-b) and Afiah (2002-b). Many efforts are devoted nowadays to increase wheat productivity under stress conditions through genetically improvement.

To carry out a successful program, the breeder should have enough knowledge about the type and relative amount of genetic variance components under aimed environments for grain yield and its attributes.

The present investigation was undertaken to estimate the type and relative amount of genetic variance components for yield and its attributes of half diallel crosses involving six bread wheat parental genotypes under two environmental conditions of newly reclaimed lands.

MATERIALS AND METHODS

Six common wheat varieties and / or lines (*Triticum aestivum* L.) representing a wide range of diversity for several agronomic characters, drought and salinity tolerance were selected for this study. The names, pedigree and origin of these genotypes are presented in table (1). These genetic materials were developed and / or screened along the last decade under stress conditions through the Desert Research Center wheat breeding program. The investigation was carried at three locations. In 1999-2000 growing season, grains from each of the parents were sown at three planting dates to overcome the differences in time of heading at Fac. Agric., Menofiya University, Shebin El-kom. During such season, all possible parental combinations without reciprocals were made between six parents giving a total of fifteen crosses.

Table (1): Name, origin, pedigree and/or selection history of the six divergent bread wheat parental genotypes.

No.	**Name**	**Origin**	Pedigree and/or selection history
P_1	Nesser	CIMMYT/ICARDA	ICW85-0024-06AP-300AP-300L-1AP-0AP
P_2	K-9	Egypt	Giza 150 / Sh-Walter (F_8 selected line)
P_3	Yecora Rojo	CIMMYT	Ciano67/Sonora64//Klien Rendidor/3/IL8156 26Y-2M-1Y-0M-302M
P_4	Mar.3	Egypt	Cham 4/Sakha 8//2* Sakha 8 Su74-3Mr-32Mr-5Sw-13Sw-0Sw
P_5	Sakha69	Egypt	Inia-RL 4220 / 7C // Yr "S"
P_6	Sahel-1	Egypt	Ns. 732/Pima//Veery "S" #5 Sd735-4Sd-1Sd-1Sd-0Sd

CIMMYT : Centro International de Mejoramiento de Maize Y Trigo (Mexico) = International maize and wheat improvement center.
ICARDA : International Center for Agricultural Research in the Dry Areas.
k-9 : Newly bred line obtained through (Abdo, 2000), M.Sc. experiments.
Mar.3 : Newly bred line obtained by the first author through Desert Research Center wheat breeding program.

In 2000/2001 growing season, the six parental genotypes and their 15 F_1 hybrids were sown at two locations, the first was the experimental farm of Desert Research Center at Maryout under rainfed with one supplemental irrigation at sowing (by the available culture drainage water, ECe 3.2 dSm^{-1}) then plants were left to grow under rainfed conditions (total rainfall 120.4 mm) during the growing season. Soil of Maryout location characterized as sandy clay loam texture with PH 7.9, ECe 3.8 dSm^{-1} and 39% calcium carbonate. Siwa experimental site private farm at El-Maraky represents the second location (saline environment) where ECe of soil was 13.5 dSm^{-1} with 18.6% Ca CO_3 and average EC of artesian irrigation water was 3.2 dSm^{-1}.

The experiment in each location was designed in a randomized complete block design with three replications. Each plot consists of two and one row for each parent and F_1 cross, respectively. Each row was three meters long with 30 cm between rows and plants within row were 10 cm apart, allowing a total of 30 plants per row. The dry method of planting was used in this concern. The studied traits were plant height, number of spikes / plant, number of kernels / spike, 1000-kernel weight and grain yield / plant.
General and specific combining ability estimates (GCA and SCA) were obtained by employing Griffing's diallel crosses analysis (1956) designated as method 2 model 1. The relative importance of additive and non-additive effects was assessed by variances ratio as follows:

$2K^2g / (2K^2g + K^2s) = 2(\Sigma g_i^2 / n\text{-}1) / [2(\Sigma g_i^2 / n\text{-}1) + \Sigma\Sigma S_{ij}^2 / \{n(n\text{-}3)/2\}]$

Where: K^2g and K^2s refer to the variances of GCA and SCA, respectively.
Heterosis was determined for individual cross in both locations as well as the combined analysis. According to the formula of Fonseca and Patterson (1968).

RESULTS AND DISCUSSION

Variation and genotype x environment interaction:

The analysis of variance for each location and the combined analysis for plant height, number of spikes / plant, number of grains / spike, 1000-kernel weight and grain yield / plant are presented in table (2). Location mean squares were highly significant for all the studied traits with mean values for Siwa location being higher than those for Maryout. The increase of grain yield / plant in Siwa location depended on the increase in yield components. Whereas, saline environment at Siwa location was more suitable than rainfed site because of favorable irrigation conditions for wheat germplasm characterized as relatively tolerant to salt affected soils.

Mean squares for genotypes, parental lines or varieties, F_1 hybrids and parents vs. hybrids were significant for all traits in both locations as well as the combined analysis except parents vs. hybrids at Maryout and the combined analysis for number of grains / spike.

Genotypes x location, parents x location, F_1 x location and parent vs. crosses x location, mean squares were significant for all traits except number of grains / spike in F_1 x location, 1000-grain weight in parent vs. cross x location. Such results indicated that the tested genotypes varied from each other and ranked differently in Maryout to Siwa locations.

The combining ability ratios (GCA / SCA) for the studied traits in both locations and the combined analysis are presented in table (2). The mean squares associated with general and specific combining ability were significant for all the studied traits. High GCA / SCA ratios exceed the unity were obtained for most cases of the studied traits. Such ratio was highly significant for grain yield / plant at Siwa saline environment indicating that additive and additive x additive types of gene action were more important

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2c

than none additive gene effects controlling this trait. In this respect Baker (1978) reported that there are instances in the literature where the relative size of mean squares have been used to assess the relative importance of general and specific combining ability. That such a procedure may be misleading can easily be seen by studying the expectations of mean squares given by Griffing (1956). However, Baker (1978) revealed that the relative importance of general and specific combining ability in determining progeny performance should be assessed by estimating the components of variance and expressing them in the ratio, 2 K^2g / (2 K^2g + K^2s) Where: K^2g and K^2s refer to the variances of GCA and SCA, respectively. When this ratio is closer to unity additive and none additive effects had an equal importance for the trait inheritance. This early shown for plant height under Siwa Oasis environment (Table 2). The greater predictability based on general combining ability recorded for grain yield / plant at the same location. These results were along the same line of those reported by Chowdry *et.al.* (1996), Darwish (1998) and El-Gamal (2002).

The mean squares of interaction between environment and both types of combining ability were significant for all traits, revealing that the magnitude of both additive and non-additive types of gene action varied from environments to another. As shown in table (2), ratios of GCA x L / GCA was much higher than SCA x L / SCA for all traits recorded except 1000-grain weight which was in reverse and number of spikes / plant which had nearly equal ratios. Such results indicated that additive types of gene action were most influenced by changes of environmental conditions. Early findings of El-Seidy and Hamada (2000) were in line with these results. Regarding to 1000-grain weight, it is fairly evident that ratio of SCA x environment / SCA, revealing that non-additive gene effects was more changed from location to another. Specific combining ability previously studied by several investigators and was more sensitive to environmental changes than GCA [Gilbert (1958), Darwish (1998) and Afiah *et.al* (2000-a)].

Mean performances:

Mean performances of parental genotypes and their hybrids at each location (Maryout and Siwa) and the combined data are presented in table (3). The parent (P_1) gave the highest value for yield / plant in Maryout. P_2 gave the highest values for plant height in Maryout and the combined analysis, number of grains / spike in Maryout.

The parental genotype (P_3) gave the highest value for number of grains / spike. P_4 gave the highest values for 1000-kernel weight, number of spikes / plant in Maryout and the combined analysis, number of grains / spikes in Siwa, P_4 gave the highest values for plant height in Siwa, number of spikes / plant in Siwa and the combined analysis. Fifteen, nine and fifteen hybrids had high values for plant height in Maryout, Siwa and the combined analysis, respectively. The best hybrids for tallness were P_2 x P_5, P_2 x P_6, P_1 x P_4 and P_3 x P_4 in Maryout and Siwa as well as combined analysis.

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Twelve, five and ten hybrids had high values for number of spikes / plant in Maryout, Siwa and the combined analysis, respectively. The best crosses were P_4 x P_5 and P_4 x P_6 in Maryout and Siwa as well as the combined analysis. The crosses P_1 x P_4 and P_4 x P_6 were the best ones for number of grains / spike in the combined analysis.

For 1000-kernel weight, the best crosses were P_1 x P_2, P_1 x P_6 and P_4 x P_5 in Maryout and P_3 x P_5 and P_4 x P_6 in Siwa.Three, three and five hybrids gave the highest values for grain yield / plant in Maryout, Siwa and the combined analysis, respectively. The best crosses were P_4 x P_6 in Maryout and Siwa as well as the combined analysis, P_1 x P_5 and P_2 x P_3 in Maryout, P_1 x P_4 and P_3 x P_4 in Siwa. These results coincide with those obtained by significant interaction between genotypes and location (Table 2). These findings are in agreement with those previously obtained by Afiah *et.al.* (1997), Kheiralla *et.al.*(2001) and Afiah (2002 a and b).

Heterosis:

Heterosis expressed as the percentage deviation of F_1 mean performance from Mid-parent and better parent values for all the studied traits at both locations and the combined analysis are presented in tables (4-a) and (4-b), respectively.

For plant height, fifteen, twelve and fourteen crosses expressed significant positive heterotic effects relative to mid parent in Maryout, Siwa locations and the combined analysis, respectively. While, twelve, twelve and nine cross combinations exhibited significant positive heterotic effect, relative to better parent in the same order. The best crosses were P_1 x $P_{3,}$ P_1 x P4 and P_3 x P_5 in both locations and the combined analysis for tall plants.

For number of spikes / plant, fourteen, ten and ten crosses exhibited significant positive heterotic effects relative to mid parent in Maryout, Siwa location and the combined analysis, respectively. While, fourteen, eight and eight from the pervious crosses expressed significant positive heterotic effects relative to better parent in the same order. The best crosses were P_1 x P_2, P_2 x P_3 and $P_{2\,x}$ P_4 in both locations and the combined analysis.

For number of kernels / spike, four, one and three crosses exhibited significant positive heterotic effects relative to mid parent in Maryout, Siwa and combined analysis, respectively. While, none of the hybrids surpassed the better parent in both locations as well as the combined analysis.

For 1000-kernel weight, five crosses in each of the two locations and the combining data expressed significant positive heterotic effects relative to mid parent meanwhile, three, three and two hybrids gave significant positive heterotic effects relative to better parent in Maryout, Siwa locations and the combined analysis, respectively. The best crosses were P_1 x P_2 and $P_{3\,+}$ x P_5 in both locations as well as the combined analysis.

For grain yield / plant; eleven, fifteen and thirteen crosses expressed significant positive heterotic effects relative to mid parent in Maryout, Siwa and the combined analysis, respectively. While, six, five and six crosses from the previous hybrids exhibited significant positive heterotic effects relative to better parent in the same order. The best crosses were P_1 x P_5, P_2 x P_3, P_2 x

4a

4b

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P_5, P_3 x P_5 and P_3 x P_6 over both locations. Significant heterotic effects for grain yield and its components in bread wheat under stress conditions previously obtained by Bedair *et al.* (1979), Afiah and Abdel-Sattar (1998) and Afiah (2002-a).

Combining ability effects:

General combining ability effects (g_i) of each parent for all traits studied at Maryout, Siwa locations and the combined analysis presented in table (5). General combining ability effects were found to be different significantly from zero for all traits studied. High positive values would be in an interest for all traits in question. The parental genotype (P_1) expressed significant positive g_i effects for 1000-kernel weight in Maryout. P_2 showed significant g_i effects for plant height in Maryout and the combined analysis. P_3 expressed significant positive g_i effects for number of kernels / spike in Siwa.

The parental genotype P_4 was the best combiner for number of spikes / plant in both locations and the combined analysis, 1000-kernel weight and yield / plant in Siwa location and combined analysis, plant height in Maryout location and number of grains / spike in Siwa. Also, P_5 gave desirable (g_i) effects for number of spikes / plant under saline conditions at Siwa Oasis. With regard to yielding capacity, P_4 was the best combiner under saline environment as well as the combined data. Also, P_4 had significant g_i effects for two or more of the yield attributes under each of the two stress types tested. Such parental genotype (P_4) was developed under similar aimed conditions through the previous segregating generations among Desert Research Center breeding program. As shown in table (5) insignificant associations between parental means and their g_i effects were detected in all cases revealing that it is not necessarily that good combiners must have a good index of intrinsic performance. These results are in partial agreement with the earlier findings of Bedair *et al.* (1979), Afiah *et al.* (1999) and Afiah (2002-a).

Specific combining ability effects of the cross combinations computed for all traits studied in Maryout, Siwa, as well as the combined analysis are presented in table (6). For plant height, four, eight and seven crosses exhibited significantly positive S_{ij} effects in Maryout, Siwa and combined analysis, respectively. The best crosses were P_1 x P_2 and P_4 x P_6.

For 1000-kernel weight, three, two and two cross combinations expressed significant positive S_{ij} effects in Maryout, Siwa and combined analysis, respectively. The best crosses were P_1 x P_2 in Maryout location and combined analysis and P_3 x P_5 in Siwa location and combined analysis.

For grain yield / plant, six, three, and five crosses gave significant positive S_{ij} effects in Maryout, Siwa and the combined analysis, respectively. The best crosses were P_1 x P_5 and P_4 x P_5 in both locations and combined analysis and P_3 x P_5 in Maryout and combined analysis.

If crosses showing high specific combining ability involve only one good combiner, such combination would throughout desirable transgressive segregates providing that the additive genetic system present in the good combiner and complementary epistatic effects present in the crosses act in the same direction to reduce undesirable plant characteristics and maximize the character in view. Therefore, most of the previous crosses might be of prime importance in breeding program for traditional breeding procedures under rainfed and saline conditions. Earlier reports of El-Hennawy (1991), Afiah *et al.* (1997) and Afiah (1999) were in accordance with these findings.

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تحليل القدرة على التآلف و قوة الهجين و علاقتهما بالاجهاد الملحى والجفافى لصفات المحصول و مساهماته فى قمح الخبز

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***وحدة تربية النباتات-قسم الاصول الوراثية النباتية-مركز بحوث الصحراء-المطرية-القاهرة-مصر**
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تم اجراء كافة الهجن التبادلية دون العكسية بين ستة اباء من قمح الخبز متباعدة وراثيا (سلالتان من نواتج غربلة المستوردات تحت ظروف الاجهاد البيئى بمصر واثنان من السلالات المرباة حديثا ضمن برامج التربية المحلية بالاضافة الى اثنان من الاصناف المسجلة) و ذلك بالمزرعة التابعة لكلية الزراعة بشبين الكوم فى موسم النمو ١٩٩٩/٢٠٠٠.

تم تقييم الآباء الستة و هجن الجيل الأول الناتجة بينها (١٥ هجين) لمحصول الحبوب / نبات واربعة من الصفات المساهمة فيه تحت الظروف الملحية السائدة بواحة سيوة والظروف المطرية بالساحل الشمالى الغربى (مريوط) خلال موسم النمو ٢٠٠٠/٢٠٠١.

بتحليل بيانات كل بيئة على حدة واختبار التجانس امكن اجراء التحليل التجميعى الذى اوضح معنوية تفاعل مكونات التباين الوراثى مع البيئة لكل الصفات تحت الدراسة ماعدا تباين الهجن بالنسبة لعدد حبوب السنبلة والاباء بالنسبة لوزن الالف حبة.

اوضح تحليل تباين القدرة على التالف ان العوامل المضيفة اكثر تاثيرا فى كل الصفات المدروسة ماعدا طول النبات تحت الظروف الملحية والتحليل التجميعى للبيانات وان التفاعل بين القدرة العامة على التالف (التباين المضيف + التفاعل بين مضيف × مضيف) والبيئة اعلى من نظيره المحسوب للقدرة الخاصة على التالف فى كافة الصفات ماعدا عدد سنابل النبات وزن الالف حبة. فى حين تراوحت الاهمية النسبية للتاثير المضيف ما بين ٤٩% لطول النبات بموقع سيوه و ٩٥% لمحصول الحبوب /نبات تحت الظروف الملحية بسيوة مما يجعل الانتخاب مجديا فى الاجيال الانعزالية التالية فى حالة ارتفاع الاهمية النسبية.

اختلف متوسط اداء التراكيب الوراثية بدرجات متفاوتة تحت الظروف السائدة بكل من الموقعين مع صغر القيم عموما تحت الظروف المطرية عنها تحت ظروف التربة المتاثرة بالملوحة فى واحة سيوه.

ابدت بعض الهجن تفوقا ملحوظا غى محصول الحبوب/نبات ومعظم الصفات المساهمة فيه مثل $P_1 \times P_5$ و $P_2 \times P_3$ تحت الظروف المطرية و $P_1 \times P_4$ و $P_3 \times P_4$ تحت الظروف الملحية. كما تفوقت الهجن التالية فى قوة الهجين منسوبة الى الاب الافضل فى الموقعين تحت الدراسة $P_2 \times P_3$, $P_1 \times P_5$, $P_2 \times P_5$, $P_3 \times P_5$, $P_3 \times P_6$.

تفوق الاب الرابع (Mar.3) فى قدرته العامة على التالف تحت الظروف الملحية وذلك بالنسبة للكفاءة المحصولية واثنين او اكثر من مكونات المحصول تحت كل من الموقعين تحت الدراسة وقد يرجع ذلك الى ان استنباط هذه السلالة خلال برنامج تربية القمح بمركز بحوث الصحراء قد تم تحت الظروف المستهدفة بالمناطق حديثة الاستصلاح.

بالسبة للقدرة الخاصة على التالف كانت افضل التوليفات الهجينة $P_4 \times P_5$ و $P_1 \times P_5$ تحت كلا من الظروف الملحية والمطرية و $P_3 \times P_5$ تحت الظروف المطرية.

كما لوحظ ان الارتباط بين متوسطات اداء الاباء فى كافة الصفات تحت الدراسة وتاثيرات القدرة العامة على التالف غير معنوية فى كل الحالات مما يؤكد انه ليس بالضرورة ان تتناسب المتوسطات مع قدرة الاب على الائتلاف.

Table (3): The genotypes mean performance for all studied measurements at each of the two locations; Maryout (Mar.) and Siwa Oasis as well as their combined data (Com).

Genotypes	Plant height (cm)			No. of spikes/plant			No. of grains/spike			1000-grain weight (g)			Grains yield/plant (g)		
	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
P_1	68.2	80.6	74.4	2.24	3.31	2.8	27.8	32.7	30.3	32.4	34.8	33.6	2.09	3.76	2.93
P_2	75.9	82.4	79.1	1.24	3.18	2.2	31.8	30.7	31.3	27.0	29.2	28.1	1.32	3.43	2.38
P_3	62.9	74.0	68.5	1.81	3.28	2.5	28.8	36.4	32.6	28.1	35.2	31.7	1.65	4.17	2.91
P_4	74.8	83.2	79.0	2.49	4.20	2.3	25.0	38.6	31.8	34.2	40.0	37.1	1.71	4.79	3.25
P_5	67.4	89.0	78.2	2.02	4.49	3.3	26.7	29.4	28.1	27.7	30.9	29.3	1.64	3.15	2.40
P_6	71.2	79.7	75.5	2.03	3.80	2.9	29.3	27.6	28.5	29.4	30.6	30.0	1.79	3.77	2.78
P_1 x P_2	82.4	83.7	83.1	2.62	4.68	3.6	28.1	29.4	28.8	35.8	37.8	36.8	1.85	4.14	3.00
P_1 x P_3	80.0	88.9	84.1	2.85	4.59	3.7	29.4	31.5	30.5	33.3	35.8	34.5	1.94	4.13	3.04
P_1 x P_4	85.1	88.3	86.7	3.07	3.95	3.51	30.6	35.0	32.8	33.8	36.4	35.1	2.18	4.85	3.52
P_1 x P_5	76.5	90.8	83.7	2.76	3.62	3.2	28.8	30.5	26.7	29.2	33.7	31.5	2.26	4.30	3.28
P_1 x P_6	80.1	87.6	83.8	2.30	4.12	3.2	30.6	33.3	31.9	36.1	35.2	35.7	2.28	4.22	3.25
P_2 x P_3	77.4	93.9	85.6	2.27	4.04	3.16	27.7	29.8	28.8	28.5	34.3	31.4	2.08	4.25	3.17
P_2 x P_4	84.4	96.6	90.5	2.98	4.68	3.83	27.8	28.7	28.3	27.6	38.1	32.9	1.75	4.38	3.07
P_2 x P_5	86.0	91.0	88.5	2.31	4.43	3.4	28.2	31.2	29.7	29.6	32.4	31.0	1.78	4.13	2.95
P_2 x P_6	83.2	95.0	89.1	2.60	3.47	3.04	30.0	30.8	30.4	28.6	35.0	31.8	1.88	3.91	2.89
P_3 x P_4	77.4	95.5	86.5	2.78	4.26	3.52	28.0	32.1	30.1	31.4	34.3	32.9	1.75	4.83	3.29
P_3 x P_5	77.5	94.0	85.7	2.51	4.18	3.35	27.6	30.6	29.1	31.7	41.5	36.6	2.23	4.32	3.28
P_3 x P_6	76.6	90.1	83.3	3.01	3.76	3.39	31.8	33.5	32.7	30.6	32.6	31.6	2.32	4.35	3.34
P_4 x P_5	75.7	85.4	80.6	2.86	5.14	4.0	26.8	29.2	28.0	35.6	37.8	36.7	2.06	4.26	3.41
P_4 x P_6	82.0	90.1	86.1	3.08	4.50	3.79	31.6	34.4	33.0	29.3	41.5	35.4	2.16	4.79	3.48
P_5 x P_6	76.7	84.6	80.7	2.60	3.69	3.15	28.7	30.5	29.6	30.6	33.0	31.8	1.85	4.20	3.03
L.S.D.															
0.05	3.39	4.21	3.80	0.250	0.279	0.263	3.169	2.614	2.892	3.043	3.01	3.03	0.189	0.282	0.236
0.01	4.53	5.63	5.08	0.334	0.362	0.351	4.236	3.493	3.865	4.066	4.02	4.04	0.252	0.337	0.315

Table (6): Estimates of specific combing ability effects (S_{ij}) for all studied traits.

Crosses	Plant height (cm)			No. of spikes/plant			No. of grains/spike			1000-grain weight (g)			Grains yield/plant (g)		
	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
P_1 x P_2	2.07	-3.63*	-0.78	0.327**	0.829**	0.578**	-1.28	-1.40	-1.34	4.36**	1.37	2.87*	-0.034	0.198	0.082
P_1 x P_3	5.99**	3.42*	4.71**	0.332**	0.677**	0.505	0.349	-1.68	-0.666	0.952	0.058	0.505	-0.148	-0.131	-0.139
P_1 x P_4	6.18**	1.28	3.73*	0.211	-0.307*	-0.05	2.52	1.28	1.9	-0.331	-1.74	-1.04	0.129	0.223	0.176
P_1 x P_5	-10.33**	3.61*	-3.36*	0.235*	-0.567**	-0.166	0.803	0.233	0.518	-3.18*	-0.929	-2.055	0.193*	0.319	0.256*
P_1 x P_6	2.86	2.56	2.71	-0.295	0.341**	0.023	0.412	1.76	0.09	3.44*	0.766	2.103	0.138	0.112	0.125
P_2 x P_3	0.345	5.35**	2.85	0.109	0.216	0.163	-1.52	-1.60	-1.56	-0.26	0.133	-0.064	0.326**	0.178	0.252*
P_2 x P_4	2.36	6.58**	4.47**	0.477**	-0.229	0.124	-1.45	-2.70	-2.08	-2.91*	1.50	-0.705	0.030	-0.061	-0.016
P_2 x P_5	7.34**	0.767	4.05*	0.138	0.232	0.185	0.066	2.21	1.14	0.836	-0.720	0.058	0.051	0.334	0.193
P_2 x P_6	2.84	6.89**	4.86**	0.358**	-0.327**	0.016	-0.392	0.963	0.288	-0.468	2.14	0.836	0.073	0.009	0.041
P_3 x P_4	1.69	7.30**	4.49**	0.052	0.024	0.038	0.108	-2.46*	-1.17	-0.089	-3.85**	1.969	0.166	0.051	0.109
P_3 x P_5	5.20**	5.59**	5.39**	0.117	0.014	0.066	-0.309	-0.736	-0.523	1.96	6.76**	4.36**	0.294**	0.209	0.252*
P_3 x P_6	2.50	3.81*	3.15	0.547**	-0.005	0.271**	1.70	1.25	1.475	0.652	-1.88	-0.614	0.309*	0.113	0.211*
P_4 x P_5	-1.58	-4.48*	-3.03	0.132	0.535**	0.334**	-0.038	-2.97	-1.504	4.04**	0.700	2.37	0.164*	0.277	0.221*
P_4 x P_6	2.98	2.34	2.66	0.278*	0.300*	0.289*	2.57	1.38	1.975	-2.49	4.500**	1.005	0.183*	0.18	0.182
P_5 x P_6	1.09	-3.30	-1.11	0.130	-0.446**	-0.158	-0.346	0.697	0.176	0.582	-0.43	0.076	-0.143	0.240	0.049
L.S.D. (S_{ij})															
0.05	3.04	3.377	3.208	0.224	0.247	0.235	2.84	2.343	2.591	2.727	2.695	2.711	0.169	0.253	0.211
0.01	4.06	5.047	4.550	0.299	0.331	0.315	3.797	3.132	3.46	3.645	3.602	3.62	0.226	0.338	0.282
L.S.D. ($S_{ij} - S_{ik}$)															
0.05	4.15	5.16	4.65	0.306	0.338	0.322	3.882	3.184	3.533	3.726	3.692	3.704	0.231	0.346	0.288
0.01	5.548	6.876	6.22	0.409	0.452	0.430	5.188	4.256	4.722	4.98	4.92	4.95	0.308	0.462	0.385
L.S.D. ($S_{ij} - S_{kl}$)															
0.05	5.492	6.82	6.16	0.463	0.447	0.455	5.13	4.235	4.68	4.94	4.871	4.4	0.304	0.455	0.379
0.01	7.34	9.12	8.23	0.618	0.597	0.607	6.86	5.66	6.26	6.58	6.51	6.54	0.407	0.608	0.507

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**

Table (4-a): Percentage of heterosis over mid parent for all studied traits.

Crosses	Plant height (cm)			No. of spikes/plant			No. of kernels/spike			1000-kernel weight (g)			Grains yield/plant (g)		
	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
$P_1 \times P_2$	14.4**	2.7	8.6**	50.5**	44.2**	47.4**	-5.2	-7.3*	-6.5	20.5**	15.1**	17.8**	8.2	15.2**	11.7**
$P_1 \times P_3$	22.0**	15.0**	18.5**	40.7**	39.3**	40.0**	37.1**	-8.8**	14.2*	10.1**	2.3	6.2	3.7	12.5**	8.1
$P_1 \times P_4$	19.0**	7.8**	13.4**	29.8**	5.2	17.5**	15.9**	-1.8	7.1	1.5	-2.7	-0.6	14.7**	13.5**	14.1**
$P_1 \times P_5$	12.8**	7.1**	9.9**	29.6**	-7.2*	11.2	5.7	1.5	3.6	-2.8	2.6	-0.1	21.2**	24.5**	22.9**
$P_1 \times P_6$	14.9**	9.3**	12.1**	7.7	15.9**	11.8	7.2	10.4**	8.8*	16.8**	7.6	12.2*	17.5**	12.1**	14.8**
$P_2 \times P_3$	11.5**	20.1**	15.8**	48.9**	25.1**	37.5**	-8.6	11.2**	-9.9*	3.5	6.5	5.0	39.4**	11.8**	25.6**
$P_2 \times P_4$	12.0**	16.7**	13.6**	59.8**	26.8**	43.3**	-2.1	-17.2**	-9.7*	-9.2*	10.1**	0.2	15.1**	6.6*	10.8**
$P_2 \times P_5$	20.0**	6.2**	13.1**	41.7**	15.5**	6.6	-3.6	3.8	0.1	8.2	7.8	8.0	19.9**	25.5**	22.7**
$P_2 \times P_6$	13.1**	17.2**	15.2**	59.0**	-0.6	29.2**	-1.8	8.7	2.0	1.4	17.1**	9.3*	20.5**	8.6*	14.6**
$P_3 \times P_4$	12.4**	21.5**	17.0**	29.3**	13.9**	21.6	4.1	-11.1**	-10.3*	0.8	-8.8*	-4.0	4.2	7.8**	6.0
$P_3 \times P_5$	18.9**	15.3**	17.1**	31.1**	7.6*	-19.4	-0.5	-6.9*	-3.7	13.6**	25.6**	19.6*	35.6**	18.0**	26.8**
$P_3 \times P_6$	14.2**	17.2**	15.7**	56.7**	6.2	31.5**	9.5*	5.3	7.4	6.2	-0.9	2.7	34.9**	9.6**	22.3**
$P_4 \times P_5$	6.1**	-0.8	2.6	26.8**	18.3**	22.6**	3.2	-14.1**	-5.2	15.0**	6.6	10.8*	22.9**	19.9**	21.4**
$P_4 \times P_6$	12.3**	10.6**	11.5**	36.3**	12.5**	24.4**	16.4**	3.9	1.3*	-7.9	17.6**	4.9	23.4**	11.9**	17.7**
$P_5 \times P_6$	10.7**	0.3	5.5*	24.4**	10.9**	6.8	2.5	7.1	4.8	2.1	7.3	4.7	7.9	21.4**	14.7**

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**

Table (4-b): Percentage of heterosis over better parent for all studied traits.

Crosses	Plant height (cm)			No. of spikes/plant			No. of kernels/spike			1000-kernel weight (g)			Grains yield/plant (g)		
	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
$P_1 \times P_2$	8.6**	1.6	5.1	16.9**	41.4**	29.2**	-11.6*	-10.1*	-10.8*	10.5*	6.8*	9.6**	-11.5*	10.1*	-0.7
$P_1 \times P_3$	17.3**	10.3**	13.8**	27.2**	38.7**	33.0**	2.1	-13.5**	-5.7	2.8	1.7	2.3	-7.2	-0.95	-4.1
$P_1 \times P_4$	17.8**	6.1*	11.9**	23.3**	-5.9	8.2	10.1	-9.4**	0.4	-1.2	-9.0**	-5.1	4.3	1.3	2.8
$P_1 \times P_5$	12.2**	2.0	7.1**	23.2**	-19.4**	1.9	3.6	-6.7	-1.6	-9.9*	-3.2	-6.6	8.1	14.4**	11.3**
$P_1 \times P_6$	12.2**	8.7**	10.5**	2.7	8.4**	5.6	4.4	1.8	3.1	11.4*	1.1	6.3	9.1*	11.9**	10.5*
$P_2 \times P_3$	1.8	14.0**	7.9	25.4**	23.2**	24.3**	-12.1*	18.2**	-15**	1.4	-2.6	-0.6	26.1**	1.9	14.0**
$P_2 \times P_4$	11.2**	16.1**	13.7**	19.7**	11.4**	15.6**	-12.6*	-25.6**	-19.1**	-19.2**	-4.8	-12.0	2.3	-8.6**	-3.2
$P_2 \times P_5$	13.3**	2.2**	7.8**	14.4*	-1.3	6.5	-3.6	1.6	-1.0	6.8	4.9	5.9	8.5	20.4**	14.5**
$P_2 \times P_6$	9.6**	15.3**	15.5**	28.1**	8.7*	18.4**	-5.7	0.3	-2.9	-2.7	14.4**	5.6	5.0	3.7	4.4
$P_3 \times P_4$	3.5	14.8**	9.2	11.7*	1.4	13.1	2.8	-16.8**	-7.0	-0.2	-14.3**	-7.3	2.3	0.84	1.8
$P_3 \times P_5$	15.0**	5.6*	10.3**	24.3**	-6.9*	8.7	-4.2	-15.2**	-10.1	12.8*	17.9**	15.4**	36.0**	3.6	19.8**
$P_3 \times P_6$	7.6**	13.1**	10.4**	48.3**	-1.1	23.0**	8.5	-7.9*	0.3	4.1	-7.4*	-1.7	29.6**	4.3	17.0**
$P_4 \times P_5$	1.2	-4.0*	-1.4	14.8**	14.5**	14.7**	0.4	-24.9**	-12.0	4.1	-5.5	-0.7	20.5**	-0.63	9.9
$P_4 \times P_6$	9.6**	2.6	6.1	23.7**	7.2*	15.5**	7.8	-10.9**	-1.6	-14.3**	3.8	-5.3	20.7**	0.0	10.4
$P_5 \times P_6$	7.7**	-4.9*	4.0	28.1**	-17.8**	5.15	-2.1	3.7	0.8	4.1	6.8	5.5	3.4	11.4**	7.4

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**

Table (5): Estimates of general combining ability effects (g_i) for all studied traits.

Parent	Plant height (cm)			No. of spikes/plant			No. of grains/spike			1000-grain weight (g)			Grains yield/plant (g)		
	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
P_1	0.005	-1.777*	-0.886	0.076	-0.118**	-0.020	0.216	0.385	0.300	2.02**	0.228	1.124	-0.145**	-0.049	-0.097*
P_2	3.088*	1.263	2.175**	-0.277	-0.106	-0.192**	0.386	-1.327*	-0.469	-1.6*	-1.347*	-1.473*	-0.190**	-0.234	-0.212**
P_3	-3.204**	-0.556	-1.88*	-0.059	-0.141*	-0.100	0.096	1.055*	0.575	-0.654	0.269	-0.192	0.011	0.084	0.047
P_4	1.708**	0.947	1.328	0.28**	0.304**	0.295**	-0.942	1.826**	0.442	1.163	2.665**	1.914**	-0.026	0.457**	0.215**
P_5	-1.663*	1.122	-0.27	-0.048	0.233**	0.092	-0.942	-1.394**	-1.158*	-0.583	-0.809	-0.696	-0.007	-0.193**	-0.100*
P_6	0.067	-0.999	-0.466	0.022	-0.172**	-0.075	1.233	-0.544	0.345	-0.346	-1.005	-0.675	0.067	-0.065	0.001
L.S.D. (g_i)															
0.05	1.339	1.665	1.502	0.099	0.109	0.104	1.253	1.033	1.143	1.203	1.188	1.195	0.075	0.116	0.093
0.01	1.790	2.226	2.008	0.132	0.146	0.139	1.624	1.381	1.527	1.607	1.588	1.597	0.099	0.149	0.124
L.S.D. ($g_i - g_j$)															
0.05	2.075	2.580	2.327	0.153	0.169	0.161	1.941	1.600	1.771	1.863	1.841	1.852	0.115	0.173	0.144
0.01	2.77	3.448	3.109	0.204	0.225	0.215	2.594	2.139	2.366	2.490	2.46	2.475	0.155	0.231	0.193
r.	0.654	-0.275	0.190	0.709	-0.323	0.193	0.065	0.144	0.105	0.256	0.37	0.313	0.392	0.406	0.399

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**
r.: Simple correlation coefficient between grains yield / plant and g_i.

Table (2): Mean squares of Maryout (Mar.), Siwa Oasis and combined (Com) ANOVA from diallel crosses for plant height, number of spikes / plant and number of grains / spike.

S. O. V.	Df		Plant height (cm)			No. of spikes/plant			No. of grains/spike		
	L	Com	Mar.	Siwa	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
Locations (L)	-	1	-	-	3544.6**	-	-	77.6**	-	-	271.63**
Reps. With L	2	4	4.94	3.56	4.25	0.0025	0.025	0.014	2.03	0.075	1.05
Genotype (G)	20	20	108**	103.11**	173.61**	0.650**	0.843**	1.13**	9.98**	22.05**	17.45**
Parents (P)	5	5	71.52**	72.15**	102.75**	0.553**	2.22**	1.11**	16.28**	53.36**	20.35**
F_1	14	14	37.23**	49.05**	48.91**	0.211**	0.658**	0.51**	7.94*	11.11**	17.56**
P. vs. F_1	1	1	1282**	1014.8**	2273.8**	7.281**	3.215**	9.81**	7.15	18.76**	1.39
G x L	-	20	-	-	37.5**	-	-	0.368**	-	-	14.58**
P x L	-	5	-	-	40.9**	-	-	0.329**	-	-	49.3**
F_1 x L	-	14	-	-	37.37**	-	-	0.359**	-	-	1.48
P. vs. F_1 x L	-	1	-	-	22.92*	-	-	0.684**	-	-	24.52**
GCA	5	5	122.23**	39.46**	106.65**	0.819**	1.061**	1.424**	17.27**	41.28**	22.85**
SCA	15	15	103.27**	124.33**	195.93**	0.593**	0.771**	1.026**	7.56*	15.64**	15.65**
GCA x L	-	5	-	-	55.15**	-	-	0.456**	-	-	35.7**
SCA x L	-	15	-	-	31.67**	-	-	0.338**	-	-	7.55**
Error	40	80	4.22	6.52	5.37	0.023	0.028	0.029	3.69	2.51	3.1
GCA / SCA	-	-	1.185	0.32	0.544	1.381	1.376	1.388	2.28	2.64	1.46
Additive	-	-	5.10	1.64	2.22	0.033	0.044	0.030	0.70	1.72	0.46
Non-additive	-	-	3.44	3.35	2.22	.014	0.028	0.011	0.26	0.50	0.27
Relative import.	-	-	0.75	0.49	0.67	0.83	0.76	0.84	0.84	0.87	0.77
GCA x L / GCA	-	-	-	-	0.517	-	-	0.320	-	-	1.562
SCA x L / SCA	-	-	-	-	0.162	-	-	0.329	-	-	0.482

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**
Relative importance expressed as 2 K^2g / (2 K^2g + K^2s).

Table (2) cont.: Mean squares of Maryout (Mar.), Siwa Oasis and combined (Com) ANOVA from diallel crosses for 1000-grain weight and grains yield / plant.

S. O. V.	Df		1000-grain weight (g)			Grains yield/plant (g)		
	L.	Com	Mar.	Siwa	Com	Mar.	Siwa	Com
Locations (L)	-	1		-	572.6**	-	-	165.0**
Reps. with L	2	4	3.37**	1.02	2.19	0.052	0.00015	0.026
Genotype (G)	20	20	24.87**	33.5**	41.77**	0.202**	0.612**	0.562**
Parents (P)	5	5	24.91**	47.7**	64.77**	0.181**	1.01**	0.682**
F_1	14	14	24.13**	25.1**	28.55**	0.126**	0.263**	0.228**
P. vs. F_1	1	1	35.16**	81.2**	111.89**	1.356**	3.538**	4.646**
G x L	-	20	-	-	16.61**	-	-	0.253**
P x L	-	5	-	-	7.865	-	-	0.504**
F_1 x L	-	14	-	-	20.61**	-	-	0.163**
P. vs. F_1 x L	-	1	-	-	41.43**	-	-	0.248**
GCA	5	5	42.64**	51.4**	77.54**	0.299**	1.508**	1.015**
SCA	15	15	18.95**	27.5**	29.85**	0.169**	0.313**	0.410**
GCA x L	-	5	-	-	16.49**	-	-	0.793**
SCA x L	-	15	-	-	16.65**	-	-	0.072**
Error	40	80	3.40	3.32	3.36	0.0131	0.0293	0.0212
GCA / SCA	-	-	2.25	1.87	2.59	1.77	4.82**	2.48
Additive	-	-	1.78	2.14	1.61	0.012	0.063	0.023
Non-additive	-	-	0.87	1.10	0.55	0.006	0.007	0.005
Relative import.	-	-	0.80	0.79	0.85	0.82	0.95	0.90
GCA x L / GCA	-	-	-	-	0.213	-	-	0.781
SCA x L / SCA	-	-	-	-	0.558	-	-	0.176

***, ** denote significant at 0.05 and 0.01 probability levels, respectively.**
Relative importance expressed as $2K^2g / (2K^2g + K^2s)$.