Analysis of combining Abilities and Gene effects for grain Yield and related traits in Durum wheat, (*Triticum durum* Desf.)

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Abstract

This study included implementation of a half diallel crosses among ten genotypes of durum wheat in 2020-2021. The next growing season 2021-2022, first generation and the parents have been planted at the Agricultural Research Station of Koya/ Erbil by using Randomized complete block design (RCBD) with three replications. The grain yield trait and its components were studied. General combining ability (G.C.A.) and specific combining ability (S.C.A.) and gene effects were estimated. The results revealed that parent (9) had desirable and high G.C.A. effects for all traits except of plant-height, while the cross (8×10) showed desirable S.C.A. effects for all traits. The additive variance (σ^2A) was higher than dominant (σ^2D) for the plant-height and number of grains/ spike. And the dominant variance was higher for the rest traits. High values of heritability in both broad sense ($H^2_{b.s.}$) and narrow sense ($H^2_{n.s.}$) were recorded for plant-height and number of grains/ spike. Average degree of dominance was greater than one for flag-leaf area, number of spikes/plant, 1000 grain weight and grain yield/plant. Whereas, moderate expected genetic advance was found for number of grains/spike and grain yield/plant.

Keywords: half diallel, combining ability, heritability, Durum wheat.

Introduction

Wheat crop is considered as a most important world's cereal crop in term of area planted and its yield. On global basis, in year 2020 the planted area was 219 million hectares which produced about 760.9 million tons. Wheat is a basic food for nearly 33% of the global population and it is the main carbohydrate source in most of the countries providing 20% food calories for the world population (7). In Iraq wheat considered as a main food, as wheat is consumed daily by almost all people. In year 2020 the cultivated area was (2.144) million hectares with the total yield (6.238) million tons (20). Durum wheat production in Iraq is becoming very limited comparing with soft wheat, thus most of the durum wheat products is import from abroad. One of the main reasons for the decline of Durum wheat production in our region is that existed varieties are with low productivity potential. So, conducting studies to developing durum genotypes are required.

One of the best methods of breeding to obtain new genetic combinations is hybridization between local verities and introduced genotypes; the hybrid is produced naturally or artificially by crossing different genotypes (11). Models in F1 generation provide information regarding genetic components effect in different traits inheritance (3).

Improving wheat genetically could started by using one of the most popular methods of crossing which is called Dialle mating to achieve targeted yield potential by developing new varieties with the best genetic makeup. Diallel cross technique is the one most commonly used to estimate inheritance and behavior of quantitative characters, such as the intersection of parents general combined ability G.C.A. and crosses specific combined ability S.C.A, gene action, genetic components and heritability. Griffing method can be used to estimate combining ability (12) as a helpful method for determining parents' potential and their superior cross combinations for future wheat improvement programs (18). Many researchers had been studied estimation of G.C.A. and S.C.A. with genetic components for the quantitative traits of wheat by using F1 generation. The findings of Kumar *et al.*,(15) showed significant G.C.A. mean square and S.C.A. mean square for number of spikes/ plant, number of spikelets/spike, number of grains/ spike, biological yield, harvest index, 1000 grains weight, and grain yield/ plant and Parveen *et al.*, (17) found significant G.C.A. mean square and S.C.A. mean square for plant height, flag leaf area, number of spikes/ plant, number of grains/ spike, number of spikelets/ spike, 1000 grain weight and grain yield/ plant. This means that additive and non-additive gene effects are important for these traits inheritance. Positive with desirable values for G.C.A. and S.C.A. effects were observed by Ayoob (13) for plant-height, number of grains/spike, number of spikes/plant, weight of 1000 grains and grain yield/plant, in addition there was high broad sense heritability for all traits. high narrow sense heritability for plant-height, and moderate for remained traits. It revealed that all traits are controlled by over dominance gene effects except plant-height which controlled by partial dominant gene effect. The research results of Hama-Amin and Towfiq (14) revealed the best effects of parents G.C.A. and crosses S.C.A. for grain yield/plant and some quantitative traits which related to the grain yield trait. Furthermore, inheritance of most of the traits is controlled by dominance gene actions, and there was moderate to high broad sense heritability for most of traits. Whereas the heritability in narrow sense was moderate or low for the traits.

Objectives of this investigation is to estimating the parents G.C.A. and the crosses S.C.A. for yield and its related traits, for half diallel crosses in durum wheat and also to determine the gene effects which control the expression of these traits, and through these genetic components could determine the appropriate breeding method in segregating generations of this crop.

Materials and Methods

Ten genotypes of durum wheat (*Triticum durum* Desf.), received from Erbil research center and ICARDA, (Table 1) lists the genotypes numbers and pedigrees. Ten genotypes were crossed in a half diallel during growing season 2020–2021. In the next planting season 2021–2022, the F1 seeds and their parents were planted using the Randomized Complete Block Design (RCBD) with three replications. Each replicate was included 55 rows, in addition 2 rows as guards, one row for each genotype, 2.0 m long, 30 cm was between row and row and 10 cm between plants, agricultural practices were used. The data were collected from mean of ten plants randomly selected in each row for plant-height, flag-leaf area, number of spikes/plant, 1000-grains weight, number of grains/spike and grain yield/ plant. Mean data of 10 plants of each replicate for all the traits were subjected to analysis of variance and the significant differences among the means were compared according to least significant difference (LSD) test. Estimates of combining ability of G.C.A. and S.C.A. and their effects of the F1 crosses were calculated. Also estimations of variance for G.C.A. and S.C.A., genetic components variance (Additive and dominance) and environmental variance were computed according to Griffing Method 2, fixed model (12).

Table 1. List of the parental wheat genotypes pedigree and their sources

Genotypes	Pedigree	source
1	LD357 (LD308/Nugget)	Erbil A.R.C
2	Cemito (Capeiti 8 / Valnova)	Erbil A.R.C
3	Acsad 65(STORK CM 470-1M-2y-CMXGDAV2 490-AA'SS")	Erbil A.R.C
4	Omrabi5 (Jori c69/Hau)	ICARDA

5	Geromtel1/Icasyr1/5/Sebatel1/4/Gnt/3/Gdfl/ T.dicds20013//Bcr	ICARDA
6	Shaba/5/OmRabi3/T.urartu500651/4/ICAMOR TA0463/3/Bcr/Gro1//Mgnl1	ICARDA
7	Sebatell1/7/Ossl1/Stj5/5/Bidra1/4/BezaizSHF// SD19539/Waha/3/Stj/Mrb3/6/Icajihan1	ICARDA
8	Ouasloukos1/5/Aznn1/4/BEZAIZSHF//SD195 39/Waha/3/Gdr2/6/Tilling/ch113/7/Terbol97 5/Geruftel2	ICARDA
9	Icassyr1/3/Bcr/Sbl5//Turartu/4/EMN096	ICARDA
10	Amedakul1/TdicoJCol//Cham1/3/Younes/Td icoAlpCol//Korifla	ICARDA

Results and Discussion

Variance analysis and genotypes mean performance:

The variance analysis as in (Table 2) showed significant differences between all Parents, crosses, parents & crosses and parents vs crosses, for all studied traits. Values of the mean performance the parents and their F1crosses (Table 3) had revealed that for plant-height parent (8) recorded the highest value 82.49 cm, for flag-leaf area parents (10 and 1) (with 47,61 cm^2 and 46.76 cm^2) were exceeded others. For number of spikes per plant parent (8) recorded (8.53) and was the best. For weight of 1000 grains parents (10, 3 and 2) (53.83 g, 52.66 g and 52.50 g) were found the best. For number of grains per spike patent (1) (93.73 grains) was best the and for grain yield parents (1 and 8) were exceeded (26.61 g, 26.53 g).

Among the F1 crosses, the highest value of plant-height was recorded by the cross combinations (4×8) (87.46 cm) while in cross (4×9), (4×6) and (4×7) produced plants of 86 cm, 85.02 cm and 84.33 cm, respectively. The highest value for traits flag-leaf area and number of spikes/plant were obtained in the cross (4×9) (52.16 cm^2 and 14.30 spikes). For weight of 1000 grain, the crosses (3×8), (3×10) and (3×9) exceeded over other crosses recording (56.66 g), (55.33 g) and (55.00 g) respectively. The best value for number of grains/spike was obtained in crosses (1×5), (5×6) and (1×6) with (104.48 grains), (100.79 grains) and (100.46 grains) respectively. For the grain yield/ plant the crosses (4×9) and (8×9) exceeded over other crosses with recording (45.49) and (42.15) respectively.

Table 2. Variance Analysis of (parents), (crosses), (parents & crosses) and (genotypes and parents and for parents against crosses and crosses) for all studied traits.

S.O.V	d.f	M.S (parents)					
		Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
Replicates	2	31.36	111.73	4.85	16.35	33.11	44.77
Parents	9	**60.43****	**41.21***	**3.65****	**41.46****	**169.62****	**38.25****
Error	18	15.05	14.24	0.88	4.58	16.06	11.35

S.O.V	d.f	M.S (crosses)					
		Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
Replicates	2	23.53	94.29	11.61	2.31	10.06	53.35
Crosses	44	**109.70****	**52.03****	**7.44***	**38.25****	**198.62****	**118.94****
Error	88	17.69	30.28	4.57	3.36	36.20	65.01

S.O.V	d.f	M.S(parents & crosses)					
		Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
Replicates	2	45.88	122.51	7.06	6.34	17.82	15.49
Parents & crosses	54	**99.64****	**49.54****	**7.51****	**39.11****	**202.67****	**120.64****
Error	108	17.09	28.59	4.05	3.72	32.64	56.39

S.O.V	d.f	M.S (Genotypes, Parents, Parents vs crosses and Crosses)					
		Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
Replicates	2	45.88	122.53	7.05	6.35	17.83	15.49
Genotypes	54	**99.65****	**49.55****	**7.52****	**39.11****	**202.67****	**120.65****
Parents	9	**60.44****	**41.23***	**3.66****	**41.47****	**169.61****	**38.26****
Parents *vs* crosses	1	**10.09****	**15.09****	**45.41****	**55.77****	**678.01****	**936.89****
Crosses	44	**109.71****	**52.04****	**7.44****	**38.25****	**198.63****	**118.95****
Error	108	17.09	28.60	4.05	3.73	32.65	56.40

* and ** represent significant differences at probability levels 5% and 1% respectively.

Table 3. Mean values of parents and their F_1 crosses for the some quantitative traits.

Ser.	Parents & crosses	Plant-height/ cm	Flag-leaf area/ cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
1.	1	73.822	46.764	7.881	45.500	93.733	26.613
2.	2	67.560	38.150	4.704	52.500	80.289	15.741
3.	3	73.115	39.583	7.425	52.667	71.067	22.790
4.	4	80.905	36.816	7.100	46.833	78.989	20.779
5.	5	73.167	38.566	6.756	43.833	85.919	20.432
6.	6	77.821	38.573	6.961	43.333	88.945	21.567
7.	7	77.800	38.324	5.743	48.833	77.241	16.792
8.	8	82.492	39.173	8.536	46.833	79.163	26.531
9.	9	72.310	40.339	6.533	48.500	78.869	20.398

10.	10	77.894	47.617	7.751	53.833	69.236	23.357
11.	2×1	62.367	40.638	8.454	43.333	82.710	22.780
12.	3×1	75.203	43.886	7.294	51.167	84.548	26.044
13.	4×1	79.333	40.253	7.447	47.000	82.643	21.663
14.	5×1	79.344	45.083	9.481	46.833	104.486	35.545
15.	6×1	73.667	45.667	7.883	44.833	100.467	27.320
16.	7×1	75.111	43.275	6.411	51.167	92.056	25.459
17.	8×1	74.522	43.295	7.456	47.167	85.100	23.921
18.	9×1	72.083	44.614	8.556	50.000	99.222	33.660
19.	10×1	74.643	45.939	8.397	53.333	83.858	30.490
20.	3×2	59.178	35.566	8.592	43.167	69.976	20.035
21.	4×2	76.679	38.915	6.844	50.167	82.545	20.814
22.	5×2	62.667	35.161	7.961	43.833	89.407	21.091
23.	6×2	73.278	36.582	6.286	53.833	88.104	21.944
24.	7×2	69.378	36.871	7.223	46.333	84.856	20.590
25.	8×2	72.033	38.881	7.002	52.333	83.213	23.218
26.	9×2	71.639	45.362	9.313	52.833	87.578	33.034
27.	10×2	59.194	35.923	10.853	42.167	70.044	23.364
28.	4×3	80.167	42.592	8.928	53.000	79.404	29.541
29.	5×3	77.312	42.367	8.997	52.000	89.241	33.998
30.	6×3	79.583	44.678	9.362	50.167	85.081	30.358
31.	7×3	76.533	46.186	8.983	51.500	85.278	28.741
32.	8×3	79.590	41.044	8.554	56.667	82.317	31.185
33.	9×3	74.667	45.746	10.348	55.000	80.481	41.185
34.	10×3	74.444	44.318	7.135	55.333	73.528	23.847
35.	5×4	77.139	40.733	8.657	49.500	86.407	30.617
36.	6×4	85.022	40.075	9.258	43.333	91.893	28.811
37.	7×4	84.333	38.347	7.639	51.333	82.514	26.198
38.	8×4	87.467	41.482	8.439	47.333	82.526	25.261
39.	9×4	86.000	52.163	14.300	45.333	97.833	45.494
40.	10×4	80.250	37.969	7.735	51.000	76.103	23.730
41.	6×5	76.319	42.293	9.208	46.667	100.798	34.246
42.	7×5	73.833	39.751	6.722	52.167	92.933	25.656
43.	8×5	71.500	30.944	6.233	48.667	90.933	22.194
44.	9×5	77.625	45.642	9.676	50.500	96.782	39.287
45.	10×5	76.744	39.583	7.878	52.000	79.607	24.819
46.	7×6	76.810	39.435	7.248	49.333	91.817	25.747
47.	8×6	76.700	36.258	8.451	46.667	86.849	26.516
48.	9×6	76.986	45.510	8.672	50.000	89.667	30.379
49.	10×6	78.164	41.354	7.117	49.667	75.975	22.464
50.	8×7	76.817	44.310	7.843	50.167	84.926	25.752
51.	9×7	74.250	40.314	6.959	51.500	88.037	26.517
52.	10×7	71.911	41.794	7.185	54.333	77.754	22.965
53.	9×8	74.111	39.906	11.978	51.333	86.333	42.154
54.	10×8	75.208	41.554	9.186	52.333	76.423	30.963
55.	10×9	67.333	30.597	5.317	53.500	69.778	15.919
Parents	Grand mean	75.69	40.39	6.94	48.27	80.34	21.50
	L.S.D 0.05	6.65	6.47	1.61	3.67	6.87	5.77
Crosses	Grand mean	75.05	41.17	8.30	49.77	85.60	27.68
	L.S.D 0.05	6.82	8.92	3.47	2.97	9.76	13.08

`Parents & crosses	Grand mean	75.16	41.03	8.05	49.50	84.65	26.55
	L.S.D 0.05	6.69	8.65	3.25	3.12	9.24	12.15

Combining ability

Variance analysis of combining ability (Table 4) revealed the significant general combining ability G.C.A. and specific combining ability S.C.A. mean squares for all traits except the S.C.A. mean square for flag-leaf area which was not significant. This indicating to the important of additive and dominant gene actions for these traits inheritance except of flag-leaf area. The ratio of the variance of G.C.A. to the variance of S.C.A, (gca/sca) was less than one for traits of flag-leaf area (cm^2), number of spikes/ plant, weight of 1000 grain and grain yield/plant as indicating to the predominance role of dominant gene effects while it was higher than one for plant-height and number of grains/spike which indicate to the existence of additive gene actions preponderance in these two traits. There are results in agreement with this study were reported by Kumar *et al*. positive and desirable G.C.A. effects for all traits (Table 5) except for the plant-height while parent (3) had desirable effects for the traits of flag-leaf area, number of spikes/plant, weight of 1000 grain and grain yield/plant. Parent (1) for plant-height, flag-leaf area and number of grains/spike, parent (5) for number of grains/spike with grain yield/plant. Then parent (10) for plant-height and weight of 1000 grain. Parent (2) for trait of plant-height, parent (4) for number of spikes/plant. While parent (6) for number of grains/spike, and parent (7) for weight of 1000 grain. Many researchers have also identified parents with desirable GCA effects on the various studied traits Din *et al*., (8), Ayoob (13) and Sharma *et al*., (19).

Table 4. Variance analysis of general and specific combining ability for 10 ×10 half diallel crosses of Durum wheat according to Method-2, (Griffing, 1956). Fixed model.

S.O.V	Df	Mean squares					
		Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
G.C.A	9	395.24**	89.13**	8.89*	89.91**	857.21**	237.55**
S.C.A	45	40.53**	41.63	7.23**	28.95**	71.75**	97.26**
Error	108	17.09	28.60	4.05	3.72	32.65	56.39
σ^2 G.C.A / σ^2 S.C.A		1.34	0.38	0.12	0.28	1.75	0.36

* and ** represent significant differences at probability levels 5% and 1% respectively.

Table 5. Estimation of G.C.A. effects for the traits of 10 × 10 half-diallel crosses in Durum wheat.

Parents	Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
1	-1.074	2.902	-0.119	-1.556	5.955	0.667
2	-7.106	-2.596	-0.553	-0.958	-2.674	-4.479
3	-0.325	1.183	0.373	2.403	-4.926	1.534
4	5.950	-0.433	0.406	-1.069	-0.937	0.132
5	-0.666	-1.055	-0.020	-1.222	5.945	1.351
6	2.114	-0.196	-0.097	-1.944	4.787	-0.099
7	0.648	-0.368	-0.906	0.917	0.296	-2.575
8	2.177	-1.278	0.303	0.153	-1.179	1.010
9	-0.624	1.598	0.801	1.042	1.863	4.693
10	-1.094	0.243	-0.189	2.236	-9.130	-2.236
S.E($\hat{gi}$)	0.683	0.883	0.332	0.319	0.944	1.240

The values of S.C.A. effects of the crosses presented in (table 6) showed that the cross (8×10) had the desirable and significant SCA effects for all traits, then crosses (1×10), (2×9), (3×5) and (5×9) which showed desirable S.C.A. effects for all traits except plant-height. While crosses (1×5), (3×7), (4×9) and (5×6) had desirable and significant S.C.A. effects for the flag-leaf area, number of spikes/plant, number of grains/spike and the grain yield/plant. Then the crosses (1×9) and (6×7) had desirable S.C.A. for plant-height, weight of 1000 grain, number of grains/spike and grain yield/plant. While the cross (3×9) had a significant desirable (S.C.A.) effect for the flag-leaf area, number of spikes/plant, weight of 1000 grains and grain yield/plant. Then cross (4×5) for the plant-height, flag-leaf area, weight of 1000 grain and grain yield/plant. Followed by the cross (8×9) for plant-height, number of spikes/plant, weight of 1000 grain and grain yield/plant. Then crosses (2×8) and (3×10) for the flag-leaf area, weight of 1000 grains and number of grains/spike. Crosses (5×7) and (7×10) have desirable S.C.A. for plant-height, weight of 1000 grain and for number of grains/spike. Following that, a cross (1×6) for plant-height, flag-leaf area, and number of grain/spike. Then the cross (2×5) for the plant-height, number of spikes/plant and number of grains/spike. Then a cross (2×10) for plant-height, number of spikes/plant and grain yield/plant. Then cross (3×6) for flag-leaf area, number of spikes/plant and grain yield/plant. then cross (3×8) for weight of 1000 grain, number of grains/spike and grain yield/spike. The cross (4×6) for number of spikes/plant, number of grains/spike and grain yield/plant. Then crosses (1×2) and (2×3) for plant-height and number of spikes/plant. crosses (2×4) and (2×6) for weight of 1000 grain and number of grains/spike then crosses (5×8) and (7×9) for plant-height and number of grains/spike. Then cross (2×7) for number of spikes/plant and number of grains/spike. The cross (4×7) for weight of 1000 grain and grain yield/plant. Then a cross (6×9) for flag-leaf area and weight of 1000 grain. Then cross (7×8) for plant-height and flag-leaf area. Crosses (1×3), (1×7), (3×4), (5×10) and (9×10) for weight of 1000 grain. Then the crosses (1×8), (6×8) and (9×10) for plant-height. While, the cross (4×8) for flag-leaf area and finally the cross (4×10) for number of grains/spike. Many researchers also found desirable S.C.A. effects for such these traits such as Hama amin and Tawfiq (14) Askander (5) and Parveen *et al.*, (17)

Table 6. Estimation of S.C.A. effects for studied traits of 10 × 10 half diallel cross in Durum wheat.

Crosses	Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
2×1	-4.617	-0.700	1.074	-3.653	-5.217	0.037
3×1	1.438	-1.231	-1.011	0.819	-1.127	-2.712

4×1	-0.706	-3.248	-0.892	0.125	-7.020	-5.691
5×1	5.920	2.205	1.569	0.111	7.941	6.972
6×1	-2.537	1.929	0.048	-1.167	5.080	0.197
7×1	0.373	-0.291	-0.616	2.306	1.159	0.811
8×1	-1.745	0.638	-0.781	-0.931	-4.321	-4.311
9×1	-1.383	-0.919	-0.178	1.014	6.759	1.744
10×1	1.646	1.762	0.653	3.153	2.388	5.504
3×2	-8.555	-4.053	0.720	-7.778	-7.069	-3.575
4×2	2.672	0.912	-1.061	2.694	1.511	-1.393
5×2	-4.726	-2.219	0.482	-3.486	1.491	-2.336
6×2	3.106	-1.657	-1.116	7.236	1.345	-0.033
7×2	0.672	-1.197	0.630	-3.125	2.588	1.088
8×2	1.798	1.723	-0.801	3.639	2.421	0.132
9×2	4.205	5.328	1.013	3.250	3.744	6.265
10×2	-7.770	-2.756	3.543	-8.611	-2.797	3.524
4×3	-0.622	0.810	0.097	2.167	0.622	1.320
5×3	3.138	1.207	0.592	1.319	3.577	4.558
6×3	2.630	2.659	1.034	0.208	0.575	2.367
7×3	1.046	4.339	1.465	-1.319	5.262	3.226
8×3	2.573	0.106	-0.174	4.611	3.777	2.086
9×3	0.452	1.932	1.122	2.056	-1.101	8.402
10×3	0.699	1.860	-1.101	1.194	2.938	-2.006
5×4	-3.309	1.189	0.220	2.292	-3.245	2.579
6×4	1.795	-0.329	0.897	-3.153	3.398	2.223
7×4	2.572	-1.884	0.087	1.986	-1.490	2.086
8×4	4.176	2.161	-0.323	-1.250	-0.002	-2.436
9×4	5.511	9.965	5.040	-4.139	12.263	14.114
10×4	0.230	-2.873	-0.535	0.333	1.525	-0.721
6×5	-0.293	2.512	1.274	0.333	5.421	6.438
7×5	-1.313	0.143	-0.403	2.972	2.047	0.325

8×5	-5.176	-7.755	-2.102	0.236	1.523	-6.722
9×5	3.751	4.067	0.843	1.181	4.330	6.687
10×5	3.340	-0.636	0.035	1.486	-1.853	-0.851
7×6	-1.116	-1.033	0.199	0.861	2.089	1.866
8×6	-2.755	-3.300	0.192	-1.042	-1.404	-0.950
9×6	0.332	3.076	-0.084	1.403	-1.628	-0.771
10×6	1.980	0.276	-0.650	-0.125	-4.328	-1.756
8×7	-1.172	4.924	0.393	-0.403	1.164	0.762
9×7	-0.937	-1.948	-0.989	0.042	1.233	-2.157
10×7	-2.807	0.888	0.228	1.681	1.942	1.220
9×8	-2.606	-1.447	2.821	0.639	1.005	9.896
10×8	-1.039	1.557	1.020	0.444	2.086	5.634
10×9	-6.113	-12.276	-3.348	0.722	-7.601	-13.093
$S.E.(\hat{S}_{ij})$	0.881	1.140	0.429	0.412	1.218	1.601

Genetic and environmental variation with heritability and expected genetic advance

Table (7) shows that the values of genetic variation: additive (σ^2A), dominance (σ^2D) and environmental variation (σ^2E) were significant for all traits. The (σ^2D) values were greater than the values of (σ^2A) for flag-leaf area, number of spikes/plant, weight of 1000 grain and grain yield/plant as indicate of the dominance gene effect importance for inheritance of these traits, while values of the (σ^2A) were greater than (σ^2D) for plant-height and number of grains/s pike to show the importance of additive gene effect for inheritance of these traits. This result explains the importance of dominant and additive genetic effects for controlling the studied traits which in agreement with those previously reported by El-Gammaal and Morad, (9) and Ayoob (13). The values of (σ^2A) and (σ^2D) which are high and significant indicate the components of genetic variance (σ^2G) had a higher value than the environmental variance (σ^2E) and through which the phenotypic variance value (σ^2P) was calculated. In table (7) also the broad heritability and narrow sense heritability, average degree of dominance with expected genetic advance are presented. The values of Heritability in broad sense ($H^2_{b.s}$) were high for plant-height (0.835), weight of 1000 grain (0.914) and number of grains/spike (0.844) but moderate for flag-leaf area (0.44), number of spikes/plant (0.49) and grain yield/plant (0.55) due to an increase in genetic variance and a decrease in environmental variance. These results are in agreement with results published by some authors (4, 10).The estimated values of heritability in narrow-sense ($H^2_{n.s}$) was high for plant-height (0.609) and for number of grains/spike (0.657) whereas moderate for weight of 1000 grain (0.332) and grain yield/plant (0.237) while it had low values for flag-leaf area (0.195) and number of spikes/plant (0.100) according to measures which defined by Adary (1). These results similar to previous studies as reported by Mousa *et al*., (16) and Ayoob (13). values of average degree of dominance (ā) was more than one for flag-leaf area, number of spikes/plant, weight of 1000 grain and grain yield/plant which indicates to the presence of over dominance for most of multiple genes controlling these traits. While it was less than one for plant-height and number of grains/spike to indicate that these traits are controlled by partial dominance. These results are in corresponded with those previous found Hama Amin and Tawfiq, (14) and Ataei *et al*,. (6). The estimated values of E.G.A (expected genetic advance) were between 0.289 for number of spikes/plant and 9.655 for number of grains/spike, according to measures which defined by Agarwal and Ahmad (2), the %GA (expected genetic advance as a percentage) was moderate for number of grains/spike and grain yield/plant, while it was low for plant-height, flag-leaf area, number of spikes/plant and weight of 1000 grain . These results in similar to those reported by Mousa *et al*., (16) and Waqar-Ul-Haq *et al*., (21).

Table 7. Estimates of additive (σ^2A), dominance (σ^2D), Environment (σ^2E), Genetic (σ^2G), Phenotypic (σ^2P) variance, degree of dominance (ā), broad (H^2b.s.) and narrow (H^2n.s.) sense heritability and expected genetic advance % (GA) for studied traits.

Variations	Plant-height/ cm	Flag-leaf area/cm^2	Number of spikes/ plant	1000-grain weight/g	Number of grains/spike	Grain yield/ plant (g)
Environment (σ^2E)	5.698 2.305±	9.533 3.856±	1.351 0.546±	1.243 0.503±	10.884 4.403±	18.799 7.604±
Additive (σ^2A)	21.008 4.682±	3.363 1.061±	0.269 0.106±	4.788 1.065±	45.809 10.154±	10.065 2.822±
Dominance (σ^2D)	7.813 0.964±	4.346 1.046±	1.063 0.177±	8.407 0.666±	13.035 1.716±	13.622 2.384±
Genetic (σ^2G)	28.822	7.709	1.332	13.195	58.844	23.687
Phenotypic (σ^2P)	34.519	17.242	2.682	14.438	69.728	42.485
($H^2_{n.s.}$) Heritability	0.609	0.195	0.100	0.332	0.657	0.237
($H^2_{b.s.}$) Heritability	0.835	0.447	0.496	0.914	0.844	0.558
degree of dominance $\bar{a}$	0.862	1.608	2.810	1.874	0.754	1.645
expected genetic advance (GA)	6.293	1.425	0.289	2.218	9.655	2.718
expected genetic advance % (GA)	8.373	3.474	3.592	4.480	11.407	10.234

Conclusion

The results of current study showed the highly significant G.C.A. and S.C.A. mean squares for almost all traits, and it was found that additive and dominant genetic effects were important in controlling the inheritance for studied traits. It is possible to use some of the crosses to derive new varieties of wheat and suitable for environmental conditions through the values of the specific combining ability effect.

Broad sense and narrow sense heritability values are high for plant-height and number of grains/spike. High heritability which accompanied with moderate genetic advance as percentage as obtained in the trait number of grains per spike, indicated to that the heritability is due to the additive gene action most likely, and selection might be effective for this trait.

Conflicts of interest

The authors have no conflict of interest.

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