



Inheritance of Some Growth and Yield Traits in Bread Wheat Using Line×Tester Analysis

Fatih Karim Hama Ali and Dana Azad Abdulkhaleq

Department of Biotechnology and Crop Science, College of Agricultural Engineering Sciences, University of Sulaimani, Iraqi Kurdistan Region.

E-mail: fatihkarim75@hotmail.com, dana.abdulkhaleq@univsul.edu.iq

Article info	Abstract
Original: 19 July 2019 Revised: 9 October 2019 Accepted: 17 November 2019 Published online: 20 December 2019 Key Words: <i>Triticum aestivum L., Genotypes, Line × tester analysis, Combining ability, Growth and yield traits.</i>	Seven Bread wheat genotypes (<i>Triticum aestivum</i> L.) were used in this investigation. Three genotypes namely (Maroof, Aras, and Hasad) were used as female parents (lines) and four genotypes namely (Alla, Tamuz-2, Adana and Sabr Beg) were used as male parents (testers). The 12 F ₁ 's hybrids with their 7 parents were evaluated during 2018-2019 growing season. Genotypes were crossed in a line×tester matting in Completely Randomized Block Design (CRBD) with three replicates at two locations; Kanipanka and Qlyasan, at Sulaimani city in Iraqi Kurdistan Region. The pooled analysis of variance confirmed that location had a significant effect on almost all of the studied traits, but it has no effect on grain yield plant ⁻¹ . The results proved a significant difference between the studied locations in all characters except final yield. At Kanipanka location, Sabr Beg and the cross Maroof×Tamuz-2 granted the highest yield; 26.303 and 23.914 g plant ⁻¹ respectively. At Qlyasan location Tamuz-2 and the cross Hasad ×Tamuz-2 granted the highest yield; 19.875 and 19.724 g plant ⁻¹ respectively. Tamuz-2 recorded the highest positive General Combining Ability values (2.331 and 2.479) for grain yield plant ⁻¹ at Kanipanka and Qlyasan, respectively. The cross Maroof ×Tamuz-2 showed the maximum positive Specific Combining Ability effect values (3.034) for grain yield plant ⁻¹ at Kanipanka, while at Qlyasan the cross Aras×Sabr Beg record the maximum value with 1.743. Testers brought many variations in the expression of the trait grain yield plant ⁻¹ at Kanipanka and Qlyasan, respectively. At both locations, the ratio of $\sigma^2_{gca} / \sigma^2_{sca}$ value was less than one (0.062 and 0.450) and the average degree of dominance value was more than one (4.005 and 1.490) which confirmed that non-additive gene effect was in control for the trait grain yield plant ⁻¹ . The maximum desirable positive heterosis value (26.082) recorded by the crosses Maroof×Tamuz-2 at Kanipanka location, while at Qlyasan location the cross Aras×Sabr Beg recorded the maximum desirable positive heterosis value (26.989) for grain yield plant ⁻¹ .

Introduction

Bread wheat (*Triticum aestivum* L.) one of the very important diet crops in the world, and its continued improvement is necessary to maintain food security in the face of a growing human population and the trouble of agricultural production due to climate change [1]. It is one of the very important diet crops in the world, and its continued improvement is necessary to maintain food security in the face of a growing human population and the trouble of agricultural production due to climate change [2]. Recently, wheat is the most widely cultivated cereal in the world with more than above 220 million ha planted annually under a wide range of climatic conditions and in different geographic regions. Depending on agro-climatic conditions, yearly are produced about 771 million tons from this China came in the top of the list by producing 134 million tons followed by India, Russian Federation, United States, and France with 99, 86, 47, 37 million

tons respectively, while Iraq produced 3million tons[3, 4].Heterosis breeding is a good tool to enhance wheat production through the development of new genotypes having a wider genetic base and better performance under various agro-climatic conditions [2]. Breeding stock,such as new genotypes and advanced lines with different morphological and economic characteristics are now available as a source for genetic experiments [5]. Combining ability and kind of gene action in different characters is crucial for additional development, information of breeding behavior. To indicate the relative magnitude of genetic variance, the evaluations of combining ability modifications and effects can be applied and doing random crosses, it is necessary to execute only high performing ones.

The most usable mating design for hybrid development is the line \times tester analysis which is an extension of the analysis of the two-factor factorial experiment established by Fisher [6,7 and8]. This design, full-sib progenies are generated through crossing lines to testers, then developed progenies as well as parents, which assessed in advanced field characters[9].

Information concerning the combining ability and gene action in a breeder material is a prerequisite to launch an effective wheat breeding program [10]. Singh & Chaudhary (1985)suggested a formula to estimatethe combining ability in line \times tester mating design [11]. In this kind of mating design, a tester line must be easy to use, provide information about the relative performance of lines into heterotic groups or patterns, and maximize the expected mean[12]. High combining ability is as a result of high genetic divergence, different in allele frequency with high mean heterosis value among the populations or lines. Smith (1986) and Hallauer and Miranda (1988) expressed that a line or a population with a low frequency of favorable alleles in the test crosses can be utilized as a tester to find lines with a big frequency of suitable alleles. Such testers would be crucial when gene action for the traits of interest is envisaged[13and14]. A suitable tester is that one which discloses a large variation between test-crosses, has the positive combining ability, has a high and significant correlation with an average of the testers applied and has acceptable *per se* performance[15]. This definition is partially agreed with other researchers who reported that a convenient tester shows large genetic differences between test-crosseswith homozygous recessive alleles and would be easy to use and provide maximum information about the lines in other combinations and other test locations[12]. A genetically broad-based tester contributes less to line \times tester interaction than a tester with a narrow genetic base[12].

This investigation aimed to estimate general and specific combining ability values for growth characters and yield component. As well as characterize potential parents and crosses for breeding program in Sulaimani – Iraqi Kurdistan Region.

Materials and Methods:

The study was conducted at two locations in Sulaimani governorate, Kanipanka Nursery Station / Sulaimani Agricultural Directorate / Ministry of Agriculture and Water Recourses (Lat. 35° 22'; N, Long. 45° 43'; E, 550 MASL, 35 Km East of Sulaimani city) and Qlyasan Agricultural Research Station / College of Agricultural EngineeringSciences/ University of Sulaimani (Lat. 35° 34' 307"; N, Long. 45° 21' 992"; E, 765 MASL, 2 Km North West of Sulaimani city) during the growing seasons of 2017-2018 and 2018-2019. The hybridization consisted of threewheatgenotypes namely (Maroof, Aras, and Hasad) which were used as female parents (lines), together with 4 wheat genotypes namely (Alla, Tamuz-2, Adana and Sabr Beg) which were used as male parents (testers) (Table 1). The verities were crossed at Qlyasan location in the growing season of (2017–2018) The 12 F₁'s hybrids with their 7 parents were evaluated during the growing season (2018-2019) following line \times tester analysis at both locations. The genotypes were cultivated on 20 November 2018 in Randomized Completely Block Design (RCBD)with three replicates. Each replicateconsisted of 19 F₁'s and their parents on a single 3m row with 0.3m apart, 0.1m plant spacing. Cultural operations, fertilization, and weed control performed according to the normal field practices and kept constant for the whole experiment. The metrological data and soils physical and chemical properties at Qlyasan and Kanipanka locations in 2018-2019 were shown in Appendices1 and 2.

Measurements of growth and yield traits were taken as an average of five plants plot⁻¹ on the; Days to heading, Plant height (cm), Number of tillers plant⁻¹, Number of leaves plant⁻¹, Flag leaf area (cm²), Spike

length (cm), At heading period, while the flag leaf growth has complete, at maximum size, photothynthetic rate was measured by using LCA4 instrument, as well as measuring other physiological activities which indicat to photothynthetic rate efficiency such as; Transpiration rate ($\mu\text{mole m}^{-2} \text{s}^{-1}$), Stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$), Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$), and Grain yield plant⁻¹ (g)[16].

Statistical analyses were carried out using XLSTAT-Pro, Version 5.1 according to Singh and Chaudhary (1985) for the following genetic parameters. The Least Significant Differences Test (LSD) at ($P \leq 0.05$) was carried out to compare the means of the characters[11].

Components of variance for general combining abilities (σ^2_{gca}) and specific combining abilities (σ^2_{sca}), General combining ability effect (\hat{g}_{ii}) and specific combining ability effect (\hat{s}_{ij}). The standard error for general combining ability effects ($S.E_{(g_i - g_j)}$) and specific combining ability effects ($S.E_{(s_{ij} - s_{ik})}$), Heterosis % (H). The proportional contribution of lines, testers and their interaction to the total variance %, Average Degree of Dominance (\bar{a}), Heritability in Broad Sense (h^2_{bs}), and Heritability in Narrow Sense (h^2_{ns}).

Table 1: The pedigree of the genotypes

Number	Variety name	Pedigree
1	Maroof (Line 1)	KTN M12/DAMAN × ADL//TAMUZ-2
2	Aras (Line 2)	SONORA 64 × LERMA ROJO 64) × SENTACLENA
3	Hasad (Line 3)	SNB//CMH79A955/3*CNO79/3/ATTILA
4	Alaa (Tester 1)	VEE/ADES × 10
5	Adana (Tester 2)	118//S2/57-S2-SR7-S2
6	Tamuz-2 (Tester 3)	SABR BEG/MAXIBAC (RAD.)
7	Sabr Beg (Tester 4)	Local variety

Results and Discussion:

The pooled analysis of variance for studied characters at both locations represents in table (2) location effect was found to be significant to highly significant due to all of the studied characters except for the trait stomatal conductance grain yield plant⁻¹ which were not significant. The mean squares due to genotypes were highly significant for most of the traits except for transpiration rates. While the interaction of (Genotypes × locations) was highly significant for days to heading, number of tillers plant⁻¹, number of leaves plant⁻¹, and photosynthetic rate and it was not significant for the rest of the characters. Parent's mean square was highly significant for most of the traits with the exception of number of leaves plant⁻¹, transpiration rate, and photosynthetic rate. The mean square for the interaction of (Parents × locations) was highly significant for the traits days to heading, number of tillers plant⁻¹ and photosynthetic rate. Crosses mean squares were highly significant for the traits days to heading, number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area, photosynthetic rate, and grain yield plant⁻¹, while the interaction of (Crosses × locations) mean squares were highly significant for days to heading, number of tillers plant⁻¹, number of leaves plant⁻¹, and photosynthetic rate. The mean squares for the (Parents vs. Crosses) were highly significant for days to heading, plant height, and flag leaf area, and transpiration rate. But they were significant for number of leaves plant⁻¹, and photosynthetic rate. The (Parents vs. Crosses × locations) mean squares were highly significant for plant height, and number of tillers plant⁻¹, and they were significant for transpiration rate, stomatal conductance, and grain yield plant⁻¹. Line's mean squares were highly significant for days to heading, plant height, number of tillers plant⁻¹, number of leaves plant⁻¹. The interaction of (Line × locations) mean squares were highly significant for days to heading, number of tillers plant⁻¹, flag leaf area, and photosynthetic rate and it was significant for transpiration rate. Tester's mean squares were highly significant for all characters except number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area, and spike length, and it was significant for stomatal conductance, while for the component of (Testers × locations) were highly significant for the traits days to heading and number of leaves plant⁻¹ and was significant for number of tillers plant⁻¹. The

interactions of (Lines \times Testers) was highly significant for photosynthetic rate and it was significant for the traits days to heading and number of leaves plant⁻¹. The (Lines \times Testers \times locations) mean squares were highly significant only for days to heading and it was significant for photosynthetic rate. The pooled analysis of variance over two location (Table 2) revealed significant differences between the locations, indicated that location had significant effect on different traits expression. The mean squares due to parents and F₁ were also significant, expressed that between parents and between F₁s difference was significant and an average heterosis was there. Parents vs. hybrids comparison were significant, indicated presence of overall heterosis for all these traits. Highly significant differences due to genotypes \times locations, indicated influence of different location on the genotypes expression.

Data in table (3) explain the significance of the studied traits according to their mean square values at both locations. At Kanipanka location, highly significant mean squares were recorded due to genotypes for the traits; days to heading, number of leaves plant⁻¹, spike length, stomatal conductance, and grain yield plant⁻¹. The mean squares due to Parents were highly significant for number of leaves plant⁻¹, spike length, and grain yield plant⁻¹, while the mean squares due to the Crosses were highly significant for number of leaves plant⁻¹, spike length, stomatal conductance, and grain yield plant⁻¹. The mean squares due to (Parents vs. Crosses) were highly significant for the traits days to heading, plant height, number of leaves plant⁻¹, stomatal conductance, and grain yield plant⁻¹, while it was significant for flag leaf area. Lines mean squares were highly significant for number of tillers plant⁻¹, flag leaf area, transpiration rate, and photosynthetic rate. The mean squares due to Testers were highly significant for number of tillers plant⁻¹, number of leaves plant⁻¹ and flag leaf area, while they were significant for days to heading and stomatal conductance.

There is a significant effect for the location on all the studied characters, except grain yield plant⁻¹. The average of both locations, significant effects for the mean squares of most of the traits was clarified for genotypes and also for their interaction with both locations. The mean squares due to (Lines \times Testers) was highly significant for photosynthetic rate and it was significant for number of leaves plant⁻¹. Concerning Qlyasan location, highly significant mean squares due to Genotypes were recorded by the traits spike length, photosynthetic rate, and grain yield plant⁻¹. Parents' mean squares were highly significant for spike length, stomatal conductance, photosynthetic rate, and grain yield plant⁻¹, and it was significant for transpiration rate. The mean squares due to the crosses was highly significant for spike length, and grain yield plant⁻¹ only. The mean squares due to (Parents vs. Crosses) were highly significant for spike length, photosynthetic rate, and grain yield plant⁻¹, while it was significant for flag leaf area. Lines mean squares were highly significant for days to heading, plant height, and number of leaves plant⁻¹, and it was significant for number of tillers plant⁻¹. The mean squares due to Testers were highly significant for spike length, and grain yield plant⁻¹, while it was significant for days to heading. The mean squares due to (Lines \times Testers) was highly significant for days to heading only.

Table (4A) shows the average of genotypes for the studied traits at Kanipanka locations. Maroof (L₁) product supposed to be referred to the earliest variety in days to heading and plant height with 147.667 days and 126.500 cm respectively. The maximum value was produced by Aras (L₂) for number of tillers plant⁻¹, flag leaf area, and transpiration rate with 12.133, 102.584 cm² and 0.823 $\mu\text{mole m}^{-2} \text{s}^{-1}$. Hasad (L₃) recorded maximum stomatal conductance with 0.483 $\text{mmole m}^{-2} \text{s}^{-1}$. Adana (T₆) recorded maximum value for photosynthetic rate with 12.380 $\mu\text{mol m}^{-2} \text{s}^{-1}$, while Sabr Beg (T₇) gave the maximum values for number of leaves plant⁻¹, spike length, and grain yield plant⁻¹ with 51.667, 17.667 cm and 26.303 g respectively. Regards to the crosses values, the cross 1 \times 4 produced maximum value for stomatal conductance with 0.840 $\text{mmole m}^{-2} \text{s}^{-1}$. The cross 1 \times 5 gave the maximum value for plant height, transpiration rate, and grain yield plant⁻¹ with 134.167 cm, 1.440 $\mu\text{mole m}^{-2} \text{s}^{-1}$, and 23.914 g respectively. The maximum number of tillers plant⁻¹ and spike length were recorded by the cross 1 \times 6 with 10.133 and 15.833 cm respectively. The cross 2 \times 5 gave the maximum flag leaf area with 108.014 cm², while the cross 2 \times 6 exhibited the maximum number of leaves plant⁻¹ and photosynthetic rate with 67.333 and 13.840 $\mu\text{mole m}^{-2} \text{s}^{-1}$ respectively.

Genotypes average for the studied traits at Qlyasan location represents in Table (4B). Maroof (L₁) produced maximum values for days to heading, plant height, and photosynthetic rate with 158.000 days,

96.773 cm, and $2.370 \mu\text{mole m}^{-2} \text{s}^{-1}$, respectively. Similarly Adana (T_6) needs long period to heading 158.000 days as Maroof (L_1). The largest flag leaf area was produced by Aras (L_2) with 75.870 cm^2 . Hasad (L_3) recorded maximum stomatal conductance with $0.700 \text{ mmole m}^{-2} \text{s}^{-1}$. Tamuz-2 (T_5) recorded maximum value for spike length, transpiration rate and grain yield plant^{-1} with 13.667 cm, $1.597 \mu\text{mol m}^{-2} \text{s}^{-1}$, and 19.875 g respectively, while Sabr Beg (T_7) gave the maximum values for number of tillers plant^{-1} and number of leaves plant^{-1} with 5.867 and 32.200 respectively. Regards to the crosses values, the cross 1×4 recorded the maximum period to heading with 157.000 days. The cross 1×5 gave the maximum value for plant height and spike length with 97.100 cm and 14.200 cm respectively. The maximum value for stomatal conductance was recorded by the cross 2×5 with $0.490 \text{ mmol m}^{-2} \text{s}^{-1}$. The cross 2×7 gave the maximum value for the traits number of tillers plant^{-1} and number of leaves plant^{-1} with 8.267 and 42.267. The cross 3×4 recorded the highest photosynthetic rate with $2.673 \mu\text{mole m}^{-2} \text{s}^{-1}$, while the cross 3×5 had greatest area of the flag leaf and the highest yield plant^{-1} with 85.350 cm^2 and 19.724 g respectively. The cross 3×6 recorded the highest rate of transpiration; $1.707 \mu\text{mol m}^{-2} \text{s}^{-1}$.

Table(5) showed different heterosis at both locations. At Kanipanka location, the cross 1×4 gave the maximum positive heterosis values for flag leaf area and stomatal conductance with 17.695 and 306.452 respectively, while gave the maximum negative value for photosynthetic rate with -39.353. The cross 1×5 gave the maximum positive value for number of tillers plant^{-1} and the highest yield plant^{-1} with 24.402 and 26.082 respectively, while gave the maximum negative value for days to heading with -1.695. The cross 1×7 recorded the maximum positive heterosis value for transpiration rate with 168.000. The maximum positive heterosis value recorded by the cross 2×6 for days to heading with 0.228, while it gave the maximum negative value for number of tillers plant^{-1} with -19.375. The cross 2×7 scored the highest value for number of leaves plant^{-1} and photosynthetic rate with 39.310 and 109.169 respectively, while gave the maximum negative value for spike length with -20.619. The cross 3×5 revealed the maximum positive value for plant height with 26.087. Regarding Qlyasan location, the cross 2×4 gave the maximum positive heterosis values for number of tillers plant^{-1} , number of leaves plant^{-1} , and stomatal conductance with 67.647, 45.542 and 86.364 respectively, while gave the maximum negative value for plant height and grain yield plant^{-1} with -3.705 and -1.935 respectively. The cross 2×5 gave the maximum positive value for days to heading and photosynthetic rate with 0.108 and 300.000 respectively. The cross 2×7 scored the highest value for grain yield plant^{-1} with 26.989. The cross 3×5 obtained the maximum positive heterosis value for plant height with 6.910. The maximum positive heterosis value recorded by the cross 3×6 for the traits flag leaf area, spike length, and transpiration rate with 36.558, 11.176, and 31.114 respectively. The positive heterosis value approved the overdominance gene effect for the parent with high value, while the negative heterosis value signifies the partial dominance gene effect of the parent with low value. Present findings are in harmony with, Rajput et al. (2018) [17]; Fellahi et al. (2013) [18] for bread wheat traits, who reported positive and negative heterosis for days to heading, plant height, tiller plant^{-1} and spike length and positive heterosis only for grain yield plant^{-1} in $10L \times 4T$ and in $5L \times 4T$ fashions, respectively; Hama-Amin & Towfiq (2019) [20] positive and negative heterosis for spike length and grain yield plant^{-1} in $4L \times 3T$ fashion; and Hama-Ali (2006) [21] positive and negative heterosis for transpiration rate and stomatal conductance, as well positive heterosis for photosynthetic rate in half-diallel fashion.

The heterosis phenomenon is the procedure through it the performance of an F_1 is exceeded to that of the mean of the crossed parents. A review of results made it clear that, besides, the highest heterosis for grain yield plant^{-1} , Maroof (L_1) × Tamuz-2 (T_3) at Qlyasan location, expressed the highest heterosis for the number of tillers plant^{-1} , as well the highest negative heterosis for days to heading, accompanied with high positive heterosis for flag leaf area, transpiration rate and stomatal conductance, as well positive heterosis for number of leaves plant^{-1} , spike length and photosynthetic rate, so that. However Aras (L_2) × Sabr Beg (T_7) at Qlyasan location expressed the highest heterosis for grain yield plant^{-1} , accompanied with most traits exhibited desirable heterosis values. So that these hybrids are considered to be the best for further use in wheat breeding programme, according to their location [2, 9 and 19].

Table (6) represents the estimation of GCA for the parents at both locations. At Kanipanka location, parent 1 gave the maximum positive GCA values for plant height and transpiration rate with 4.306 and 0.293 respectively. Parent 2 exhibited a maximum negative GCA value for plant height with -5.153. Parent 3 showed the maximum negative GCA values for transpiration rate and photosynthetic rate with -0.227 and -2.757. Parent 4 gave the maximum negative GCA value for number of leaves plant⁻¹ with -9.917, while it gave maximum positive value (0.147) for stomatal conductance. The highest positive GCA values (8.277, 1.153, and 2.331) were recorded by parent 5 for flag leaf area, spike length and grain yield plant⁻¹ respectively, while the same parent obtained maximum negative value for number of tillers plant⁻¹ with -1.317. Maximum positive GCA value for days to heading obtained by parent 6 with 0.750, while it obtained maximum negative GCA values for flag leaf area, spike length, stomatal conductance, and grain yield plant⁻¹ with -4.892, -0.847, -0.173, and -1.857 respectively. Parent 7 obtained the maximum positive GCA values for number of tillers plant⁻¹, number of leaves plant⁻¹, and photosynthetic rate with 1.194, 13.861, and 1.201 respectively. At Qlyasan, parent 1 recorded the maximum positive GCA values for days to heading and plant height with 1.778 and 2.306 respectively, while it gave maximum negative value for number of tillers plant⁻¹ with -2.144. Parent 2 gave the maximum negative GCA values for days to heading and plant height with -2.139 and -3.611 respectively, while recorded maximum positive value (3.381) for number of leaves plant⁻¹. Parent 3 showed the maximum negative GCA value for number of tillers plant⁻¹ with -0.550. Parent 4 gave the maximum positive GCA value for number of tillers plant⁻¹ with 0.958, while it gave maximum negative value (-0.811) for spike length. The highest positive GCA values (6.182, 0.733, 0.067, and 2.479) were recorded by parent 5 for flag leaf area, spike length, stomatal conductance and grain yield plant⁻¹ respectively, while the same parent obtained maximum negative value for transpiration rate with -0.108. Maximum positive GCA value for transpiration rate obtained by parent 6 with 0.101, while obtained maximum negative GCA values for flag leaf area, photosynthetic rate, and grain yield plant⁻¹ with -4.534, -0.246, and -1.428 respectively. Parent 7 obtained the maximum positive GCA value (0.234) for photosynthetic rate, while recorded maximum negative value (-0.072) for stomatal conductance. The high positive GCA effect values for the parents indicate their contributions in the inheritance of this trait to their hybrids, while the negative values indicate to the contribution of these parents in reducing the trait mean in some of their hybrids. These results indicated the suitability of the hybridization method to improve these traits. Given that the general combining ability effects is foremost a function of additive genetic variance and has a major role in the chosen of suitable perfect general combining parents for hybridization. The above data revealed that line Aras reported the highest positive GCA effect for (shorter) plant height and photosynthetic rate traits under Kanipanka location. Where, under Qlyasan location Aras reported the highest positive GCA effect for Number of leaves plant⁻¹, (shorter) plant height and less days to heading, thereby, suggesting good general combiner for these traits. The tester Tamuz-2 was good general combiner for grain yield plant⁻¹, flag leaf area and spike length, whereas, tester Sabr Beg registered the highest positive GCA effect for Number of leaves and number of tillers plant⁻¹, whilst Alaa for stomatal conductance and less days to heading under Kanipanka location. Where, under Qlyasan location the tester Tamuz-2 recorded the highest positive GCA effect for grain yield plant⁻¹, flag leaf area, spike length and stomatal conductance, while Adana for transpiration rate, then Sabr Beg for photosynthetic rate, thereby, suggesting good general combiner for these traits [2 and 9].

The estimation of SCA effect values at both location represents in Table (7). At Kanipanka, the cross 1×4 produced the maximum negative SCA effect values for spike length, transpiration rate, photosynthetic rate, and grain yield plant⁻¹ with -0.542, -0.230, -4.179, and -2.101 respectively, while produced the maximum positive values for flag leaf area and stomatal conductance. The cross 1×5 showed the maximum positive values for number of tillers plant⁻¹ and grain yield plant⁻¹ with 0.467 and 3.034 respectively. The cross 1×7 showed the maximum negative SCA effect values for the traits number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area, and stomatal conductance with -0.578, -11.528, -6.545, and -0.227 respectively. The cross produced the highest positive values for plant height and spike length with 10.931 and 0.750 respectively. The highest negative value (-6.958) for plant height was recorded by the cross 2×4 and the

highest positive value (0.417) for days to heading was recorded by the crosses 2×6 and 3×7. Both crosses (2×7 and 3×6) were showed the maximum negative value (-0.250) for days to heading, and the cross 2×7 recorded the highest positive value (7.889) for number of leaves plant⁻¹. The cross 3×4 showed the maximum positive values for transpiration rate and photosynthetic rate with 0.183 and 3.708 respectively. At Qlyasan, the cross 1×4 gave the maximum positive SCA effect value (0.369) for spike length, while recorded the maximum negative value (-0.219) for transpiration rate. The cross 1×6 showed the maximum positive values for days to heading and stomatal conductance with 1.889 and 0.095 respectively. The cross 1×7 showed the maximum negative effect for plant height and spike length and with -1.828 and -0.442 respectively, while it gave the maximum positive value (0.300) for transpiration rate. The highest negative values were recorded by the cross 2×5 for number of tillers plant⁻¹, number of leaves plant⁻¹, and grain yield plant⁻¹ with -0.761, -2.925, and -1.196 respectively. The highest positive values were recorded by the cross 2×7 for plant height, number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area, and grain yield plant⁻¹ with 2.089, 1.217, 3.708, 4.563, and 1.743 respectively. The highest negative value (-3.952) for flag leaf area was recorded by the cross 3×4. At Kanipanka location, the crosses 1×5 gave the maximum mean and The maximum desirable positive heterosis value was recorded for grain yield plant⁻¹ for 1×5 cross in Kanipanka location. This value is exceeding all other possible crossed, but not exceed Sabr Beg parent (T₇). The maximum positive effect for SCA was recorded for the cross 1×4 which means that this cross has increased in grain yield value compares to their parents. Specific combining ability Effects is primarily a function of dominance variances; it contribute in the determining of superior or the best cross combination for commercial utilization of heterosis. In self-pollinated crops like barley or wheat, SCA effects are not too important as they are particularly associated with non-additive gene effects. The above data revealed that the crosses Maroof × Tamuz-2, Hasad × Sabr Beg, Aras × Alaa, Aras × Adana and Maroof × Adana under Kanipanka location, while under Qlyasan location the crosses Aras × Sabr Beg, Hasad × Alaa and Hasad × Tamuz-2 showed high positive SCA effect, thereby, suggesting good specific combinations for grain yield plant⁻¹ and other attributing traits because these hybrids(crosses) were the results of good x good general combiners mostly and reported high positive SCA effect. Present finding are in harmony with [10, 20 and 21].

The proportional contribution of lines, testers and their interactions to total variance at both locations represents in Table (8). At Kanipanka location, the lines contributed more to the total sum square for transpiration rate and photosynthetic rate with 75.803% and 47.768% respectively, while testers brought many variations in the expression of the traits days to heading, number of tillers plant⁻¹, number of leaves plant⁻¹, flag leaf area, spike length, and grain yield plant⁻¹ with 71.360, 53.135, 69.585, 53.118, 57.146, and 55.883% respectively. The contribution of line × tester was slightly greater than that of testers and lines for plant height and stomatal conductance with 52.960 and 49.022%. At Qlyasan location, the lines contributed more to the total sum square for days to heading, plant height, number of tillers plant⁻¹, number of leaves plant⁻¹ with 47.280, 77.101, 39.993, and 46.484% respectively, while testers contributed more to the total variation for flag leaf area, spike length, and grain yield plant⁻¹ with 46.518, 77.899, and 78.845% respectively. Line × tester contribution to the total sum square was more than that of testers and lines for transpiration rate, stomatal conductance, and photosynthetic rate with 67.475, 45.483, and 70.985%. The results of the present study revealed a large variation between parents and hybrids for the traits under study [2 and 7]. It is noticeable that hybrid combinations surpassed their parents with respect to plant height in (Kanipanka location) and transpiration rate and photothynthetic rate (Qlyasan location) traits As well displayed that testers and the interaction lines × testers fetched numerous variations in the expression of the researched traits. These results are in accordance with the results of [10, 21 and 22].

Table(9) describes some genetic parameters for the studied traits at both locations. At Kanipanka location, the variance component due to GCA (σ^2_{gca}) was greater than the variance component due to SCA (σ^2_{sca}), making the ratio of $\sigma^2_{gca} / \sigma^2_{sca}$ value more than one for days to heading, number of tillers plant⁻¹ and transpiration rate with 2.667, 131.5 and 2.235 respectively, that confirm the large contribution of additive gene action in the inheritance of these traits, while for the rest of the traits this ratio was less than one which confirmed the importance of non-additive gene effect in controlling the traits. The average degree of

dominance value for days to heading, number of tillers plant⁻¹ and transpiration rate were less than one with 0.617, 0.087 and 0.936 respectively, but there were more than one for the rest of the traits which confirming the importance of non-additive gene effect in the inheritance of almost all of the traits. Heritability estimates in the broad sense were ranged from 0.203 to 0.98, while in the narrow sense were ranged from 0.021 to 0.97. At Qlyasan location, the variance component due to GCA (σ^2_{gca}) was less than the variance component due to SCA (σ^2_{sca}), making the ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ value less than one for all of the studied traits except grain yield plant⁻¹ which confirmed the importance of non-additive gene effect in controlling the traits. The average degree of dominance values was more than one for all of the studied traits except plant height and transpiration rate which confirming the importance of non-additive gene effect in the inheritance of these traits. Heritability estimates in the broad sense were ranged from 0.043 to 0.863, while in the narrow sense were ranged from 0.018 to 0.97. Due to the above results there is a non-additive gene effect for grain yield plant⁻¹ based on the ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ value which was less than one and the average degree of dominance value was more than one. Similar results were obtained by the researchers [2 and 9]. The cross 3×5 gave the maximum mean and desirable positive heterosis value for the trait grain yield plant⁻¹ but did not exceed the parent Tamuz-2 (T₅) at Qlyasan location, while the cross 2×5 recorded the maximum negative effect for SCA which means that this cross has decreased in grain yield value compares to their parents. The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ value was less than one and the average degree of dominance value was more than one. These parameters indicating the non-additive gene effect to control grain yield plant⁻¹.

Conclusion:

This research appeared the rewarding parents and crosses of bread wheat that can exploited by the plant breeders to start active breeding strategies. The experimented breeding material had adequate genetic variability and may be more exploited in breeding programs. The study demonstrated the combining ability of wheat parents in varied locations. In ANOVA the SCA and GCA demonstrated that 7 viz. plant height, number of leaves plant⁻¹, flag leaf area, spike length, photosynthetic rate, stomatal conductance and grain yield plant⁻¹ at the first location, while 7 viz. days to heading, number of tillers plant⁻¹, number of leaves plant⁻¹, spike length, photosynthetic rate, transpiration rate and stomatal conductance at the second location of the 10 traits studied were controlling by non-additive gene action consequently proposing that selection of excellent plants should be postponed to later generation. Among the lines, Aras among testers Tamuz-2 for the both locations showed maximum GCA effects and were looked to be good general combiner for most of the quantitative traits studied and thence, for furthermore breeding programs in bread wheat it can be exploited. Crosses Maroof × Tamuz-2 and Aras × Sabr Beg for the first and second location, respectively showed excellent SCA performance for the yield and most yield attributes traits under search and can be exploited effectively to gain segregates in order to transfer a population with high potential for yield.

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Table 2: Pooled analysis of variance for combining ability (L×T) at Kanipanka and Qlyasan locations

S.O.V	d.f	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Locations	1	2548.430**	20451.084**	238.237**	3644.817**	15103.493*	64.726*	6.480*	0.039 ^{n.s}	1778.211**	265.414 ^{n.s}
Replicates / Locations Error (a)	4	6.877	178.236	1.820	42.987	837.095	7.170	0.413	0.029	9.728	40.631
Genotypes / Locations	36	9.274**	180.926**	5.329**	173.559**	225.680**	4.887**	0.221 ^{n.s}	0.069 ^{n.s}	14.409**	22.120*
Genotypes	18	9.988**	253.124**	5.285**	190.719**	385.672**	7.392**	0.228 ^{n.s}	0.092*	15.089**	29.718**
Genotypes × Locations	18	8.559**	108.729 ^{n.s}	5.373**	156.399**	65.687 ^{n.s}	2.381 ^{n.s}	0.214 ^{n.s}	0.045 ^{n.s}	13.728**	14.523 ^{n.s}
Parents / Locations	12	4.460*	132.723 ^{n.s}	6.926**	49.064 ^{n.s}	273.392**	9.651**	0.133 ^{n.s}	0.065 ^{n.s}	11.840**	24.929*
Parents	6	5.937**	208.120**	5.752**	60.419 ^{n.s}	499.016**	14.880**	0.099 ^{n.s}	0.119*	7.516 ^{n.s}	36.283**
Parents × Locations	6	2.984**	57.326 ^{n.s}	8.100**	37.709 ^{n.s}	47.768 ^{n.s}	4.422 ^{n.s}	0.168 ^{n.s}	0.011 ^{n.s}	16.163**	13.574 ^{n.s}
Crosses / Locations	22	9.604**	89.104 ^{n.s}	4.193**	242.280**	135.901**	2.399 ^{n.s}	0.158 ^{n.s}	0.058 ^{n.s}	15.806**	17.326 ^{n.s}
Crosses	11	6.970**	123.668 ^{n.s}	5.083**	251.798**	190.932**	3.411 ^{n.s}	0.152 ^{n.s}	0.077 ^{n.s}	18.270**	28.099**
Crosses × Locations	11	12.237**	54.540 ^{n.s}	3.303**	232.762**	80.870 ^{n.s}	1.386 ^{n.s}	0.164 ^{n.s}	0.039 ^{n.s}	13.342**	6.553 ^{n.s}
Parents vs. Crosses / Locations	2	34.529**	1480.190**	8.250**	164.602 ^{n.s}	926.971**	3.667 ^{n.s}	1.443**	0.208*	14.452*	58.006**
Parents vs. Crosses	1	67.504**	1947.158**	4.711 ^{n.s}	300.661*	1847.757**	6.253 ^{n.s}	1.844**	0.104 ^{n.s}	25.539*	8.132 ^{n.s}
Parents vs. Crosses × Locations	1	1.554 ^{n.s}	1013.221**	11.789* *	28.542 ^{n.s}	6.184 ^{n.s}	1.080 ^{n.s}	1.042*	0.311*	3.365 ^{n.s}	107.881**
Lines / Locations	4	23.944**	197.601*	9.252**	56.428 ^{n.s}	194.336**	0.520 ^{n.s}	0.467*	0.020 ^{n.s}	40.653**	2.420 ^{n.s}
Lines	2	19.500**	375.441**	10.572* *	82.363 ^{n.s}	91.006 ^{n.s}	0.961 ^{n.s}	0.235 ^{n.s}	0.038 ^{n.s}	46.560**	0.770 ^{n.s}
Lines × Locations	2	28.389**	19.760 ^{n.s}	7.932**	30.493 ^{n.s}	297.666**	0.080 ^{n.s}	0.699*	0.003 ^{n.s}	34.746**	4.070 ^{n.s}
Testers / Locations	6	6.917**	43.481 ^{n.s}	6.678**	582.368**	251.806**	5.609*	0.055 ^{n.s}	0.096 ^{n.s}	3.697 ^{n.s}	41.500**
Testers	3	2.370**	61.827 ^{n.s}	8.398**	570.863**	486.014**	10.263**	0.077 ^{n.s}	0.133*	4.536 ^{n.s}	82.440**
Testers × Locations	3	11.463**	25.135 ^{n.s}	4.959*	593.874**	17.599 ^{n.s}	0.956 ^{n.s}	0.034 ^{n.s}	0.060 ^{n.s}	2.858 ^{n.s}	0.561 ^{n.s}
Lines x Testers / Locations	12	6.167**	75.750 ^{n.s}	1.264 ^{n.s}	134.186*	58.470 ^{n.s}	1.420 ^{n.s}	0.106 ^{n.s}	0.051 ^{n.s}	13.578**	10.207 ^{n.s}
Lines × Testers	6	5.093*	70.665 ^{n.s}	1.596 ^{n.s}	148.743*	76.700 ^{n.s}	0.802 ^{n.s}	0.162 ^{n.s}	0.062 ^{n.s}	15.707**	10.038 ^{n.s}
Lines × Testers × Locations	6	7.241**	80.836 ^{n.s}	0.932	119.629 ^{n.s}	40.241 ^{n.s}	2.037 ^{n.s}	0.051 ^{n.s}	0.041 ^{n.s}	11.450*	10.377 ^{n.s}
Error (b)	72	1.886	66.848	1.305	56.303	52.857	2.132	0.163	0.048	4.222	11.012

Table 3: Mean squares of the analysis of variance for line × tester including parents at both location

S.O.V	d.f	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Kanipanka Location											
Replicates	2	0.123 ^{n.s}	163.039 ^{n.s}	3.429 ^{n.s}	80.579**	96.182 ^{n.s}	1.000 ^{n.s}	0.180 ^{n.s}	0.041 ^{n.s}	11.043 ^{n.s}	23.386**
Genotypes	18	2.382**	331.584 ^{n.s}	7.349 ^{n.s}	302.047**	266.340 ^{n.s}	7.579**	0.301 ^{n.s}	0.090**	27.187 ^{n.s}	27.966**
Parents	6	1.159 ^{n.s}	239.274 ^{n.s}	12.928 ^{n.s}	81.317**	323.609 ^{n.s}	16.575**	0.058 ^{n.s}	0.036 ^{n.s}	21.199 ^{n.s}	31.892**
Crosses	11	1.058 ^{n.s}	149.825 ^{n.s}	4.902 ^{n.s}	443.361**	165.327 ^{n.s}	3.265**	0.204 ^{n.s}	0.092**	30.769 ^{n.s}	20.401**
Parents × crosses	1	24.286**	2884.790**	0.798 ^{n.s}	71.965**	1033.862*	1.068 ^{n.s}	2.828 ^{n.s}	0.388**	23.722 ^{n.s}	87.625**
Lines	2	0.694 ^{n.s}	274.840 ^{n.s}	10.840**	7.528*	210.971**	0.674 ^{n.s}	0.851**	0.020 ^{n.s}	80.837**	3.409 ^{n.s}
Testers	3	2.769*	75.192 ^{n.s}	9.551**	1131.213**	322.003**	6.840 ^{n.s}	0.033 ^{n.s}	0.159*	6.809 ^{n.s}	41.803 ^{n.s}
Lines × Testers	6	0.324 ^{n.s}	145.470 ^{n.s}	0.599 ^{n.s}	244.713*	71.775 ^{n.s}	2.340 ^{n.s}	0.074 ^{n.s}	0.083 ^{n.s}	26.059**	15.364 ^{n.s}
Exp. Error	36	0.882	116.882	1.147	96.690	36.126	3.537	0.072	0.041	4.203	14.759
Qlyasan Location											
Replicates	2	13.632 ^{n.s}	193.432 ^{n.s}	0.211 ^{n.s}	5.396 ^{n.s}	1578.008**	13.340**	0.646**	0.018 ^{n.s}	8.413**	57.876**
Genotypes	18	16.166 ^{n.s}	30.269 ^{n.s}	3.309 ^{n.s}	45.072 ^{n.s}	185.020 ^{n.s}	2.194**	0.141 ^{n.s}	0.047 ^{n.s}	1.630**	16.274**
Parents	6	7.762 ^{n.s}	26.172 ^{n.s}	0.924 ^{n.s}	16.811 ^{n.s}	223.175 ^{n.s}	2.726**	0.209*	0.094**	2.480**	17.965**
Crosses	11	18.149 ^{n.s}	28.383 ^{n.s}	3.484 ^{n.s}	41.199 ^{n.s}	106.475 ^{n.s}	1.533**	0.112 ^{n.s}	0.024 ^{n.s}	0.844 ^{n.s}	14.250**
Parents × crosses	1	44.772 ^{n.s}	75.590 ^{n.s}	15.703 ^{n.s}	257.238 ^{n.s}	820.079*	6.265**	0.057 ^{n.s}	0.028 ^{n.s}	5.182**	28.388**
Lines	2	47.194**	120.361**	7.663*	105.329**	177.701 ^{n.s}	0.367 ^{n.s}	0.083 ^{n.s}	0.021 ^{n.s}	0.469 ^{n.s}	1.431 ^{n.s}
Testers	3	11.065*	11.770 ^{n.s}	3.806 ^{n.s}	33.523 ^{n.s}	181.610 ^{n.s}	4.379**	0.078 ^{n.s}	0.034 ^{n.s}	0.585 ^{n.s}	41.198**
Lines × Testers	6	12.009**	6.031 ^{n.s}	1.930 ^{n.s}	23.660 ^{n.s}	45.166 ^{n.s}	0.499 ^{n.s}	0.139 ^{n.s}	0.020 ^{n.s}	1.098 ^{n.s}	5.050 ^{n.s}
Exp. Error	36	2.891	16.815	1.463	15.916	69.587	0.728	0.254	0.056	4.240	7.265

Table 4A: Means of the genotypes at Kanipanka locations

Genotypes	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate ($\mu\text{mole m}^{-2} \text{s}^{-1}$)	Stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$)	Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Grain yield plant ⁻¹ (g)
Maroof (1) × Alaa (4)	144.667	122.000	9.200	39.000	99.057	13.500	1.037	0.840	5.563	14.639
Maroof (1) × Tamuz-2 (5)	145.000	134.167	8.667	42.333	104.706	15.500	1.440	0.513	9.433	23.914
Maroof (1) × Adana (6)	145.667	126.667	10.067	48.333	92.939	13.167	1.377	0.327	13.597	16.929
Maroof (1) × Sabr Beg (7)	145.000	132.333	10.133	46.333	90.771	15.833	1.563	0.243	12.680	18.717
Aras (2) × Alaa (4)	145.000	130.167	8.733	25.000	93.228	14.333	0.953	0.457	12.250	18.138
Aras (2) × Tamuz-2 (5)	145.000	114.167	7.067	35.667	108.014	15.333	0.987	0.470	12.663	18.322
Aras (2) × Adana (6)	146.667	115.500	8.600	54.333	97.706	13.667	1.097	0.347	10.667	16.780
Aras (2) × Sabr Beg (7)	145.333	117.500	10.067	67.333	102.226	12.833	0.940	0.620	13.840	18.333
Hasad (3) × Alaa (4)	145.000	121.000	7.733	40.667	85.328	13.500	0.930	0.507	10.333	15.733
Hasad (3) × Tamuz-2 (5)	145.000	130.500	6.067	31.667	101.225	15.333	0.797	0.487	5.677	18.693
Hasad (3) × Adana (6)	146.000	119.167	7.533	44.667	83.794	13.333	0.780	0.170	5.840	14.658
Hasad (3) × Sabr Beg (7)	146.000	130.667	9.133	62.333	97.460	14.500	0.830	0.467	6.957	20.893
Maroof (1)	147.667	126.500	8.600	39.000	86.863	15.000	0.583	0.280	6.417	16.595
Aras (2)	146.000	113.500	12.133	45.000	102.584	14.667	0.823	0.263	6.983	22.497
Hasad (3)	146.667	109.167	8.333	45.000	80.152	12.333	0.480	0.483	6.817	20.199
Alaa (4)	146.000	106.333	8.067	37.667	81.466	10.333	0.393	0.133	11.930	17.526
Tamuz-2 (5)	147.333	97.833	5.333	42.000	98.956	14.833	0.687	0.200	9.570	21.339
Adana (6)	146.667	104.333	9.200	37.000	73.547	12.833	0.643	0.297	12.380	19.385
Sabr Beg (7)	146.667	110.500	10.133	51.667	89.227	17.667	0.583	0.323	6.250	26.303
LSD ($p \leq 0.05$)	1.555	17.903	1.774	16.283	9.953	3.114	0.445	0.333	3.395	6.362

Table 4B: Means of the genotypes at Qlyasan locations

Genotypes	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Maroof (1) × Alaa (4)	157.000	95.033	7.000	34.367	70.110	12.633	1.037	0.383	1.760	14.111
Maroof (1) × Tamuz-2 (5)	155.667	97.100	6.000	33.133	75.953	14.200	1.167	0.367	1.677	18.953
Maroof (1) × Adana (6)	156.667	94.933	5.133	29.300	65.017	12.433	1.340	0.410	1.680	14.998
Maroof (1) × Sabr Beg (7)	156.333	94.733	5.133	31.667	64.973	13.033	1.647	0.203	1.920	16.089
Aras (2) × Alaa (4)	154.000	87.500	7.600	40.533	73.580	11.800	1.583	0.410	1.573	13.528
Aras (2) × Tamuz-2 (5)	154.667	88.933	5.800	33.133	76.227	13.433	1.407	0.490	1.907	18.001
Aras (2) × Adana (6)	147.667	88.967	6.733	34.633	65.833	12.467	1.430	0.227	2.353	15.826
Aras (2) × Sabr Beg (7)	153.667	92.733	8.267	42.267	77.467	13.567	1.403	0.383	2.210	19.514
Hasad (3) × Alaa (4)	154.333	92.800	6.733	34.733	71.467	11.767	1.430	0.310	2.673	15.282
Hasad (3) × Tamuz-2 (5)	154.667	95.667	5.133	31.767	85.350	13.200	1.277	0.357	1.227	19.724
Hasad (3) × Adana (6)	154.667	94.033	5.667	34.000	74.533	12.767	1.707	0.297	0.620	14.133
Hasad (3) × Sabr Beg (7)	156.333	95.300	5.000	31.600	75.427	13.233	1.273	0.210	1.963	16.800
Maroof (1)	158.000	96.733	4.933	26.967	63.787	12.367	1.080	0.290	2.370	13.999
Aras (2)	153.333	91.367	4.533	27.200	75.870	12.600	0.963	0.283	0.943	14.318
Hasad (3)	156.667	91.100	4.733	30.033	57.713	11.133	1.110	0.700	0.977	13.898
Alaa (4)	156.667	90.367	4.533	28.500	71.067	10.967	1.550	0.157	1.280	13.272
Tamuz-2 (5)	155.667	87.867	5.733	32.833	72.203	13.667	1.597	0.343	0.010	19.875
Adana (6)	158.000	88.233	5.333	31.267	51.447	11.833	1.493	0.400	0.303	12.875
Sabr Beg (7)	157.000	89.633	5.867	32.200	63.833	12.767	1.490	0.507	2.320	16.415
LSD (p≤0.05)	2.815	6.790	2.003	6.606	13.814	1.413	0.834	0.392	3.410	4.463

Table 5: Heterosis values at both locations

Crosses	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Kanipanka Location										
Maroof (1) × Alaa (4)	-1.476	4.796	10.400	1.739	17.695	6.579	112.287	306.452	-39.353	-14.191
Maroof (1) × Tamuz-2 (5)	-1.695	19.614	24.402	4.527	12.696	3.911	126.772	113.889	18.015	26.082
Maroof (1) × Adana (6)	-1.019	9.747	13.109	27.193	15.876	-5.389	124.457	13.295	44.671	-5.900
Maroof (1) × Sabr Beg (7)	-1.472	11.674	8.185	2.206	3.096	-3.061	168.000	-19.337	100.211	-12.739
Aras (2) × Alaa (4)	-0.685	18.423	-13.531	-39.516	1.307	14.667	56.712	130.252	29.538	-9.363
Aras (2) × Tamuz-2 (5)	-1.136	8.044	-19.084	-18.008	7.188	3.955	30.684	102.878	53.000	-16.408
Aras (2) × Adana (6)	0.228	6.044	-19.375	32.520	10.947	-0.606	49.545	23.810	10.174	-19.871
Aras (2) × Sabr Beg (7)	-0.683	4.911	-9.581	39.310	6.591	-20.619	33.649	111.364	109.169	-24.864
Hasad (3) × Alaa (4)	-0.911	12.297	-5.691	-1.613	5.592	19.118	112.977	64.324	10.242	-16.594
Hasad (3) × Tamuz-2 (5)	-1.361	26.087	-11.220	-27.203	13.032	12.883	36.571	42.439	-30.716	-9.999
Hasad (3) × Adana (6)	-0.455	11.632	-14.068	8.943	9.037	5.960	38.872	-56.410	-39.156	-25.941
Hasad (3) × Sabr Beg (7)	-0.455	18.968	-1.083	28.966	15.079	-3.333	56.113	15.702	6.480	-10.144
S.E	0.767	8.827	0.875	8.029	4.908	1.536	0.219	0.164	1.674	3.137
Qlyasan Location										
Maroof (1) × Alaa (4)	-0.212	1.586	47.887	23.918	3.980	8.286	-21.166	71.642	-3.562	3.491
Maroof (1) × Tamuz-2 (5)	-0.744	5.200	12.500	10.814	11.704	9.091	-12.827	15.789	40.896	11.907
Maroof (1) × Adana (6)	-0.844	2.649	0.000	0.630	12.844	2.755	4.145	18.841	25.686	11.617
Maroof (1) × Sabr Beg (7)	-0.741	1.663	-4.938	7.042	1.823	3.714	28.145	-48.954	-18.124	5.798
Aras (2) × Alaa (4)	-0.645	-3.705	67.647	45.542	0.152	0.141	25.995	86.364	41.529	-1.935
Aras (2) × Tamuz-2 (5)	0.108	-0.763	12.987	10.383	2.958	2.284	9.896	56.383	300.000	5.290
Aras (2) × Adana (6)	-5.139	-0.928	36.486	18.472	3.417	2.046	16.418	-33.659	277.540	16.396
Aras (2) × Sabr Beg (7)	-0.967	2.468	58.974	42.312	10.902	6.965	14.402	-2.954	35.444	26.989
Hasad (3) × Alaa (4)	-1.489	2.278	45.324	18.679	10.990	6.486	7.519	-27.626	136.928	12.492
Hasad (3) × Tamuz-2 (5)	-0.961	6.910	-1.911	1.060	31.392	6.452	-5.665	-31.629	148.649	16.805
Hasad (3) × Adana (6)	-1.695	4.870	12.583	10.930	36.558	11.176	31.114	-46.061	-3.125	5.578
Hasad (3) × Sabr Beg (7)	-0.319	5.459	-5.660	1.553	24.111	10.739	-2.051	-65.193	19.110	10.842
S.E	1.388	3.348	0.988	3.257	6.811	0.697	0.411	0.193	1.681	2.201

Table 6: Estimation of GCA effects at both locations

\hat{g}_{ii}	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$)	Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Grain yield plant ⁻¹ (g)
Kanipanka Location										
Maroof (1)	-0.278	4.306	0.933	-0.806	0.497	0.264	0.293	0.027	0.360	0.571
Aras (2)	0.139	-5.153	0.033	0.778	3.922	-0.194	-0.067	0.019	2.397	-0.086
Hasad (3)	0.139	0.847	-0.967	0.028	-4.419	-0.069	-0.227	-0.046	-2.757	-0.485
Alaa (4)	-0.472	-0.097	-0.028	-9.917	-3.833	-0.458	-0.087	0.147	-0.576	-1.809
Tamuz-2 (5)	-0.361	1.792	-1.317	-8.250	8.277	1.153	0.014	0.036	-0.701	2.331
Adana (6)	0.750	-4.042	0.150	4.306	-4.892	-0.847	0.024	-0.173	0.076	-1.857
Sabr Beg (7)	0.083	2.347	1.194	13.861	0.448	0.153	0.050	-0.011	1.201	1.335
S.E (\hat{g}_{ii}) Line	0.383	4.414	0.437	4.014	2.454	0.768	0.110	0.082	0.837	1.568
S.E (\hat{g}_{ij}) Tester	0.443	5.096	0.505	4.635	2.833	0.887	0.127	0.095	0.966	1.811
Qlyasan Location										
Maroof (1)	1.778	2.306	-0.367	-2.144	-3.981	0.197	-0.094	0.004	-0.038	-0.375
Aras (2)	-2.139	-3.611	0.917	3.381	0.282	-0.061	0.064	0.040	0.214	0.304
Hasad (3)	0.361	1.306	-0.550	-1.236	3.699	-0.136	0.030	-0.044	-0.176	0.072
Alaa (4)	0.472	-1.367	0.928	2.283	-1.276	-0.811	-0.042	0.031	0.205	-2.106
Tamuz-2 (5)	0.361	0.756	-0.539	-1.583	6.182	0.733	-0.108	0.067	-0.194	2.479
Adana (6)	-1.639	-0.500	-0.339	-1.617	-4.534	-0.322	0.101	-0.026	-0.246	-1.428
Sabr Beg (7)	0.806	1.111	-0.050	0.917	-0.373	0.400	0.049	-0.072	0.234	1.054
S.E (\hat{g}_{ii}) Line	0.694	1.674	0.494	1.629	3.406	0.348	0.206	0.097	0.925	1.100
S.E (\hat{g}_{ij}) Tester	0.802	1.933	0.570	1.881	3.932	0.402	0.237	0.111	1.068	1.271

Table 7: Estimation of SCA effects at both locations

$\hat{\$}_{ij}$	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate ($\mu\text{mole m}^{-2} \text{s}^{-1}$)	Stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$)	Photosynthetic rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Grain yield plant ⁻¹ (g)
Kanipanka Location										
Maroof (1) × Alaa (4)	0.056	-6.694	-0.289	4.917	6.023	-0.542	-0.230	0.212	-4.179	-2.101
Maroof (1) × Tamuz-2 (5)	0.278	3.583	0.467	6.583	-0.439	-0.153	0.072	-0.004	-0.184	3.034
Maroof (1) × Adana (6)	-0.167	1.917	0.400	0.028	0.962	-0.486	-0.001	0.019	3.202	0.236
Maroof (1) × Sabr Beg (7)	-0.167	1.194	-0.578	-11.528	-6.545	1.181	0.159	-0.227	1.161	-1.168
Aras (2) × Alaa (4)	-0.028	10.931	0.144	-10.667	-3.232	0.750	0.047	-0.164	0.471	2.054
Aras (2) × Tamuz-2 (5)	-0.139	-6.958	-0.233	-1.667	-0.557	0.139	-0.021	-0.039	1.009	-1.902
Aras (2) × Adana (6)	0.417	0.208	-0.167	4.444	2.304	0.472	0.079	0.046	-1.764	0.743
Aras (2) × Sabr Beg (7)	-0.250	-4.181	0.256	7.889	1.485	-1.361	-0.104	0.157	0.284	-0.895
Hasad (3) × Alaa (4)	-0.028	-4.236	0.144	5.750	-2.791	-0.208	0.183	-0.048	3.708	0.048
Hasad (3) × Tamuz-2 (5)	-0.139	3.375	-0.233	-4.917	0.996	0.014	-0.051	0.043	-0.824	-1.132
Hasad (3) × Adana (6)	-0.250	-2.125	-0.233	-4.472	-3.266	0.014	-0.078	-0.065	-1.438	-0.979
Hasad (3) × Sabr Beg (7)	0.417	2.986	0.322	3.639	5.060	0.181	-0.054	0.070	-1.446	2.063
S.E ($\hat{\\$}_{ij}$)	0.974	1.243	0.987	1.232	1.172	1.044	0.859	0.835	1.053	1.121
Qlyasan Location										
Maroof (1) × Alaa (4)	0.111	0.950	0.256	-0.033	2.373	0.369	-0.219	0.012	-0.204	0.180
Maroof (1) × Tamuz-2 (5)	-1.111	0.894	0.722	2.600	0.758	0.392	-0.023	-0.041	0.111	0.436
Maroof (1) × Adana (6)	1.889	-0.017	-0.344	-1.200	0.537	-0.319	-0.058	0.095	0.167	0.388
Maroof (1) × Sabr Beg (7)	-0.889	-1.828	-0.633	-1.367	-3.667	-0.442	0.300	-0.066	-0.073	-1.003
Aras (2) × Alaa (4)	1.028	-0.667	-0.428	0.608	1.579	-0.206	0.169	0.002	-0.643	-1.083
Aras (2) × Tamuz-2 (5)	1.806	-1.356	-0.761	-2.925	-3.232	-0.117	0.059	0.045	0.089	-1.196
Aras (2) × Adana (6)	-3.194	-0.067	-0.028	-1.392	-2.910	-0.028	-0.126	-0.125	0.588	0.536
Aras (2) × Sabr Beg (7)	0.361	2.089	1.217	3.708	4.563	0.350	-0.102	0.078	-0.035	1.743
Hasad (3) × Alaa (4)	-1.139	-0.283	0.172	-0.575	-3.952	-0.164	0.050	-0.014	0.847	0.903
Hasad (3) × Tamuz-2 (5)	-0.694	0.461	0.039	0.325	2.474	-0.275	-0.037	-0.004	-0.201	0.760
Hasad (3) × Adana (6)	1.306	0.083	0.372	2.592	2.373	0.347	0.184	0.029	-0.755	-0.924
Hasad (3) × Sabr Beg (7)	0.528	-0.261	-0.583	-2.342	-0.895	0.092	-0.198	-0.012	0.108	-0.739
S.E ($\hat{\\$}_{ij}$)	1.033	1.128	0.999	1.125	1.211	0.964	0.915	0.848	1.053	1.082

Table 8: Proportional contribution of lines, testers and their interactions to total variance at both locations

Contribution (%)	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Kanipanka Location										
Contribution of Lines	11.933	33.353	40.205	0.309	23.201	3.752	75.803	3.863	47.768	3.038
Contribution of Testers	71.360	13.687	53.135	69.585	53.118	57.146	4.379	47.114	6.036	55.883
Contribution of (Lines × Testers)	16.706	52.960	6.660	30.106	23.680	39.103	19.818	49.022	46.196	41.079
Qlyasan Location										
Contribution of Lines	47.280	77.101	39.993	46.484	30.344	4.352	13.519	16.161	10.112	1.825
Contribution of Testers	16.627	11.309	29.790	22.192	46.518	77.899	19.007	38.356	18.903	78.845
Contribution of (Lines × Testers)	36.093	11.590	30.217	31.325	23.138	17.748	67.475	45.483	70.985	19.330

Table 9: Estimation of some genetic parameters for the studied traits at both locations

Parameters	Days to heading	Plant height (cm)	Number of tillers plant ⁻¹	Number of leaves plant ⁻¹	Flag leaf area (cm ²)	Spike length (cm)	Transpiration rate (μmole m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Photosynthetic rate (μmol m ⁻² s ⁻¹)	Grain yield plant ⁻¹ (g)
Kanipanka Location										
σ ² gca (Line)	0.030	10.780	0.853	-19.765	11.599	-0.139	0.065	-0.005	4.565	-0.996
σ ² gca (Tester)	0.272	-7.708	0.995	98.500	27.803	0.500	-0.014	0.008	-2.139	2.937
σ ² gca (Average)	0.030	9.581	9.468	8.565	4.033	0.039	-0.038	0.0004	0.203	0.217
σ ² sca =σ ² D	0.012	35.503	0.072	70.828	19.911	0.387	0.017	0.023	8.220	3.481
σ ² gca/σ ² sca	2.667	0.270	131.5	0.120	0.202	0.100	2.235	0.017	0.025	0.062
σ ² A	0.063	19.162	18.935	17.131	8.067	0.080	-0.076	0.001	0.406	0.434
Ā	0.617	1.925	0.087	2.876	2.222	3.110	0.936	7.737	6.363	4.005
h ² b.s	0.203	0.586	0.98	0.731	0.699	0.283	0.540	0.637	0.863	0.443
h ² n.s	0.170	0.204	0.97	0.142	0.201	0.048	0.214	0.021	0.040	0.049
Qlyasan Location										
σ ² gca (Line)	2.932	9.528	0.478	6.805	11.045	-0.011	-0.056	0.0008	-0.024	-3.619
σ ² gca (Tester)	-0.105	0.638	0.208	1.096	15.160	0.431	-0.006	0.0015	-0.057	4.016
σ ² gca (Average)	0.265	0.964	0.067	0.756	2.643	0.045	-0.0012	0.00017	-0.0109	0.396
σ ² sca =σ ² D	3.682	0.142	0.481	1.513	7.293	0.089	0.054	0.00047	-0.105	0.879
σ ² gca/σ ² sca	0.072	6.788	0.139	0.096	2.759	0.529	-0.022	0.361	0.103	0.450
σ ² A	0.530	1.928	0.134	1.513	5.287	0.089	-0.002	0.00034	-0.021	0.792
Ā	3.728	0.383	2.679	3.220	1.204	1.382	0.326	1.66	3.16	1.490
h ² b.s	0.814	0.269	0.558	0.638	0.351	0.417	0.380	0.043	---	0.408
h ² n.s	0.102	0.251	0.122	0.103	0.147	0.213	---	0.018	---	0.195

Appendix 1: The Metrological data at Qlyasan and Kanipanka location during the growing season 2018-2019.

Period	Qlyasan Location			Kanipanka Location		
	Temp. C°		Rainfall mm	Temp. C°		Rainfall mm
	Max.	Min.		Max.	Min.	
October	39.8	17.3	84.6	39.8	17.0	40.3
November	17.5	9.8	116.7	27.1	10.1	112.2
December	18.0	8.0	316.1	16.9	6.9	291.7
January	11.5	-2.5	151.2	16.3	-1.4	157.0
February	17.2	1.5	156.9	16.8	1.9	143.1
March	19.5	1.6	265.7	18.9	2.3	185.3
April	26.0	5.5	177.3	27.1	6.6	134.0
May	36.0	10.4	44.1	39.1	11.3	21.0
June	41.8	21.6	4.6	43.9	20.5	0.0
Total			1317.2			1084.6

Appendix 2: Soils physical and chemical properties at Qlyasan and Kanipanka locations in 2018-2019

Soil Properties	Qlyasan Location	Kanipanka Location	
P.S.D	Silty clay	Clay	
Sand (g/Kg)	58.3	41.6	
Silt (g/Kg)	420.7	429.2	
Clay (g/Kg)	521.0	529.2	
pH	7.13	7.64	
E.C. (dS/m)	0.61	0.54	
Organic Matter (g/Kg)	21.60	27.8	
Total Nitrogen (mg/Kg)	1.07	1.03	
Available Phosphate (mg/Kg)Soil	5.95	5.45	
CaCO ₃ (g/Kg)	107.00	119.4	
Soluble Cations & Anions (mmole/ L)	Calcium (Ca ⁺²)	0.39	1.72
	Potassium (K ⁺)	0.12	0.16
	Sodium (Na ⁺)	0.31	0.46
	Carbonate (CO ₃ ⁼)	0.00	0.00
	Bicarbonate (HCO ₃ ⁼)	3.11	2.99
	Chloride (Cl ⁻)	0.49	0.48
	Sulphate (SO ₄ ⁼)	0.77	0.83