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Heterosis And Combining Ability For Some Important Characters In Half Diallel Crosses Of Bread Wheat (Triticum Aestivum L.)

Eng. Rawda Abdo , Assistant prof. Abdulhameed AL Khaled

Abstract

A half diallel mating crosses was carried out amongst six diversed Bread wheat cultivars ***(Triticum aestivum L.).*** *the six parents and its fifteen F_1 crosses were grown in a field experiment at the agricultural research center of Idlib, to estimate Heterosis over mid parents (HMP) and better parents (HBP), general combining ability (GCA) and specific combining ability (SCA) for the characters of (number of days to heading (DH), plant height(PH), Main spike length (MSL), number of productive tellers (PT), main spike Kernel number (SKN), main spike Kernel weight (SKW), thousand kernel weight (TKW), and grain yield of the individual plant (PGY). Comparing Means performance, reflects that parent had sufficient variation for most investigated characters , which makes these parents eligible to enter breeding programs for achieving the desired genetic advance; and that was evident in the resulting F_1 crosses for most studied characters. The analysis of variance for combining ability showed that mean square due to general combining ability (GCA) were significant for the characters of plant height, number of productive tellers, and individual plant grain yield. While, mean square due to specific combining ability (SCA) were significant for the rest characters, reflecting the importance and participation of both additive and non- additive gene effects in the inheritance of these characters. General Combining ability were higher than [1]those of specific combining ability, consequently the GCA/SCA ratios were more than unity for the characters; number of days to heading, plant height, spike length, number of productive tellers, and grain yield of the individual plant, indicating the prevailing of additive gene effect which have considerable roles in the inheritance of these characters. specific Combining ability were higher than those of General combining ability, consequently the SCA / GCA ratios were more than unity for the characters of main spike Kernel number, main spike Kernel weight and thousand kernel weight, indicating the prevailing of non-additive gene effect which have considerable roles in the inheritance of these characters. The cultivars Doma $_4$ and Doma $_2$ were good combiners for early heading, Sham $_{12}$ for plant height, Doma $_2$ and Sham $_{12}$ for spike length, Wafea for number of productive tellers and doma$_4$These results seem to be useful for wheat breeding program in making the proper decision when initiating a crossing Program.*

Keywords*: Heterosis, Combining Ability, Gene Action, Bread Wheat.*

Introduction: .1

Wheat is the main food source for the majority of the population of West Asia and North Africa (WANA) regions, these regions are the highest consumers of wheat in the world, and the total production and productivity per unit area in theses region is still generally low and cannot meet the growing need of the population (Abdalla, 1999). Thus, the increase in

Idlib University -Faculty of Agricultural Engineering- Dept of Field Crops (Plant Breeding)

population and the consequent increase in demand for agricultural products are expected to be greater in areas with high population density and low agricultural production, therefore, it is necessary to work hard in these areas to increase agricultural production in the future (Anderesen et al., 1999).

(Rajaram, 2005) pointed out that by 2025, we need to increase production by 40% to meet the world's wheat needs as a result of the dramatic increase in population, so there is an urgent need to develop wheat genotypes with a high grain yield potential, and this can be achieved by investigating the greatest genetic capacity of wheat available germplasm. In addition, achieving high productivity requires the presence of genotypes possessing special agricultural characters that increase productivity directly or indirectly due to the influence of physiological processes associated with productivity (Acevedo, 1991).

Improving the efficiency of the use of available genetic resources is the greatest challenge in plant breeding, in order to achieve significant improvement in plant breeding programs (Iqbal, 2004). In addition, genetic improvement of crops requires three basic requirements: (1) a source of genetic diversity that can be used to improve plants, (2) a method for propagating desired genotypes, and (3) a strategy for transferring and selecting desired genes (Clegg, 1986). (; Al-Ghazawi et al., 2018, Ljubicic et al., 2016 Tadesse et al., 2019). This prompted plant breeders to search for new ways to increase production and productivity by using new genetic resources in wheat genetic improvement programs in the one hand, and applying scientific research methods in wheat cultivation and production programs (Hassan et al., 2016 and Al-Ghazawi et al., 2018) on the other hand.

selection and hybridization is one of the most important methods used to improve self-pollinated crops (Chahal & Gosal, 2002), where the breeder resorts to hybridization after the selection becomes unable to achieve his desires to reach higher production and better quality.

The choice of parents for hybridization is very important, as it must be from two different groups and this is essential for obtaining a distinct hybrid and for the hybrid to emerge. Genetic changes in the plant are the first foundation and cornerstone on which the breeder works. (Sahukee et al., 2022).

During breeding programs, it is necessary to select pure lines of high general combining ability (GCA) that indicates the additive gene effect. On the base of that predicting, progenies and making choice of cross combination and genotypes can be carried out. Combining ability investigations carried out by breeders to select parents with efficient transferring desirable genes to the progenies (Madic et al., 2005). For starting a breeding program to improve any crop, the breeder need to knew the type of gene action and genetic system controlling the inheritance of the interest characters and the best breeding strategy to be used to improve them. Combining ability analysis of Griffing (1956) is most widely used as biometrical tool for identifying parental lines in terms of their ability to combine in hybrid combination. With this method, the resulting total genetic variation is partitioned into the variance effects of general combining ability, as a measure of additive gene action and specific combining ability, as a measure of additive gene action. The main objectives of this study were to detect the magnitude of both general and specific combining ability (GCA and SCA) as well as heterosis for grain yield and some agronomic characters in 28 wheat crosses made among six bread wheat genotypes using half diallel crosses.

The present study were carried out during the two successive seasons 2021/2022 and 2023/2022 at the experiment field of Kafer-yahmool research station, Faculty of Agriculture, Idlib University, Syria. Aiming to study the general (GCA) and specific (SCA) combining ability and heterosis through half diallel mating among six different wheat cultivars. These genotypes represented a wide range of variability. The commercial names, pedigree and origin these genotypes are presented in table 2. In 2021/2022 season, the six parental genotypes were planted and all possible combinations of crosses without reciprocals between each two of the six parents, have been done to produce 15 F_1 hybrids. In 2022/2023 season, grains of the 15 F_1 hybrid and the 6 parents were sown in Randomized Complete Block Design (RCBD) with three replications. Each plot consisted of four rows for parents and F_1. Each row was 3m long and 25 cm apart, and the grains within row were spaced 10 cm apart. All recommended cultural practices were considered. Data were recorded on 10 individual guarded plants chosen randomly from each row. The studied characters were (number of days to heading (DH), plant height(PH), spike length (SL), number of productive tellers (PT), main spike Kernel number (SKN), main spike Kernel weight (SKW), thousand kernel weight (TKW), and grain yield of the individual plant (PGY). Data analysis was done according to Steel and Torrie (1980) General and specific combining ability estimates were obtained by employing Griffing diallel cross analysis, model 1 (fixed model) method 2 (Griffing, 1956). Heterosis effect (Heterobeltiosis) was computed as the percentage increase of F_1 over mean and better parent according to Wynne et al. (1970).

Table 1: Area, production and yield of wheat crop in Idlib region for the year 2022

genre	irrigated			rainfed			total		
	Area (ha)	**Production (tons)**	**Yield (tons/ha)**	**Area (ha)**	**Production (tons)**	**Yield (tons/ha)**	**Area (ha)**	**Production (tons)**	**Yield (tons/ha)**
hard	**12665**	**50660**	**4**	**12750**	**19125**	**1.50**	**25415**	**69780**	**2.7**
soft	**2235**	**8840**	**3.955**	**2250**	**3475**	**1.54**	**4485**	**12315**	**2.7**

(Ministry of Agriculture and Irrigation statistics, 2022).

The cultivated area of irrigated wheat crop in Idlib region in 2022, was about 14,900 ha, giving 5,950 tons of cereals, giving an average yield of 4 t/ha (Table 1). The most important factors of production instability are: farmers displacement and rural migration, due to wars, fluctuating rainfall rates from year to year and the substituting of other competing crops (Ministry of Agriculture and Irrigation, Syrian Salvation Government, 2022).

2. Justifications and Objectives:

2.1 Justifications

As a result of the reaching of local cultivars to the highest production ceiling, on one hand, and due to the tremendous increase of population and decreasing of agricultural areas capable to growing wheat on the other hand, plant breeders had to work on introducing new genotypes from different environments and investigating their genetic potential for important yield characters and characters, and then emerging them into a specific crossing plan through the local wheat breeding program.

2.2 Objectives

developing of individual hybrids of bread wheat by the method of semi-cross breeding (Half Diallel Mating Design).

Studying the genetic behavior of the yield and yield character in the resulting hybrids, through the estimating (Heterosis, general combining ability and specific combining ability).

Identifying the best combiner parents with a general ability to adapt and the crosses which have desired specific combining ability for studied characters.

Determining the gene action that controls the studied characters.

3. Literature Review:

3.1 Heterosis:

Heterosis appears as a result of the dominance genetic interaction, or non-allelic genetic interaction (Epistasis), and this phenomenon increases by the increase of genetic diversity amongst parents. Heterosis compared to the better parents indicates the superiority of the hybrid over its best parents, while estimating the heterosis compared to mid parents, helps in providing the breeder with information about the importance of the dominance or over dominance gene action.

Heterosis depends on the ability of the lines involved in the hybridization to be compatible, as it increases as the hybrids are more monolithic, that is, the more their gene structures complement each other (Hassan, 1991). The phenomenon of Heterosis was interpreted by Pellew and Keeble in 1910 as the result of the combined influence of desirable dominant genes originating from the parents. Heterosis can also be defined as the increase in the growth, size and yield of F1 plants resulting from the mating of different parents compared to the rate or best of its parents, which is common in cross- pollinated and self-pollinated crops.

(Kalhoro et al., 2015) studied the performance of six hybrids (F1) resulting from half-cross-breeding amongst four parents and the results showed a significant differences amongst the hybrids in the characteristics of: (plant height, number of shoots in the plant, spike length, number of spikelets per spike, number of grains per spike, weight of 1,000 grains, and grain yield in the plant), and showed that each F1 hybrid recorded negative effects of Heterosis for plant height characteristic and determined the highest negative Heterosis (-14.39%) over mean parent and (-26.43%) compared to the parents Best, while the estimates of Heterosis were positive for all F1 hybrids for the number of tillers in the plant, and three hybrids recorded the highest values over mean parent (28.78%, 21.64%, 13.7%) and compared to the best parents (35.38%, 27.3%, 20.27%), the results varied for the spike length character, where three hybrids showed positive Heterosis effects over mean parent and the best parents, and three hybrids showed equally negative Heterosis effects over mean parent and the best parents, and yields were distinguished The grain in the plant has the highest value of Heterosis compared to the average of the parents was (10.37%), while the highest values of the heterosis compared to the best parents were (16.04%).

During her study to determine the genetic behavior of the characters that make up the grain yield of soft wheat, namely: (number of spikes/plants, number of grains/spikes, thousand kernel weight and grain yield), (Duma 44828x Golan 2), (Research 6 x Duma 4), (Duma 44828 x Sham10) and (Duma x 2 ox 1115) for the characteristics of the number of spikes / plants, number of grains/spikes, thousand kernel weight and grain yield/plant respectively. Among (Anis, 2018) several hybrids significantly outperform in their performance and effects in the desired direction and obtain significant and desirable Heterosis such as the hybrid (ACS-w-J19-9148× Sham6) for the characteristics of the number of spike grains and the yield of individual plants and hybrids (ACS-w-J15-9144 ×Sham6) for the weight of 1000 grains and the yield of individual plants.

In a study carried out by (Gammaal., 2018 & Yahya) amongst 7 parents of soft wheat and its cross-breeding hybrids, the results showed a significant Heterosis in (F1) for all studied characters , and the heterosis for the grain yield character ranged between 4.64 (75.50) %, and the best of these hybrids was (P1xP2, P1xP6, P2xP5, P2xP6, P4xP5).

In an experiment on soft wheat hybrids, (Sham 10×Golan 2) found a desirable negative Heterosis of high significance for the number of days to Heading compared to the average and best parents respectively (-3.40%) and (-1.97%), and the hybrid (Sham 10×Doma 6) possessed a negative Heterosis and highly significant compared to the average and best parents (-2.01%) and (-1.62%) respectively for the number of days to maturity.

The hybrid (Sham 10×Golan 2) was the carrier of the heterosis compared to the average and best parents for the grain filling period period character and the hybrid (sixth 12×Egypt 2) for the plant height characteristic, this is evidence of the superiority of these hybrids in this study.

A study was conducted by (Bilgin et al.,2022) showed the emergence of Heterosis in several hybrids and for several characters , where the heterosis ranged from -12.71 to 8.23% for plant height, -15.46 to 8.36% for spike length, -16.62 to 24.80% for the number of grains per spike, -23.61 to 36.50% for grain weight, -17.13 to 8.84% for harvest index, -44.26 to 15.83 for grain yield, -17.61 to 8.38% for the thousand kernel weight.

3.2. Combining ability and gene action

The concept of combining ability expresses the relative ability of a self-pollinated line to transmit special or desirable characters to the resulting hybrids, when crossed with another self-pollinated line (Chaudhari, 1971), and is important for estimating the potential of self-pollinated line, and determining the nature of the gene action in differentiated quantitative characters (Alam et al.). 2008) and the ability to consolidate helps determine the pedagogical value of parental lines for camel production (Ünay et al., 2004).

The scientist (Griffing, 1956) broke down the total variance into: General Combining Ability (σ^2GCA) for parents, and Specific Combining Ability (σ^2SCA) variance for crosses (Yan and Hunt, 2002).

General Combining Ability is defined as the overall average of a line in a series of hybrids, i.e. it is used as evidence of the general behavior of a line or the location of that line when it is introduced into a series of hybrids. The variation of the GCA test is evidence of the additive action of the genes and therefore inherited from one generation to the next, and the effect of the general ability to match the parents involved in the sclerosis may vary and is due in large part to the environmental impact or to the interaction (genetic × environmental). (Akmine et al., 1964).

The Specific Combining Ability (SCA) is defined as the deviation of the average value of a hybrid from the average general ability of its parents and thus constitutes a measure of the deviation of the efficiency of F1 from the average efficiency of its parents. Therefore, the specific ability for a hybrid can be large or small, depending on whether the effectiveness of the parents is large or small, and accordingly, the specific ability to adapt high, does not necessarily mean a high efficiency of the hybrid in the face of its parents who were given this hybrid, because it does not It gives additional information and the specific combining ability reflects the extent of interaction of parental genes, which appear in F1 as Dominance or overdominance. That is, it uses a guide or indicator of cases in which the behavioral or administration of certain hybrids is better or worse than the grand mean of the tested line involved in the hybridization program, so the variation of the SCA test is evidence of non-additive gene action (Sabbouh et al., 2010).

Genetic variation is the main base for the genetic development of any crop, as hybridization amongst genetically divergent lines produces sufficient genetic variations for effective selection of desired characters , and lines and their hybrids are selected based on the effects of general ability and average good behavior, as the correct selection of pure lines - which combine well to produce high-productivity hybrids - depends on the gene action that governs the characters to be improved, and the ratio of general ability variations to specific ability variations σ^2GCA/σ^2SCA is an important indicator to determine the nature of the gene-action The dominant inheritance of characters , which can be an additional gene action, no additionality, or both (Al-Khaled, 2018).

Tayade et al., 2019) showed in a study to estimate the compatibility ability of soft wheat hybrids that the average squares of general compatibility ability (GCA) and specific (SCA) were highly significant for all studied characters , which reflects the importance of the effects of added and non-added genes in inheriting these characters , and the general Combining ability was less than that of the specific and therefore the GCA/SCA ratios were less than one, which indicates the predominance of the effect of non-additive gene action ion, which has a major role in inheriting these characters, in general, the AKAW-4924 APA genotype was good for characters : early Heading, maturation, weight of 1000 grains. While the AKAW-4925 APA had good qualities: number of grains per spike, grain yield/piece, and K-307 APA was good for plant height character, this indicates that these models are useful in hybridization programs for soft wheat.

In a study to determine compatibility and select the best parents to be included in a hybridization program, Al-Abd Al-Wahid et al., 2020 obtained sufficient variation in most of the characters studied (counting days until spill, plant height, spikes/plant count, number

of grains/spikes, plant biological yield, thousand grains weight, grain yield/plant). A number of parents with a general combining abilityto grain yields and their components, which are proposed to be used as important parents in the soft wheat hybridization program, have been identified for their ability to pass on these characters to their offspring, namely Duma 64453, ACSAD 1252 and Jawahir14. Many positive crosses have also been obtained with the specific ability to adapt resulting from positive parents with the general ability to adapt and carrying the heterosis at the level of the average parents and the best parents, the most important of which are (Jawaher 14×Duma 4), (ACSAD 1252×Jawaher 14), (Duma×Sham 6), (ACSAD 1149× Sham 6). This qualifies it to be an important material for selection during subsequent isolationist generations, to reach distinct lines of wheat for the quality of grain yield.
Mahdy et al., 2021) in a study that included seven parents of soft wheat and their half-reciprocal hybrids showed that there were significant differences between genetic structures and hybrids, and the variation was due to the general and specific Combining ability with high significance for all studied characters (number of days until 50% of spikes, plant height, number of spikes/plant, spike length, number of spike grains, thousand kernel weight , and grain yield in the plant), which indicates the importance of both additive and non-additive gene action in inheriting them. The variance ratio of the general Combining ability to the specific combining ability σ^2GCA/σ^2SCA was less than unity for all the characters studied, suggesting that the non- additive gene action played the most important role in their inheritance.

A study (Abboud et al., 2023) when comparing the averages of the studied characters of the parental lines used in the hybridization program confirmed that they possess a sufficient amount of variation in most of the studied characters (number of days until spikelet, plant height, number of spikes /plant, number of spikes / spike, number of grains / spike, vital yield / plant, thousand kernel weight), qualifies them to enter the hybridization program and work through the resulting individual hybrid isolations, and the results also showed the control of the non-additive gene action of the work of genes in controlling the inheritance of all characters except the number of spikes / The plant that rules by inheritance the additive gene action. A number of parents with a general cobining abilityto grain yield components have been obtained, which are proposed to be used as important parents in the soft wheat cross breeding program for their ability to pass on these characters to their offspring, the most important of which are Duma, ICARD6 and Duma48114.
(Khoury et al., 2023) in the study of the general and specific compatibility of GCA and SCA for soft wheat hybrids proved the control of the additive action of gene work in controlling the inheritance of all studied characters (spike length, number of grains / plant, weight of 1000 grains and grain yield of individual plants) except for the weight of 1000 grains in which the non-additive genetic act dominated, and a number of parents have high and significant effects of the general combining ability grain yields and their components, which are proposed to be used as important parents for future hybrids in a crop hybridization program. Soft wheat for its ability to inherit these characters to its offspring and the most important of these parents: (L-68467, L-1300 and (L-68017), and a number of desirable hybrids have been obtained for the effects of the specific ability to compatibility resulting from parents desirable for the effects of the general ability to compatibility and carrier of the heterosis at the level of the average and best parents, and the most important of these hybrids: (L-1300× L-68467) and (L-68017×L-68467), which qualifies them to be an important material for selection in subsequent isolated generations to reach more distinguished lines of wheat for the quality of yield Granularity.

4. Materials and Methods:

4.1. Materials:

4.1.1. plant Material:

The plant material of this research included several local and introduced genotypes of soft wheat, which are pure varieties (not less than 95% purity). The local varieties originate from the General Department of Agricultural Scientific Research of the Ministry of Agriculture and Irrigation, and the plant material originally belongs to varieties approved by the Syrian Varieties Accreditation Committee, while the inputs are two Turkish varieties introduced to Syria through the General Administration of Agricultural Scientific Research in 2019. Table 2.

Table 2: The specifications of the parents

Genetic type	
Duma 4	It is grown in the second stability zone, with a protein content of 16.1%, the number of days to the spasm is 120 days, and until full maturity is 136 days.
Duma 2	It is grown in the second stability zone, drought-resistant, the number of days until Heading is 119 days, and until full maturity is 159 days.
Sham 10	It is characterized by its high productivity and suitability for irrigated agriculture, its productivity in the conditions of this cultivation is 8000 kg / ha.
Sham 12	The average bacqueria, intended for agriculture in the first settlement zone, has a protein content of 10.1%, can be grown irrigated and give a productivity of 6-7 tons/ha, while Baala yields a productivity of 3-4 tonnes/ha.
Wafiya	It is characterized by high productivity, an early maturing variety with a high ability to adapt to different environments and resistant to dormancy, the number of days until maturity is 165 days, the percentage of protein in it is 14.5-12.6% and the percentage of gluten is 85%, with a short-overcrowded spike.
Jihan 99	High productivity, resistant to dormancy, has the ability to resist diseases and resist drought moderately, the number of days until full maturity 167

According to the reports of the releasing varieties by the Syrian general commission for scientific agricultural research (GCSAR)

4.2. Methods:

4.2.1. Place of implementation of the experiment: The experiment was carried out at the Agricultural Scientific Research Center in Idlib during the agricultural seasons 2020/2021 and 2021/2022.

Table 3: per year rainfall of experiment site during 2022 season

December	**January**	**February**	**March**	**April**	**May**	**Total**
128.5	**91**	**35.5**	**79**	**0**	**0**	**334**

According to the rainfall criteria of the Agricultural Scientific Research Station in Idlib

The research center is located 17 km at the north of Idlib city, in the first stability zone at longitudes 36.10 west and 37.15 east, latitudes 35.10 south and 36.15 north and an altitude of 335 m above sea level, with an average rainfall of 334 mm per year (Table 3.)

Table 4: Results of the soil analysis of the experiment site

element	**Nitrogen content (mg/kg)**	**Soil assessment**	**potassium content (mg/kg)**	**Soil assessment**	**Phosphorus content (mg/kg)**	**Soil assessment**	**pH**	**Soil texture**

value	30.38	Very rich	226.8	moderate	20.68	Very rich	7.94	Moderately acidic

According to the r the soil fertility laboratory at the Faculty of Agricultural Engineering at the University of Idlib

The soil of the experiment site is medium loamy clay red, poor in organic matter with basic pH, very rich in nitrogen, medium potassium content, and rich in phosphorus (Table 4).

4.2.2. Cultural Practices

Data were recorded on 10 individual guarded plants chosen at random from each row. The studied characters were (number of days to heading (DH), plant height (PH), spike length (SL), number of productive tellers (PT), main spike Kernel number (SKN), main spike Kernel weight (SKW), thousand kernel weight (TKW), and grain yield of the individual plant (PGY).

Table 5: Half diallel mating design array

Parents	P_1	P_2	P_3	P_4	P_5	P_6
P_1	*	$P_2 \times P_1$	$P_3 \times P_1$	$P_4 \times P_1$	$P_5 \times P_1$	$P_6 \times P_1$
P_2	*	*	$P_3 \times P_2$	$P_4 \times P_2$	$P_5 \times P_2$	$P_6 \times P_2$
P_3	*	*	*	$P_4 \times P_3$	$P_5 \times P_3$	$P_6 \times P_3$
P_4	*	*	*	*	$P_5 \times P_4$	$P_6 \times P_4$
P_5	*	*	*	*	*	$P_6 \times P_5$
P_6	*	*	*	*	*	*

Parents and the (F_1) were planted at the Agricultural Research Center of Idlib season 2022-2023 for evaluation, in mid-November (15/11/2022), each plot consisted of four rows for parents and F_1. Each row was 3m long and 25 cm apart, and the grains within row were spaced 10 cm apart, with three replications. All recommended cultural practices were considered.

4.2.3. Experimental Design and Statistical Analysis:

The experiment was carried out according to Randomized Complete Block Design (R.C.B.D). analysis of variance has been done using statistical analysis software (Genstat-12). Least significant differences test (LSD) was used for means comparison at (0.05). significance level.

4.2.4. Genetic indicators studied:

Heterosis: heterosis was estimated as a percentage using the following equations: -
Heterosis due to mid parents: $HMP = [(MF_1 - MP) / MP] \times 100$

MP$=(MP_1+MP_2)/2$
$MF_1=F_1/n$
Where:
HMP: Heterosis due to mean Parents, MF_1 : F_1 mean
MP mean Parents, MP_1 mean OF the first parent, MP_2 Mean of the second parent
n: The number of F_1 plants.
Heterosis due to the Beter Parents: $HBP = [(MF_1 - BP) / BP] \times 100$

MF_1=F_1/n
Where:
HBP: Heterosis due to Beter Parents, MF_1 : F_1 mean
The Heterosis Significance was calculated according to the t-test. (Sinha & Khanna1975).
General and Specific Combining Ability calculated according to the model-one - and method-tow of Griffing, (1956).

4.2.5. Studied Characters:

Number of days to heading: It is the number of days from germination until spike Emergence out of sheaths for 50% of the plants.
Plant height (cm): the height of the main stem from the ground surface level to the top of the spike (except awn length) at the stage of full maturity for (10) randomly selected plants from each experimental plot.
Spike length (cm): It is measured starting from the base of the spike to the end of the fertile spikelets, so that the average length of (10) randomly selected spikes is calculated from each experimental plot.
Number of productive tillers: Number of productive spikes taken from (10) randomly selected plants from each experimental plot before harvesting.
Number of grains/main spike: According to the average number of grains for (10) main spikes which selected randomly from each experimental plot.
Grain weight per spike (g): Taking the average grain weight of the previously selected spikes.
Thousand kernel Weight (g): recorded by taking an average of 3 replications (samples) of the weight of one thousand grains for each genotype.
Grain yield/plant(g): Grain yields were calculated for (10) randomly selected plants from each experimental plot.

Note: All character scores were recorded from the same ten randomly selected plants.

5. Conclusions and Discussion:

Table.6: Mean Performance of the six parents and their 15 F_1 crosses for the characters:
(DH), (PH), (MSL) and (PT)

Genotypes	Days to Heading (DH)	plant Height /cm (PH)	Main Spike Length/cm((MSL)	Number Productive Tillers (PT)
Wafea (W)	118.4^{d}	82.46 ^{c}	7.69 ^{d}	13.19 ^{a}
$Gehan_{99}$ (G_{99})	117.3^{c}	83.53^{c}	11.57 ^{c}	11.50 ^{a}
$Doma_4$ (D_4)	113.6^{a}	86.89 ^{b}	12.59 ^{ab}	13.43 ^{a}
$Sham_{10}$ (SH_{10})	115.7^{b}	87.88 ^{b}	11.85 ^{bc}	12.33 ^{a}
$Doma_2$ (D_2)	113.0 ^{a}	88.49 ^{b}	12.78 ^{a}	11.17 ^{a}
$Sham_{12}$ (SH_{12})	116.0^{b}	98.34 ^{a}	12.12 ^{abc}	11.67 ^{a}
Parents Mean	115.67	87.93	11.44	12.22
$LSD_{0.05}$	0.932	1.349	0.917	2.414
G_{99}×W	119.7^{e}	82.50 ^{b}	11.49 ^{cd}	11.43 ^{bcd}
D_4×W	117.0^{cd}	82.95^{b}	12.52 ^{abc}	17.08 ^{a}
SH_{10}×W	118.3^{de}	93.07 ^{a}	10.90 ^{d}	16.66 ^{a}

D_2×W	116.5[bcd]	82.91 [b]	13.00 [ab]	14.40 [ab]
SH_{12}×W	117.0[cd]	95.36 [a]	12.23 [bcd]	12.33 [bcd]
D_4×G_{99}	115.0[ab]	87.41 [ab]	12.36 [bc]	9.77 [d]
SH_{10}×G_{99}	116.3[bc]	85.66 [ab]	11.41 [cd]	11.90 [bcd]
D_2×G_{99}	116.0[bc]	83.33 [b]	13.78 [a]	12.17 [bcd]
SH_{12}×G_{99}	117.0[cd]	91.12 [ab]	13.21 [ab]	13.31 [bc]
SH_{10}×D_4	115.7[abc]	93.40 [a]	11.54 [cd]	12.89 [bc]
D_2×D_4	114.0[a]	85.32 [ab]	12.88 [ab]	12.76 [bcd]
SH_{12}×D_4	115.3[abc]	88.07 [ab]	12.73 [abc]	13.60 [bc]
D_2×SH_{10}	114.7[ab]	91.53 [ab]	12.91 [ab]	11.61 [bcd]
SH_{12}×SH_{10}	116.0[bc]	92.86 [ab]	12.27 [bc]	10.89 [cd]
SH_{12}×D_2	114.0[a]	94.62 [a]	13.27 [ab]	13.11 [bc]
Crosses Mean	116.17	88.67	12.43	12.93
LSD $_{0.05}$	1.839	10.850	1.338	3.063

Table. 7: Mean Squares from analysis of variance for the characters: (DH), (PH), (MSL) and (PT)

Sources of variation	Days to Heading (DH)	plant Height /cm PH))	Main Spike Length/cm (MSL)	Number of Productive Tillers (PT)
Rep Lines	0.1851	1.212	1.3972	2.498
Lines	12.8761**	95.450**	10.6966**	2.620
Error (Lines)	0.2625	2.731	0.2538	1.761
CV%	0.4	1.9	4.4	10.9
Rep Crosses	0.317	37.90	3.7143	6.463
Crosses	7.107**	66.05	1.9557**	11.594**
Error (Crosses)	1.210	42.08	0.6402	3.353
CV%	0.9	7.3	6.4	14.2
GCA	**29.57**	**196.17****	**11.24**	**12.76****
SCA	**1.17**	**28.55**	**2.50**	**7.88****
Error (GCA, SCA)	0.926	30.575	0.513	2.803

Table. 8: Heterosis Percentage over mid and Beter parents in the Semi-Reciprocal Hybrids for the characters: (DH), (PH), (MSL) and (PT)

Crosses	Days to Heading (DH)		plant Height /cm PH))		Main Spike Length/cm((MSL)		Number of Productive Tillers (PT)	
	H(MP)	H(BP)	H(MP)	H(BP)	H(MP)	H(BP)	H(MP)	H(BP)
G_{99}×W	1.56*	0.20*	-0.59	-1.23	19.31**	-0.69	-7.40	-13.34
D_4×W	3.15**	0.53**	-2.04	-4.53	23.38**	-0.62	28.29**	27.15*
SH_{10}×W	-0.06	0.11	9.28	5.91	11.53	-8.04	30.56**	26.30*
D_2×W	0.69	0.31**	-3.00	-6.30	26.97**	1.69	18.23	9.15
SH_{12}×W	-0.17	0.09	5.49	-3.03	23.43**	0.88	-0.80	-6.54
D^4×G_{99}	-0.38	0.12	2.62	0.64	-0.06	-4.10	-21.60*	-27.25*
SH_{10}×G_{99}	-0.14	0.05	-0.05	-2.52	-2.62	-3.77	-0.14	-3.51
D_2×G_{99}	0.75	0.27**	-3.11	-5.83	13.15**	7.80	7.34	5.78
SH_{12}×G_{99}	0.31	0.09	0.21	-7.34	11.49*	8.96	14.91	14.09

SH_{10}×D_4	0.86	0.18*	6.88	6.28	-5.59	-8.36	0.03	-4.07
D_2×D_4	0.61	0.09	-2.70	-3.58	1.54	0.78	3.77	-4.99
SH_{12}×D_4	0.46	0.15	-4.91	-10.45	3.01	1.09	8.37	1.24
D_2×SH_{10}	0.26	0.15	3.79	3.44	4.80	0.99	-1.19	-5.86
SH_{12}×SH_{10}	0.12	0.02	-0.27	-5.57	2.38	1.24	-9.28	-11.73
SH_{12}×D_2	-0.44	0.09	1.29	-3.79	6.58	3.83	14.80	12.34

Table .9: Values of general compatibility ability effects in parents for the characters: (DH), (PH), (MSL) and (PT)

Parents	Days to Heading (DH)	Plant Height /cm PH))	Main Spike Length/cm((MSL)	Number of Productive Tillers (PT)
Wafea	1.65**	-2.19	-1.19**	1.15*
$Gehan_{99}$	0.77**	-2.77*	0.04	-0.94*
$Doma_4$	-0.98**	-1.04	0.27	0.49
$Sham_{10}$	0.05	1.63	-0.29	-0.06
$Doma_2$	-1.36**	-0.57	0.80**	-0.34
$Sham_{12}$	-0.13	4.93**	0.37**	-0.31
SE	0.18	1.03	0.13	0.31

Table .10: Values of Specific Compatibility Effects in Crosses for the characters: (DH), (PH), (MSL) and (PT)

Crosses pedigree	Days to Heading (DH)	plant Height /cm PH))	Main Spike Length/cm((MSL)	Number of Productive Tillers (PT)
G_{99}×W	1.24*	-1.00	0.49	-1.51*
D_4×W	0.31	-2.28	1.28**	2.72**
SH_{10}×W	0.62	5.17	0.23	2.84**
D_2×W	0.20	-2.79	1.24**	0.86
SH_{12}×W	-0.53	4.16	0.91*	-1.23
D_4×G_{99}	-0.80	2.76	-0.10	-2.50*
SH_{10}×G_{99}	-0.49	-1.66	-0.50	0.17
D_2×G_{99}	0.59	-1.79	0.79*	0.71
SH_{12}×G_{99}	0.02	0.49	0.65	1.83**
SH_{10}×D_4	0.59	4.34	-0.59	-0.27
D_2×D_4	0.33	-1.53	-0.33	-0.11
SH_{12}×D_4	0.44	-4.29	-0.06	0.70
D_2×SH_{10}	-0.03	2.00	0.25	-0.72
SH_{12}×SH_{10}	0.07	-2.17	0.05	-1.47
SH_{12}×D_2	-0.51	1.79	-0.04	1.03
SE	0.49	2.83	0.37	0.86

5.1. Number of days to heading:

Early Heading protect the plant from exposure to high temperatures in periods later than the flowering and grain filling periods, so we relied on lower average values and negative results for both Heterosis and compatibility (Aboudi et al., 2021), and this character is important in distinguishing the most early flowering varieties (Jubail and Faleh, 2014).

5.1.1. Analysis of variance and comparing of means

The results of the statistical analysis showed that there are differences in this character amongst parents and crosses Table (7), the value of the character in the parental lines ranged from (113.00) to (118.4) days, with a grand mean of 115.67) days Table (6), and it was found that the two lines Doma4 and Doma2 are the earliest in Heading, while the Wafea line was the most late in the Heading, and the existence of significant differences amongst parents was reflected in the resulting hybrids, where the value of the character ranged amongst crosses from (114.00) to (119.7) days with a grand mean of (116.17) days Table 6, the hybrids (D4×D2) and (D2 ×SH12) were the earliest in the Heading, while the hybrid (W×G99) was the most delayed.

5.1.2. Heterosis

The differences amongst parental lines and their semi-reciprocal hybrids led to the emergence of Heterosis, data of Table (8) shows that five hybrids had negative desirable non-significant Heterosis over mean parents (MP), and it ranged between (-0.06, -0.44)% and the hybrid (D2 ×SH12) was the best, while the rest of the hybrids had a positive undesirable highly significant and non-significant Heterosis, while no desirable negative Heterosis was shown for this character compared to the best parents and all crosses had Undesirable positive Heterosis, highly significant, significant and non-significant, and our results agree with the results of (Al-Abdulwahid et al., 2020).

5.1.3 Combining ability and gen action:

The data of Table (7) indicate that there is a non-significant difference of the general and specific combining abilities, but the values of the general were greater than the specific to indicate that the additive gene action is greater than the dominance gene action (11.24, 2.50) respectively, and these results agreed with the results of (Tadbeer et al., 2015). Table (10) data showed that Doma2 was one of the most important parents to improve the characteristic of the earliness in Heading because it had the highest negative desirable and highly significant value -1.36** followed by Doma4, which had a negative desirable highly significant general combining ability and, then Sham12, which had negative, desirable, but non-significant general Combining ability, while the rest had a positive non-significant general Combining ability.

The D4×G99 hybrid achieved the highest negative desirable non-significant specific Combining ability value (-0.80), resulting from two parents, one positive Combining ability and the other negative Combining ability (additive × not additive) (table, 10), in addition to this hybrid, it possessed four hybrids of a specific Combining ability negative, desirable and non-significant, two of which resulted from parents, one positive Combining ability and the other negative Combining ability (additive ×non- additive),and one hybrid resulting from two parents Both are positive for general compatibility (additive × additive , and only one hybrid due to the reaction (not additive × not additive) is the desired interaction in this character.

5.2. Plant Height / cm:

The characteristic of plant height is an important indicator of plant growth and development, and gives an idea to predict the growth rate and productivity of the crop (Kaur, 2017). It plays an important role in the grain filling period in wheat, especially under drought and heat stress conditions, due to its ability to store carbohydrates, which in turn support grain filling after flowering (Sallam et al., 2015).

5.2.1. Analysis of variance and comparing of means

Plant height means in lines ranged from (82.46) cm to (98.34) cm with a grand mean of (87.93) cm Table (6) and (7) and this indicates the presence of high significant differences, and it was found that Sham12 is the highest while Wafea was the shortest, and the value of this character in hybrids ranged from (82.5) cm to (95.36) cm with a grand mean of (88.67) cm. the hybrids (SH12×W), (SH10×W) and (SH12×G99) are the highest while the hybrid (W×G99) is The shortest.

5.2.2. erosis

Table (8) indicates that seven hybrids showed positive desirable non-significant Heterosis over mean parents (MP) which ranged between (0.21, 9.28) %. the hybrid (SH10×W) was the best, while four crosses showed positive desirable non-significant Heterosis over best parents (BP) and ranged from (6.28, 0.64) % and the hybrid (SH10× D4) was the best, and these results came in line with the results of (Aboudi et al., 2021) for this character.

5.2.3 Combining ability and gen action:

Table (7) showed that the general Combining ability showed a highly significant differences, while of the specific Combining ability was not significant, indicating to the control of the additive gen action in this character inheritance. These results agreed with (Aboulela, 2006).

The effects of the general combining ability in Table (9) ranged between (-2.77*, 4.93**) and Sham12 gave the highest significant positive value (4.93**) for the general ability to conform, followed by Sham10 which was positive for compatibility but not significant, and the rest of were negative for the general ability to compliance.

The effects of specific Combining ability (Table, 10) ranged between (-4.29, 5.17) and the hybrid SH10×W achieved the highest positive but non-significant value in the specific Combining ability (5.17), resulting from parents, one positive Combining ability and the other negative Combining ability (additive × not additive), and six hybrids gave a specific Combining ability positive desirable and non-significant, five of which resulted from parents, one positive Combining ability and the other negative Combining ability (additive × no additive), and one hybrid was from parents both negative compatibility (not additive × not additive), while eight hybrids had negative and non-significant values of the Combining ability in this capacity, one of which was the result of parents both positive compatibility (additive × additive), two resulted from parents, one positive Combining ability and the other negative Combining ability (additive × not additive), and five hybrids both parents had negative compatibility ability (not additive × no additive).

5.3. Main Spike Length/cm:

The spike length is an important key characteristic which positively correlated with final production, due to the positive correlation with the number and weight of grains in the spike, and the final grain yield is significantly affected by changes in the upper part of the spike (Socrates, 2014 and Protic et al., 2019).

5.3.1. Analysis of variance and comparing of means.

The variation among lines was high in this character, indicating the genetic diverse amongst them (Table, 7) and the averages of the lines ranged from (7.69) cm to (12.78) cm with a grand mean of 11.44) cm, and the two lines Doma4 and Doma2 are the longest in the main spike characteristic, while Wafea line is the shortest in this characteristic, and this was reflected in the resulting hybrids, the value of the character in the hybrids ranged from (10.90) cm to (13.78) cm with a grand mean of (12.43) cm, and the hybrids were (D2×G99) and (SH12× G99) They are the longest of the main spike, while the hybrid spike (SH10×W) is the least tall (Table 6).

5.3.2 Heterosis

Heterosis percentages of this character in (Table, 8) show desirable positive and highly significant values over mean parent at five hybrids: (D2× W, ×W SH12, W× D4, G99× W, G99×D2), (26.97**, 23.43**, 23.38**, 19.31**, 13.15**) % respectively, while one hybrid gave a positive desirable significant strength (11.49*)%, which is (SH12× G99), and the rest of the hybrids ranged from a desirable non-significant positive Heterosis, to negative undesirable non-significant. These results corresponded with the results obtained by (Raj, Kandakar.2013), and in the same table we note the emergence of a desirable positive Heterosis that is not significant compared to the best parents (BP) in nine crosses whose value ranged between (8.96, 0.78) % and the hybrid (SH12× G99) was the best, while the rest of the hybrids, in which the heterosis was negative, undesirable and insignificant.

5.3.3 Combining ability and gen action:

The data of Table (7) indicate a non-significant variation of combining ability for spike length characteristic, but the values of variance of the general combining ability were greater than the specific combining ability (29.57, 1.17) respectively, and this result was consistent with his findings (Khoury et al., 2023).

The results of Table (9) showed that the values of the effects of the general Combining ability were positive and high (0.80**) in Doma2, followed by the Sham12 (0.37**), while the Gehan99 and Doma4 had positive and non-significant values for the effects of the general combining ability, while the rest had negative general compatibility ability for this character.

The values of specific Combining ability effects (Table, 10) ranged between (-0.59, 1.28**), the highest was in the hybrid D4×W, which gave a positive and highly significant value (1.28**), which produced from two parents, one positive Combining ability and the other is negative Combining ability (additive × not additive), followed by the hybrid D2×W, which possessed a highly significant positive value of (1.24**), resulting from parents, one positive Combining ability and the other negative Combining ability (additive × not additive), and also The hybrid SH12×W possessed a specific positive and significant compatibility ability (*0.91), which resulted from two parents, one is positive compatibility and the other is negative compatibility ability (additive × not additive), and the hybrid D2×G99 possessed a significant desirable positive effect value for the specific Combining ability (*0.79), which is a result of both parents positive general compatibility ability (additive × additive .

5.4. Number of Productive Tillers

The characteristic of number of productive tillers is one of the most important characteristics that predict high wheat productivity under rainfed conditions (Shahrly and Khiti, 2011 and Saada and Lawand, 2016). It is one of the basic production components by which the productive capacity of the cultivated variety can be predicted. They are determined in the early stages of plant growth (branching stage) (Al-Ameri and Al-Obaidi, 2016).

5.4.1 Analysis of variance and means comparison

The results recorded in Table (6) show that there were no significant differences in the number of productive tillers among parents, as the values ranged from (11.67) to (13.19) with a grand mean of 12.22), and Doma4 gave the largest number of smashes, followed by Wafea, while the Sham12 was the least number of smashes. As for the crosses, there were high significant differences amongst them for this character, ranging from (9.77) to (17.08) with a grand mean of (12.93), and the two hybrids (D4×W, SH10×W) outperformed the rest of the crosses with significant differences.

5.4.2 Heterosis

Table (8) showed that two hybrids possessed a desirable positive Heterosis of high significance over mean parent (MP): (D4×W, SH10×W) with a value of (28.29**, 30.56**) respectively, while seven hybrids gave a desirable non-significant positive Heterosis ranging between (0.03, 18.23) %, the best of which was the hybrid (W ×D2), and the rest of the hybrids were negative undesirable significant and non-significant. The two hybrids (D4×W, SH10×W) also possessed a positive desirable significant Heterosis compared to the best parents (BP) whose value ranged between (27.15*, *26.30) % and owned five hybrids of a desirable non-significant positive Heterosis with a value between (1.24, 14.09), the best of which is the hybrid (G99×SH12), while the rest of the hybrids had an undesirable negative Heterosis significant and non-significant, this result was similar to (Kalhoro et al., 2015.)

5.4.3 Combining ability and gen action:

The results of Table (7) show a high variation of the general and specific combining abilities for the characteristic of the number of productive stags, which indicates the contribution of both additive and non-additive gene action in the inheritance of this character and this is consistent with the results of (Akl, 2015).

The effects of the general ability to compatibility in Table (9) ranged between (-0.06, 1.15) and Wafea was the best parent to improve this character because it had the highest significant high positive value for the general Combining ability (1.15*), followed by Doma4, which gave a positive but non-significant value to the Combining ability (0.49), which has a positive and desirable effect on this character, while Gehan99 had a significant negative value for the general ability to comply and therefore will negatively affect this character in the hybrids that will enter out.

The effects of specific Combining ability (Table, 10) ranged between (-1.51*, 2.84**) and the hybrid SH10×W achieved the highest significant positive value in those effects (2.84**)) which is a product of two parents, one positive compatibility and the other negative compatibility ability (additive × not additive), followed by the hybrid D4×W, which gave a significant positive value on compatibility (2.72**), resulting from parents both positive compatibility (additive × additive), and the hybrid SH12×G99, which gave a high positive value. Significant in the specific Combining ability 1.83 **) resulting from parents both negative Combining ability (not additive × not additive), while five hybrids possessed positive non-significant values for the Combining ability ranged between (0.17, 1.03) distributed on three hybrids resulting from parents both negative Combining ability (not additive × not additive) and two hybrids resulting from parents, one positive Combining ability and the other negative Combining ability (additive × not additive).

Table 11: Mean Performance of the six parents and their 15 F_1 crosses for the characters:
(SKN), (SKW), (TKW)and (PGY)

Genotypes	Main spike kernels number (SKN)	Main spike kernels weight/g (SKW)	thousand kernel weight/g (TKW)	Individual Plant Grain Yield (PGY)
Wafea (W)	73.00 ^{a}	4.443^{a}	39.00 ^{c}	17.08 ^{a}
Gehan$_{99}$ (G_{99})	66.70 $^{a\,b}$	3.130^{bc}	42.67^{ab}	13.37^{b}
Doma$_{4}$ (D_4)	64.3 0$^{a\,b}$	3.370 ^{b}	42.08 ^{ab}	18.98 ^{a}
Sham$_{10}$ (SH_{10})	63.30 $^{a\,b}$	2.707^{bc}	41.94 ^{ab}	17.07^{a}
Doma$_{2}$ (D_2)	55.70^{b}	2.520 ^{c}	43.66 ^{a}	12.68 ^{b}
Sham$_{12}$ (SH_{12})	53.70^{b}	2.457 ^{c}	40.94 ^{bc}	13.23 ^{b}
Parents Mean	62.80	3.10	41.71	15.40
$LSD_{0.05}$	16.02	0.784	2.694	3.055
G_{99}×W	34.00 ^{d}	1.273 ^{de}	43.03 ^{b}	19.18 ^{ab}
D_4×W	71.50 ^{ab}	2.920 ^{bc}	44.40 ^{b}	19.17 ^{ab}
SH_{10}×W	24.33 ^{d}	1.193 ^{e}	43.24 ^{b}	11.33 ^{d}
D_2×W	78.65^{a}	3.67 ^{ab}	48.55 ^{a}	23.31 ^{a}
SH_{12}×W	59.00 ^{bc}	2.620 ^{bc}	43.17 ^{b}	13.50 ^{cd}

D_4×G_{99}	76.00 [a]	4.143 [a]	45.16 [ab]	17.31 [bc]
SH_{10}×G_{99}	67.33 [abc]	2.730 [bc]	43.50 [b]	16.09 [bcd]
D_2×G_{99}	55.00 [c]	2.460 [cd]	43.51 [b]	17.59 [bc]
SH_{12}×G_{99}	74.33 [ab]	3.753 [ab]	42.14 [b]	14.66 [bcd]
SH_{10}×D_4	58.67 [bc]	2.930 [bc]	45.64 [ab]	19.28 [ab]
D_2×D_4	63.33 [abc]	2.240 [cde]	44.23 [b]	19.40 [ab]
SH_{12}×D_4	63.33 [abc]	3.180 [abc]	46.05 [ab]	15.95 [bcd]
D_2×SH_{10}	69.33 [abc]	3.143 [abc]	43.48 [b]	17.91 [abc]
SH_{12}×SH_{10}	64.00 [abc]	2.597 [bc]	42.53 [b]	15.05 [bcd]
SH_{12}×D_2	59.33 [bc]	2.350 [cde]	42.32 [b]	10.64 [d]
Crosses Mean	61.20	2.75	44.06	16.69
LSD $_{0.05}$	16.37	1.208	3.865	5.517

Table (12) Mean Squares from analysis of variance for the characters (SKN), (SKW), (TKW)and (PGY) in the agricultural season 2022/2023

Sources of variation	Main spike kernels number (SKN)	Main spike kernels weight/g (SKW)	thousand kernel weight/g (TKW)	Individual Plant Grain Yield (PGY)
Rep Lines	54.89	0.0109	1.518	9.457
Lines	153.56	1.6699**	7.703*	20.777**
Error (Lines)	77.56	0.1858	2.192	2.819
CV%	14.0	13.9	3.5	10.9
Rep Crosses	16.34	0.1549	0.274	22.97
Crosses	658.93**	2.0023**	8.681	33.44**
Error (Crosses)	95.79	0.5214	5.340	10.88
CV%	16.0	26.3	5.2	19.8
GCA	134.42	0.81	8.51	44.34**
SCA	623.49	2.26	12.57**	24.79**
Error (GCA, SCA)	87.506	0.412	4.371	8.997

Table. (13) Heterosis Percentage over mid and Beter parents in the Semi-Reciprocal Hybrids for the characters: (SKN), (SKW), (TKW)and (PGY)

Crosses	Main spike kernels number (SKN)		Main spike kernels weight/g (SKW)		thousand kernel weight/g (TKW)		Individual Plant Grain Yield (PGY)	
	H(MP)	H(BP)	H(MP)	H(BP)	H(MP)	H(BP)	H(MP)	H(BP)
G_{99}×W	-51.31**	-53.42**	-66.37**	-71.34**	5.38	0.85	26.00	12.29
D_4×W	4.13	-2.05	-25.26	-34.28*	9.52*	5.50	6.33	1.02
SH_{10}*W	-64.30**	-66.67**	-66.62**	-73.14**	6.85	3.11	-33.63*	-33.66*
D_2×W	22.25*	7.74	5.41	-17.40	17.47**	11.21*	56.62**	36.45*
SH_{12}×W	-6.84	-19.18	-24.06	-41.04**	8.01	5.46	-10.90	-20.95
D_4×G_{99}	16.03	14.00	27.49	22.95	6.57	5.84	7.02	-8.80
SH_{10}×G_{99}	3.59	1.00	-6.45	-12.78	2.84	1.96	5.76	-5.70
D_2×G_{99}	-10.08	-17.50	-12.92	-21.41	0.80	-0.35	35.05	31.60
SH_{12}×G_{99}	23.55*	11.50	34.37	19.91	0.81	-1.23	10.26	9.70

SH_{10}×D_4	-8.09	-8.81	-3.57	-13.06	8.64*	8.45	6.98	1.60
D_2×D_4	5.56	-1.55	-23.94	-33.53	3.17	1.31	22.53	2.21
SH_{12}×D_4	7.34	-1.55	9.15	-5.64	10.94**	9.43*	-0.93	-15.93
D_2×SH_{10}	16.53	9.47	20.28	16.13	1.60	-0.40	20.40	4.94
SH_{12}×SH_{10}	9.40	1.05	0.58	-4.06	2.64	1.41	-0.63	-11.80
SH_{12}×D_2	8.54	6.59	-5.56	-6.75	0.05	-3.07	-17.91	-19.60

Table (14) Values of general compatibility ability effects in parents for the characters: (SKN) (SKW), (TKW)and (PGY)

Parents	Main spike kernels number (SKN)	Main spike kernels weight/g (SKW)	thousand kernel weight/g (TKW)	Individual Plant Grain Yield (PGY)
Wafea	-2.27	0.08	-0.42	0.80
$Gehan_{99}$	1.05	0.08	-0.13	-0.34
$Doma_4$	3.74	0.28	0.74	1.85*
$Sham_{10}$	-2.66	-0.24	-0.18	-0.06
$Doma_2$	0.67	-0.13	0.71	-0.01
$Sham_{12}$	-0.53	-0.07	-0.71	-2.25**
SE	1.74	0.12	0.39	0.56

Table (15) Values of Specific Compatibility Effects in Crosses for the characters:(SKN) (SKW), (TKW) and (PGY)

Crosses pedigree	Main spike kernels number (SKN)	Main spike kernels weight/g (SKW)	Thousand kernel weight/g (TKW)	Individual Plant Grain Yield (PGY)
G_{99}×W	-26.44	-1.74	0.19	2.40
D_4×W	8.37	-0.28	0.69	0.20
SH_{10}×W	-32.40	-1.49**	0.45	-5.73**
D_2×W	18.59**	0.87*	4.87**	6.19**
SH_{12}×W	0.14	-0.24	0.91	-1.37
D_4×G_{99}	9.56	0.93**	1.16	-0.53
SH_{10}×G_{99}	7.29	0.04	0.43	0.16
D_2×G_{99}	-8.38	-0.34	-0.46	1.61
SH_{12}×G_{99}	12.16*	0.89*	-0.41	0.93
SH_{10}×D_4	-4.07	0.05	1.69	1.16
D_2×D_4	-2.73	-0.76*	-0.61	1.23
SH_{12}×D_4	-1.53	0.12	2.63*	0.03
D_2×SH_{10}	9.66	0.67	-0.43	1.65
SH_{12}×SH_{10}	5.54	0.06	0.03	1.04
SH_{12}×D_2	-2.46	-0.30	-1.07	-3.43*
SE	4.79	0.33	1.07	1.54

5.5. Main spike kernels number:

The number of grains per spike is one of the three important components that have a direct impact on the yield of grains, which is influenced by the genetic nature of the plant as well as the environmental factor that affects the increase of grains number of spikes (Kadum et al., 2019).

5.5.1. Analysis of variance and means comparison

The highest value of the average number of grains in the main spike was (73.00) at the Wafea line , outperforming the rest of the lines with the most number of grains, followed by Gehan99, while Sham12 had the lowest number of grains in the main spike (53.70), and high significant differences appeared amongst the crosses, so their value was from (24.33) grains to (78.65) grains with a grand mean of (61.20) grains (Table, 11), and the hybrids (D2×W, G99×(D4) were the most numerous grains in the spike, while the hybrid was (SH10×W) is the least numerous.

5.5.2. Heterosis

High significant, positive and desirable values appeared for the number of main spike grains compared to mean parents (MP) at the two hybrids (D2×W, SH12× G99) with a value of (22.25*, 23.55*) % Table (13), while eight hybrids gave a desirable non-significant positive Heterosis ranging between (3.59, 16.53) %, the best of which is the hybrid (SH10 ×D2), and the rest of the hybrids were negative undesirable, highly significant and non-significant. While seven hybrids gave a desirable non-significant positive Heterosis compared to the best parents (BP) its value between (1.00, 14.00) %, the best of which is the hybrid (G99 × D4), while the rest of the hybrids had a negative undesirable significant and non-significant Heterosis, this result matched what he found (Anis, 2020).

5.5.3. Combining ability and gen action

Referring to Table (12), we find that the variation of the general and specific combining ability was not significant, but the value of this variation in the specific ability was greater than in the general ability, which indicates the dominance of the dominance gene action in inheriting this character over the additive gene action and this is consistent with its findings (Raiyani et al., 2015).

Table (14) shows that Doma4 had the highest positive but non-significant value for the effects of the general combining ability, followed by Gehan99 and then Doma2, while the rest had negative and non-significant values for the general combining ability.

Amongst the values of the effects of the specific Combining ability for this character (Table, 15), we note that the hybrid D2×W had the highest significant positive value for these effects (18.59**), which resulted from parents, one positive general Combining ability and the other negative Combining ability (additive × not additive), followed by the hybrid SH12×G99, which carried a significant positive value for the effects of the specific Combining ability (12.16*), resulting from parents, one positive general Combining ability and the other negative Combining ability (additive × Not additive), and six other hybrids had positive but non-significant values for the specific Combining ability in this capacity ranged between (0.14,9.66), one of which is a product of parents who are both positive General Combining ability (additive × additive), while there were three hybrids resulting from parents, one positive general Combining ability and the other negative Combining ability (additive × not additive) and two hybrids resulting from parents both negative general Combining ability (not additive × not additive).

5.6. Main spike kernels weight/g:

The weight of the spike grains, especially the main spike, is one of the most important components of effective grain yield, which depends on the rate and length of the grain supply period with nutrients that start from fertilization to maturity, and it is also one of the qualities that indicate the productive capacity of the variety. (Kneževic et al., 2015 Protich et al., 2012).

5.6.1. Analysis of variance and means comparison

The results of the analysis of variance (Table 11) showed that there were significant differences in this character amongst the parental lines, where Wafea outperformed with an average of (4.44) g over all lines with significant differences for this character, and some of these differences continued for the resulting generation, as high significant variations appeared in hybrids, where the value of the character in crosses ranged from (1.193) g to (4.143) g with a grand mean of (2.75) g and the hybrid (D4×G99) with an average grain weight of (4.143) g, while the hybrid (W×SH10) with an average weight Cereal (1.193) g is the least for this characteristic.

5.6.2. Heterosis

The results of Table (13) show that six hybrids were given a positive desirable non-significant Heterosis compared to mid parents (MP) whose value ranged from (0.58, 34.37) % of which was the best hybrid (G99×SH12), and the rest of the crosses were negative undesirable highly significant and non-significant, while three positive hybrids were desirable and non-significant for the heterosis compared to the best parents (BP) whose value ranged between (22.95, 16.3) %, the best of which was hybrid (G99×D4), while the rest of the crosses owned the heterosis undesirable, negative highly significant, significant and non-significant. These results were similar to what they indicated (Dahhak et al., 2016).

5.6.3. Combining ability and gen action

Table (12) showed that there was a non-significant variation for both the general and specific combining abilities, but the values of the variance of the specific Combining ability (2.16) were greater than the specific Combining ability (0.81) and these results were contrary to what he found (Al-Sulaiman et al., 2016).

Table (14) also showed that Doma4 gave the highest positive and non-significant value for the effects of general compatibility ability 0.28, followed by Gehan 99 and Wafea, while the effects of general compatibility ability for the rest of were negative.

As for the effects of the specific combining ability, the hybrid D4×G99 gave the highest significant positive value of the effects in this character (0.93**), resulting from parents both positive general Combining ability (additive × additive), followed by hybrids SH12×G99 and D2× who possessed a specific Combining ability positive and significant value (*0.89, *0.87) respectively, and both resulted from parents, one positive general Combining ability and the other negative general Combining ability (additive × not additive , It also possessed five hybrids of positive and non-significant values for the effects of the specific combining ability, ranging from (0.04, 0.67), three of which resulted from parents, one positive and the other negative general Combining ability (additive × not additive), and two resulting from parents both negative general Combining ability (not additive × not additive).

5.7. Thousand kernel weight/g:

The thousand kernel weight is one of the most important technological indicators and an important element of productivity associated with the number and weight of grains in the spike and the number of spikes per unit area. (Dayan, 2016; Saada and Londe, 2016; Sheikhmous, et al., 2013).

5.7.1 Analysis of variance and means comparison

The results of the analysis of variance (Table, 12) showed significant differences amongst parents in the values of this character, which ranged between (39.00) g and (43.66) g and a grand mean of 41.71 g, where the lines Doma4 Doma2 and Gehan 99 gave the highest weight per thousand grains, while the Wafea line was the least in this character, as for hybrids, the variation was not significant amongst them for this character, as their values in hybrids ranged from (42.14) to (48.55) g and a grand mean of (44.06) g (Table, 11), and possessed The hybrids (×W D2) and (D4×SH12) had the highest values for the average weight of 1,000 grains, while the hybrid (G99×SH12) was the lowest.

5.7.2 Heterosis

The hybrids (×W D2) and (D4×SH12) had high desirable positive Heterosis values compared to mid parents (MP) of (17.47**, 10.94**) respectively, and significant in the hybrids (×W D4) and (D4×SH10) reached (9.52*, 8.64*) % respectively, while the rest of the hybrids had a desirable but non-significant positive Heterosis ranging between (0.80,8.01) %, the highest was hybrid W) ×SH12).

As for the heterosis compared to the best parents (BP), the hybrids (×W D2) and (D4×SH12) gave a significant positive Heterosis of (11.21*, 9.43*) % respectively, while nine hybrids with a desirable but non-significant positive Heterosis with values ranging between (0.85, 8.45) % had hybrid virtues (D4×SH10). The rest of the hybrids had an undesirable and non-significant negative Heterosis. This is consistent with the results of (Bilgin et al.,2022).

5.7.3 Combining ability and gen action

It is clear from Table (12) that the variation of the specific Combining ability was high, while the variation of the general Combining ability was non-significant, and this shows the control of the dominance gene action (non-additive) over the additive gene action in inheriting this character, and this is confirmed by the results of (Tayade et al., 2019).

Doma4 and Doma2 had positive but non-significant values of compatibility effects of (0.71, 0.74) respectively, while the rest of had negative and non-significant effects values for the general combining abilityTable (14).

Table (15) indicated that the hybrid D2×W had a significant positive effect value for the specific Combining ability (4.87**), resulting from two parents, one positive and the other negative general Combining ability (additive × not additive), and the hybrid SH12×D4 had a significant positive value for the specific Combining ability (2.63*) and it resulted from two parents, one positive general Combining ability and the other negative general Combining ability (additive × not additive . He also possessed eight hybrids positive and non-significant value of the specific combining ability, five of which resulted from parents both negative generals Combining ability (not additive × not additive) and three resulted from parents, one positive general Combining ability and the other negative general Combining ability (additive × not additive), and the rest of the crosses had a specific Combining ability negative and non-significant.

5-8 Individual Plant Grain Yield/g:

This characteristic is a complex quantitative characteristic resulting from the interaction amongst the components of production on the one hand and the environmental conditions and systems in which they are grown on the other, and also reflects the impact of adverse biological and abiotic stresses to which the plant has been exposed (Saada and Land 2016).

5.8.1 Analysis of variance and comparison of averages

The variation of lines was highly significant for this character table, 12), its values ranged from (12.68) g to (18.98) g with a grand mean of 15.40) (g (Table, 11), and the two lines Doma4 and Wafea outperformed the rest of the lines with significant differences, while Doma2 was the least weight of grain, and there was a high variation of significance in the resulting hybrids, if the values of this character in hybrids ranged from (10.64) g to (23.31) g with a grand mean of (16.69) Table (11), and the hybrids (D2×W) is the highest weight for this character, while the hybrid (SH12×D2) is the least weight.

5.8.2. Heterosis

The desired positive strength values of the high significance of the grain yield characteristic of one plant (Table, 13) appeared among the resulting hybrids, as a result of genetic and environmental distancing amongst parents, the best of which was in the hybrid (D2×W)

(56.62**) % compared to the parents' average (MP) and nine hybrids showed a desirable non-significant positive Heterosis ranging between (5.76, 35.05) %, the best of which was the hybrid (G99 × (D2), while it was negative significant, non-significant and undesirable in the rest of the hybrids. Compared to the best parents (BP), strength was shown Positive desirable hybrid is significant in hybrid(D2×W) (36.45*) % only. This result was consistent with the findings of (Gammaal., 2018 & Yahya), and seven hybrids gave a desirable but non-significant positive Heterosis with values ranging between (1.02 and 31.60) %, the highest in the hybrid (G99×(D2), while the negative heterosis was undesirable, significant and non-significant, in the rest of the hybrids.

5.8.3. Combining ability and gen action.

There was a significant variation of the general and specific abilities (Table 12) and this indicates that both additive and nonadditive gene action of genes contribute to the inheritance of this character, but the values of general variance of ability were greater than the specific combining ability, and this agrees with the results of (Al-Dahhak, 2016) and disagree with what he found (Mahdy et al., 2021). The data of Table (14) showed that parental Doma4 had positive effects on the general ability to adapt and significant in the line (1.85*), and non-significant in Wafea, while the rest of the lines had negative values for the effects of the general ability to compatibility and non-significant, except for Sham12, which was negative and highly significant and therefore will negatively affect the hybrids in which it will enter.

Table (15) showed that the hybrid D2×W was positive and high significant for the effects of the specific Combining ability (6.19**), resulting from two parents, one positive general Combining ability and the other negative general Combining ability (additive × not additive), and ten hybrids possessed positive and non-significant values for the effects of the specific ability to agree, of which only one hybrid resulted from parents both positive general Combining ability (additive × additive , while four hybrids resulted from parents, one of whom is positive The general compatibility is negative, the other is negative general compatibility (additive × not additive), and five hybrids resulting from parents both negative general Combining ability (not additive × not additive). Four hybrids possessed high negative values of significant, significant and non-significant, for the effects of their ability to agree.

6. Conclusions:

The additive gene action dominated the characteristics of number of days to heading, plant height and spike length, while the non-additive gene action dominated the characteristics of main spike kernel number spike, main spike kernel weight and thousand kernel weight, and both additive and non-additive gene actions contributed to inheriting the characteristics of the number of productive tillers and grain yield per plant. Through the results of this research, it was possible to identify a number of parental lines with a highly significant and desirable general Combining ability for the studied characters, which contributes - when hybridized with similar lines - to achieving significant genetic progress in the resulting hybrids, being a guide to the general behavior of a line, like: Doma2 and Doma4 for the characteristics of the number of days to heading, spike length and thousand kernel weight, Doma4 and Wafea in the characteristics of the number of productive tillers, main spike kernel weight and individual plant grain yield, and Sham12 for plant height, while the line Wafea was distinguished in the characteristic of main spike kernel number. Most of hybrids which had desired significant heterosis also possessed a specific combining ability, which is considered to be the first point for working on their segregated generations in the subsequent seasons, namely; hybrid (Sh12×D2) resulting from the genetic interaction (additive × non additive) is the best in the characteristic of the number of days until heading and is recommended to improve this character. Hybrid (D2×W) resulting from genetic interaction (additive × not additive) which is the best in the characteristics of spike length, main spike kernel number spike, main spike kernel weight, grain yield and thousand kernel weight. The hybrid (D4×W) is distinguished for the character of number of productive tillers resulting from the genetic interaction (additive × additive). this interaction is desirable for the plant breeder, and the hybrid (Sh12×W) resulting from the genetic interaction (additive × non additive) characterized by the plant height, and spike length.

7. Recommendations:

set of local parents Doma2 and Doma4 and the introduced Turkish genotype Wafea into breeding programs aiming at improve bread wheat yield, and study the important characters in the segregating generations of the developed hybrids.

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