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Article

Effects of general and specific combining ability and interaction between them for double crosses in zucchini squash (*Cucurbita pepo* L.)

Ayman H. Hamdan*, Hussein A. Al-Zubaae
Department of Horticulture and Landscape, College of Agriculture, University of Anbar.
*Correspondence: mailto:mailto:Aymanalali367@gmial.com
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Abstract

This study used six inbred lines of squash (*Cucurbita pepo* L.), which were introduced into a half-diallel crossing program to derive 15 single cross hybrids. According to Rawlings and Cockerham's method of deriving 45 double-cross hybrids, single-cross hybrids were introduced into a double-cross. They included them in various trial experiments and estimations of the general and specific combining ability and gene action of the traits studied. The results showed highly significant differences in the mean square deviations for the double-crosses in all the studied traits. Inbred lines 6, 4 and 1 showed the highest general combining ability with the desired direction on fruit diameter and plant yield, respectively. Also, the double cross hybrids of order S1x2, t(23)(..), t(2.)(6.) showed the highest effect of the specific combining ability to combine on plant yield. Therefore, the effects of the specific combining ability are more important than the effects of the general combining ability in most of the studied traits, including the plant yield, referring to the importance of the dominant genet action and the dominant × dominant in the inheritance of these traits.

Keywords: Genetic, squash, half-diallel, combining ability, single cross, Double-cross, breeding plant, hybrids.

Introduction

Summer zucchini squash (Cucurbita pepo L.) is one of the most important vegetable crops of the Cucurbitaceae family. Squash (zucchini) is rich in niacin and amino acids and contains many minerals that are beneficial to humans. One hundred grams of zucchini contains water, about 94% of its weight, 4.2 gm of carbohydrates, 0.1 g of protein, 0.1 g of fat, 0.1 g of fiber, and is rich in phosphorous and mineral salts. It also contains vitamin C and vitamin A[1]. Summer zucchini squash originated in central and North America, and from there, it spread to all parts of the world[2]. Local varieties suffer from genetic deterioration and low production rates. Therefore, recent studies have focused on developing new hybrids from this crop because of its high nutritional value and wide use in medical fields, especially in seeds and fruits.Despite[3,4] the large number of breeding programs, its production still needs to catch up to the level of ambition due to environmental change, genetic asymmetry between mated parents and genetic mixing caused by open pollination. In addition to the unofficial entry of seeds to farmers, which leads to the transmission of diseases to local varieties, and for this reason, the focus was directed to the development of double cross hybrids and to take advantage of the genetic divergence between inbred lines to produce the best hybrids[5]. Double cross is one of the mating systems through which it is possible to obtain more information about the genetic mechanism that governs various traits. It also[6] provides additional information that includes the interaction components between the variations and effects of the different gene actions of parents and double cross hybrids that control the traits of the crop after knowing the genetic diversity between the parents and the resulting single hybrids after their introduction in a half-diallel cross-breeding program, as the parents of the double crosse hybrids and their inclusion in a comparison trial experiment according to a specific design to know the significant differences[7].

Materials and Methods

Field research was carried out in the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Anbar, in two seasons, fall 2020 and spring 2021. In the fall season of 2021, six inbred lines of zucchini squash obtained from the National Program for the production of inbred hybrids were introduced into the Department of Horticulture in the half-diallel hybridization program to derive single cross hybrids from them. According to scientific recommendations, the experimental field was prepared in three seasons: perpendicular plowing, smoothing, and leveling.

The seeds of inbred lines were sown in the autumn season of 2020 manually, at a rate of 6 lines for each inbred, with a length of 1 m per line. The distance between one line and another was 0.75 m, and between a hole and another was 0.80 m, and at a rate of 3 seeds per hole, it was thinned to one plant at the stage of 4 leaves.

Crosses were carried out between the six inbred lines in one direction, without the reciprocal cross, to derive 15 individual single cross hybrids, according to what was stated[8] The seeds of inbred lines were multiplied by self-pollination. At full physiological maturity, the fruits were harvested separately from the mother plants and for each cross and the inbred lines. The seeds were extracted manually after being dried for planting in the following season. In 2021, the first generation of 15 single cross hybrid were planted to produce the 45 double cross hybrids according to[9]. At full physiological maturity, the fruits were harvested from the mother plants and for each double cross hybrid separately, and their seeds were extracted to be planted in the following season (variety trial experiment).

A comparison experiment (variety trial experiment) between single and double cross hybrids with their parents (inbred lines) was carried out in the autumn of 2021. The genotypes (6 inbred lines, 15 single cross hybrids and 45 double cross hybrids) were sown manually on 15/9/2021 in three greenhouses with an area of 500 m^2 in three replications according to the randomized complete block design (R.C.B.D.). All necessary measurements were taken (plant length (cm), number of internodes, number of female flowers, number of fruit set flowers, fruit set percentage, internode length). The effects of general and specific combining[9] and mentioned by[10] for double-crossing as a genetic method rather than a statistical method, as the mathematical model of this method includes:

Y(ij)(kl)m=u+gi+s2ij+s3ijk+s4ijkl+t(ij)(..)+t(i.)(j.)+t(ij)(k.)+tijkl

Where Y(ij)(kl)m is the mean of the experimental unit, u is the general mean of the trait, gi is the general type I effect of inbred line I, sij is the unique effect of the two inbred lines (i and j), sijk is the unique effect of inbred lines (i, j and k), Sijkl Special effect of inbred lines (i, j, k and l), tij Special effect of inbred lines (i and j) yielding from the particular arrangement (--) (ij), tij.k Special effect of inbred lines (i, j and k) yielding to the particular order (kl)(ij), eijkl the effect of random error associated with the value of the double cross hybrid (kl)(ij). The least squares method was applied to estimate environmental variance (σ^2E), additive variance (σ^2A), dominant variance (σ^2D), and the components of the internal variance (σ^2AA, σ^2AD, σ^2DD and σ^2AAA). Using estimates of genetic components of variance, the genetic components of the variances can be estimated based on the estimation of the genetic components of the variances, which depend on the mean of the squares built in the above table. Whereas the estimation of the genetic components of the variances is done according to the following equations[10] :

$S^2 10=(4/3F)\{6S^2 g-3S^2 02+2S^2 03+(4/3)S^2 t2-2S^2 t3+2K\}$

$S^2 01=(8/F^2)(S^2 t2-4S^2 t3+3K)$

$S^2 20=(32/F^2)\{S^2 02-S^2 t3-(4/9)S^2 t2+S^2 t3-K\}$

$S^2 11=(128/F^3)(S^2 t3-K)$

$S^2 02=(128/F^4)K$

$S^2 30=(256/F^3)(S^2 03-S^2 t3+k)$

Whereas:

F=1, The inbreeding coefficient

$S^2 10$=Additive genetic variance

$S^2 01$=Variance due to dominance deviation

$S^2 20$= Additive X additive component of variance

$S^2 11$= Additive X dominance component of variance

$S^2 02$= Dominance x dominance component of variance

$S^2 30$=Additive x additive x additive component of variance.

Results

The results of the analysis of variance shown in Table 1 showed that there were highly significant differences in the mean squares of deviations for the double cross hybrids in all the studied traits. Therefore, it has been split into the components of the general and specific combining ability, which are 1-line general, 2-line specific, 3-line arrangement, 4-line arrangement, and 5-line arrangement.

S.O.V	**d.f**	**Plant height**	**Fruit diameter**	**Fruit length**	**No. of Female flowers**	**No. of flower set**	**Rate of fruit set %**	**Plant yield**
Replications	2	2	2.16	0.029	0.139	9.36	16.82	36.36
Total	134	134	291.29	0.428	6.889	6.75	6.31	37.18
Hybrids	44	44	883.83	1.301	20.399	18.29	15.81	102.77
1-Line General	88	88	1.59	0.001	0.287	0.92	1.31	4.42
Error	5	5	756.20	1.279	24.700	9.04	17.19	176.09
2-Line Specific	9	9	637.04	2.095	17.964	28.73	20.97	106.02
2-Line Arrangement	9	9	509.15	0.939	17.726	14.37	11.82	82.28
3-Line Arrangement	16	16	1248.60	1.141	24.125	18.76	17.04	83.05

4-Line Arrangement	5	5	962.80	1.061	13.372	14.34	8.36	123.04

Table 1. Analysis of variance for double cross hybrids for the studied traits.

Estimates of the effects of the general combining ability of each inbred line for the traits studied are presented in Table 2. Inbred line 2 gave the highest positive combining effect in plant height with a value of 2.733 and fruit set ratio with a value of 0.767, and inbred line 6 gave the highest positive overall combining effect in fruit diameter with a value of 0.941 and the number of female flowers with a value of 0.211**.**

Trait	**Inbred lines**						**S.E.**
	1	2	3	4	5	6	
Plant height	0.370	2.730	0.830	0.070	-2.500	-1.500	**0.490**
Fruit length	0.550	-0.3481	0.200	-0.253	-0.127	-0.028	**0.100**
Fruit diameter	-0.074	-0.0246	0.050	-0.090	0.100	0.040	**0.010**
No. of female flowers	-0.233	-0.2222	0.080	0.210	-0.0444	0.210	**0.030**
No. of fruit set	-0.122	0.080	0.320	-0.300	-0.278	0.300	**0.060**
Rate of fruit set	0.280	0.770	0.710	-1.478	-0.646	0.370	**0.100**
Plant yield	130.704	9.3630-	34.607-	59.096-	60.519-	32.882	**29.780**

Table 2. Estimates of the effects of general combining ability for each gi of the studied trait.

Trait	**Plant height**	**Fruit diameter**	**Fruit length**	**No. of female**	**No. of fruit set**	**Rate of fruit set**	**Plant yield**
S (1×2)	2.11	0.123-	0.093-	0.100	0.133	0.243	72.930
S (1×3)	0.989-	0.008-	0.247	-0.385	-0.185	0.328	-51.144
S (1×4)	0.833	0.083	0.140-	-0.037	-0.396	1.139	15.082
S (1×5)	2.267-	0.081	0.254	0.200	0.304	0.506	72.044
S (1×6)	0.678	0.108-	0.285	-0.111	0.022	0.338	51.959
S (2×3)	0.078-	0.053	0.059-	0.159	0.115	-0.066	-8.374
S 2×4)	0.367-	0.012-	0.142	-0.104	-0.022	0.157	-15.811
S (2×5)	0.811	0.003-	0.107-	-0.422	-0.229	0.360	-73.111
S (2×6)	0.256	0.06	0.230-	0.044	0.082	0.074	15.007
S (3×4)	0.644	0.066-	0.318-	-0.126	-0.025	0.157	2.989
S (3×5)	1.933	0.034	0.097	0.000	0.063	0.212	4.726
S (3×6)	0.678-	0.033	0.237	0.430	0.356	0.084	17.196
S (4×5)	1.133-	0.081-	0.006	0.404	-0.056	-1.126	-22.044
S (4×6)	0.089	0.014-	0.057	0.074	0.200	0.473	-9.148
S 5×6)	1.844-	0.07	0.3774-	-0.226	-0.359	-0.598	-42.133
S.E.	0.189	0.0053	0.027	0.042	0.031	0.038	7.991

Table 3. Estimates of the effect of specific combining ability on the sij of inbred lines i and j in each double cross hybrid for the traits studied.

Table 4 shows the values of the effects of the specific combining ability of the interaction of two inbred lines of type t(ij)(..) for the traits studied. It is noted that t(14)(..) showed the highest positive value of the effect of the specific combining ability on the height of the plant (8.167), while the hybrid t(46)(..) showed the highest positive effect of specific combining ability on the diameter of the fruit of 0.256. Whereas the hybrid t(34)(..) showed the highest positive effect of a specific combining ability on the length of the fruit, which amounted to 1.591. The hybrid t(56)(..) also gave the highest positive effect of a specific combining ability on the number of female flowers by 1.204. The hybrid t(23)(..) also gave the highest positive effect of a specific combining ability on the number of flowers set, the percentage of fruit set and the plant yield, which amounted to 1.574, 2.238 and 385,425, respectively, and this is consistent with what other researchers have obtained. Table 5 shows the estimates of the effects of the specific combining ability of the order t(i.)(j.) on the studied traits. It is noted that this arrangement t(3.)(4.) showed the highest positive, specific interaction effect of the two inbred lines on plant height, which amounted to 3.222. Also, t(2.)(6.) showed the highest, positive, specific interaction effect of the two inbred lines in the diameter of the fruit by 0.212 and in the plant yield by about 99.694, where the arrangement t(3.)(5.) showed the highest positive specific interaction effect for the two inbred lines in the length of the fruit (0.500). While arrangement t(2.)(5.) showed the highest positive special interference effect for the two strains on the number of female flowers with a value of 0.7778, and arrangement t(1.)(3.) had the highest positive specific interaction effect on the number of flower sets with a value of 0.602, and in the rate of the fruit set (1.843).

Trait	Plant height	Fruit diameter	Fruit length	No. of female flow-	No. of fruit set	Rate of fruit set	Plant yield
T(1.)(2.)	-0.194	-0.068	-0.522	-0.194	-0.167	-0.162	26.954
T(1.)(3.)	2.306	-0.063	-0.335	0.074	0.602	1.843	68.463
T(1.)(4.)	-4.083	0.064	0.369	0.287	0.102	-0.394	25.417
T(1.)(5.)	1.167	0.101	0.129	-0.222	-0.259	-0.269	-68.370
T(1.)(6.)	0.806	-0.034	0.360	0.056	-0.278	-1.019	-52.463
T(2.)(3.)	-2.722	0.029	0.228	-0.593	-0.787	-1.119	-192.713
T(2.)(4.)	2.500	-0.119	0.404	-0.269	0.306	1.662	28.713
T(2.)(5.)	-0.694	-0.053	-0.178	0.778	0.407	-0.584	37.352
T(2.)(6.)	1.111	0.212	0.069	0.278	0.241	0.203	99.694
T(3.)(4.)	3.222	0.089	-0.795	0.093	-0.130	-0.573	45.546
T(3.)(5.)	-2.917	-0.074	0.500	-0.083	0.009	0.146	-13.324
T(3.)(6.)	0.111	0.019	0.403	0.509	0.306	-0.297	92.028
T(4.)(5.)	1.417	0.094	0.202	0.130	-0.083	-0.551	41.963
T(4.)(6.)	-3.056	-0.128	-0.179	-0.241	-0.194	-0.144	-141.639
T(5.)(6.)	1.028	-0.068	-0.653	-0.602	-0.074	1.257	2.380
S.E.	0.580	0.025	0.108	0.097	0.088	0.233	21.306

Table 5. Effects of specific combining ability for interaction two inbred lines t(i.)(j.) for each double cross hybrid for the studied traits.

The effects of the specific combining ability for three inbred lines are presented in Table 6. The cross t(5x6)(2.) showed the highest value of the effect of specific combining ability with the plant height with a value of 8.972. In contrast, the cross t(2x6)(4.) showed the highest value for the effect of the specific combining ability on the fruit diameter (0.511), and on the number of fruit set (1.667), and the plant yield (364.685).

While the cross t(1x2)(3.) showed the highest value of the effect of the specific combining ability on the fruit length (1.7037), and the cross t(2x5)(3.) showed the highest value of the effect of the specific combining ability on the number of female flowers (1.750). The cross t(1x3)(4.) showed the highest value of the effect of specific combining ability on the rate of fruit set (2.382). These results agree with The effects of the specific combining ability for four inbred lines, shown in Table 7. It is noted that the double-crosses (6×3) (2×1) and (5×4) (2×1) and (3×2) (4×1) and (6 x 5) (4 x 1) and (6 x 5) (3 x 2) and (5 x 4) (6 x 3) gave the best upbeat, specific combining ability on plant height that reached to 9.333 for the previous six crosses. Followed by double crosses (3 × 2) (4 × 1) and (6 × 5) (4 × 1) and (6 × 5) (3 × 2), gave the best positive specific combining ability in the fruit diameter (0.373) for the previous three crosses. At the same time, the double-crosses (6 × 2) (4 × 1) and (5 × 3) (4 × 1) and (5 × 3) (6 × 2) gave the best positive specific combining ability on the fruit length (1.4741) for the previous three crosses. Whereas, the effects of the specific combining ability for four strains, the double-crosses (6×3) (2×1), (5×4) (2×1) and (5×4) (6×3) gave the best positive specific combining ability in the number of female flowers reached 1.444 for the previous three crosses. As for the effects of the specific combining ability for four inbred lines, the double-crosses (6 × 2) (5 × 1), (4 × 3) (5 × 1) and (4 × 3) (6 × 2) gave the best positive specific combining ability in the number of the flower's sets reached 1.000 for the previous three crosses. The double crosses (3 × 2) (6 × 1) and (5 × 4) (6 × 1) and (5 × 4) (3 × 2) gave the best specific combining ability in the rate of fruit set (3.199). The double crosses (5 × 2) (4 × 1) and (6 × 3) (4 × 1) and (6 × 3) (5 × 2) gave the best positive specific combining ability effect for the plant yield, which amounted to 226.3148. The double-crosses that gave positive values indicate the possibility of transferring the studied trait from the parents they own to their crosses. Whereas, for the hybrids that gave negative values, this means that the inbred that entered them gave low values in their crosses, and thus, they gave values for the trait below the general average of crosses. These results are consistent with what was obtained. Types of genetic action are presented in Table 8, which consists of epistasis, additive, dominance genetic variance, two-way interaction variances (additive × additive), (dominant × dominant), (dominant × additive), and three-way interaction variances (additive × additive × additive) as it is clear from them that some of them were negative in some of the studied traits and are considered zero. It is clear from the estimates of these variance components that the additive variance was negative in all traits and that the other components had a negative value in some traits and were considered zero. Thus, the appropriate method can be adopted to improve these traits, either deriving hybrid varieties or using the recurrent selection method for specific combining ability. It has been shown that plant height, fruit diameter, the number of female flowers, the rate of fruit set and the plant yield are influenced by the dominant genes. This confirms that the dominant epistasis inherits these traits. Whereas, for gene interaction, the dominant epistasis gene action (additive x additive)is dominant in the characteristics of the fruit diameter, length, number of female flowers and flower sets. At the same time, the epistasis gene action (dominant × dominant) was dominant in the inheritance of all the studied traits.

Trait	**Plant height**	**Fruit diameter**		**Fruit length**	**No. of female flow-**	**No. of fruit set**	**Rate of fruit set**	**Plant yield**
(1x2)(3.)	-4.083	-0.155		1.704	-1.500	-0.704	1.458	-8.954
(1x2)(4.)	-8.139	0.063		0.409	0.259	-0.852	-3.431	0.074

(1x2)(5.)	4.028	-0.018		-1.188	-0.278	-0.259	0.044	21.852
(1x2)(6.)	7.806	-0.028		-1.969	1.130	1.482	1.606	40.935
(1x3)(2.)	0.083	-0.195		-1.546	0.972	1.046	1.151	109.130
(1x3)(4.)	0.583	0.091		-0.266	0.250	0.935	2.382	104.741
(1x3)(5.)	-0.194	0.146		1.142	0.269	-0.102	-1.074	51.065
(1x3)(6.)	4.139	-0.168		0.000	-1.343	-0.676	1.228	-128.009
(1x4)(2.)	8.861	0.119		-0.107	-0.852	-0.046	1.992	-48.759
(1x4)(3.)	0.417	-0.100		0.945	1.444	0.102	-3.358	-51.843
(1x4)(5.)	-5.972	-0.401		-0.327	0.000	0.398	1.246	121.870
(1x4)(6.)	-11.472	0.511		0.226	-0.019	-0.250	-0.668	29.565
(1x5)(2.)	-8.889	0.294		0.954	-0.139	-0.315	-0.794	-265.232
(1x5)(3.)	7.722	0.008		-1.867	-0.065	0.648	2.180	157.787
(1x5)(4.)	4.778	0.182		-0.213	-0.417	-0.574	-0.776	-139.269
(1x5)(6.)	-1.278	-0.282		1.383	0.176	-0.278	-1.147	109.972
(1x6)(2.)	0.139	-0.149		1.222	0.213	-0.519	-2.187	177.907
(1x6)(3.)	-6.361	0.310		-0.447	0.046	-0.648	-2.122	-165.454
(1x6)(4.)	6.861	-0.402		-0.299	-0.380	0.389	2.219	9.037
(1x6)(5.)	0.972	0.172		0.244	0.232	0.222	0.053	-126.417
(2x3)(1.)	4.000	0.350		-0.157	0.528	-0.343	-2.609	-100.176
(2x3)(4.)	7.611	-0.069		0.607	-0.713	-0.639	-0.223	-270.278
(2x3)(5.)	-4.944	-0.198		0.244	-0.361	0.120	1.278	-101.750
(2x3)(6.)	-12.111	-0.024		-0.238	-0.639	-0.713	-0.684	86.778
(2x4)(1.)	-0.722	-0.182		-0.302	0.593	0.898	1.439	48.685
(2x4)(3.)	-8.056	-0.013		-1.110	-0.296	0.306	1.844	15.778
(2x4)(5.)	7.722	0.222		1.298	0.148	0.769	1.945	135.111
(2x4)(6.)	6.056	-0.266		0.921	-0.982	-1.361	-1.904	-142.148
(2x5)(1.)	4.861	-0.276		0.234	0.417	0.574	0.750	243.380
(2x5)(3.)	6.472	0.277		-0.406	1.750	0.370	-3.152	39.778
(2x5)(4.)	-9.861	-0.213		-1.402	-0.824	-0.482	0.454	-123.194
(2x5)(6.)	-2.861	0.105		1.218	0.213	0.352	0.779	-85.259
(2x6)(1.)	-7.944	0.177		0.747	-1.343	-0.963	0.581	-218.843
(2x6)(3.)	8.389	-0.139		-0.416	0.639	0.815	0.969	146.111
(2x6)(4.)	7.889	0.338		-0.018	1.546	1.667	1.538	364.685
(2x6)(5.)	-6.111	0.048		-0.177	-0.287	-1.037	-2.682	-92.565
(3x4)(1.)	-1.000	0.009		-0.680	-1.694	-1.037	0.977	-52.898
(3x4)(2.)	0.444	0.082		0.504	1.009	0.333	-1.621	254.500
(3x4)(5.)	0.389	0.181		-1.822	-0.380	-1.000	-2.181	-225.769
(3x4)(6.)	6.611	-0.095		0.407	1.250	1.444	1.680	115.259
(3x5)(1.)	-7.528	-0.153		0.725	-0.204	-0.546	-1.105	-208.852
(3x5)(2.)	-1.528	-0.078		0.161	-1.389	-0.491	1.874	61.972
(3x5)(4.)	1.972	-0.183		0.686	1.204	1.417	1.449	286.287
(3x5)(6.)	1.250	0.268		-0.572	0.222	-0.361	-1.926	-166.056
(3x6)(1.)	2.222	-0.143		0.447	1.296	1.324	0.894	293.463
(3x6)(2.)	3.722	0.163		0.654	0.000	-0.102	-0.285	-232.889
(3x6)(4.)	-13.389	0.073		-0.232	-0.833	-1.583	-3.035	-166.296
(3x6)(5.)	7.667	-0.055		-0.064	0.556	0.972	1.832	289.778
(4x5)(1.)	1.194	0.219		0.540	0.417	0.176	-0.471	17.398
(4x5)(2.)	2.139	-0.009		0.104	0.676	-0.287	-2.399	-11.917
(4x5)(3.)	-2.361	0.002		1.136	-0.824	-0.417	0.732	-60.519
(4x5)(6.)	1.861	-0.023		-1.376	-0.009	0.361	1.037	138.963
(4x6)(1.)	4.611	-0.110		0.073	0.398	-0.139	-1.551	-38.602
(4x6)(2.)	-13.944	-0.072		-0.904	-0.565	-0.306	0.366	-222.537
(4x6)(3.)	6.778	0.023		-0.176	-0.417	0.139	1.356	51.037

(4x6)(5.)	-3.556	-0.096		0.649	0.102	-0.083	-0.459	-73.176
(5x6)(1.)	0.306	0.110		-1.628	-0.407	0.056	1.094	16.444
(5x6)(2.)	8.972	-0.153		-1.041	0.074	0.685	1.903	177.824
(5x6)(3.)	-8.917	-0.213		0.636	-0.778	-0.611	0.094	-123.722
(5x6)(4.)	1.694	0.119		0.727	-0.093	-0.278	-0.577	-65.787
S.E.	0.807	0.025		0.114	0.100	0.095	0.213	19.727

Table 6. Estimates of the effects of the specific combining ability of the three inbred lines of t(ij)(k.) for each hybrid for the traits studied.

Trait	Plant height	Fruit diameter	Fruit length	No. of female flowers	No. of fruit set	Rate of fruit set	Plant yield
(1x2)(3x4)	-11.500	-0.297	0.196	-1.111	-0.222	2.044	128.065
(1x2)(3x5)	2.167	0.029	-1.034	-0.333	-0.389	-0.416	1.620
(1x2)(3x6)	9.333	0.268	0.838	1.444	0.611	-1.629	-129.685
(1x2)(4x5)	9.333	0.268	0.838	1.444	0.611	-1.629	-129.685
(1x2)(4x6)	2.167	0.029	-1.034	-0.333	-0.389	-0.416	1.620
(1x2)(5x6)	-11.500	-0.297	0.196	-1.111	-0.222	2.044	128.065
(1x3)(2x4)	2.167	-0.076	0.516	0.167	-0.056	-0.670	31.815
(1x3)(2x5)	3.000	0.171	0.338	0.278	0.889	2.241	46.509
(1x3)(2x6)	-5.167	-0.095	-0.854	-0.444	-0.833	-1.571	-78.324
(1x3)(4x5)	-5.167	-0.095	-0.854	-0.444	-0.833	-1.571	-78.324
(1x3)(4x6)	3.000	0.171	0.338	0.278	0.889	2.241	46.509
(1x3)(5x6)	2.167	-0.076	0.516	0.167	-0.056	-0.670	31.815
(1x4)(2x3)	9.333	0.373	-0.712	0.944	0.278	-1.374	-159.880
(1x4)(2x5)	-8.333	-0.191	-0.762	-1.167	-0.111	2.408	226.315
(1x4)(2x6)	-1.000	-0.182	1.474	0.222	-0.167	-1.033	-66.435
(1x4)(3x5)	-1.000	-0.182	1.474	0.222	-0.167	-1.033	-66.435
(1x4)(3x6)	-8.333	-0.191	-0.762	-1.167	-0.111	2.408	226.315
(1x4)(5x6)	9.333	0.373	-0.712	0.944	0.278	-1.374	-159.880
(1x5)(2x3)	-5.167	-0.201	0.696	0.056	-0.500	-1.825	-48.130
(1x5)(2x4)	-1.000	-0.076	-0.076	-0.278	-0.500	-0.779	-96.630
(1x5)(2x6)	6.167	0.277	-0.620	0.222	1.000	2.604	144.759
(1x5)(3x4)	6.167	0.277	-0.620	0.222	1.000	2.604	144.759
(1x5)(3x6)	-1.000	-0.076	-0.076	-0.278	-0.500	-0.779	-96.630
(1x5)(4x6)	-5.167	-0.201	0.696	0.056	-0.500	-1.825	-48.130

(1x6)(2x3)	-4.167	-0.172	0.016	-1.000	0.222	3.199	208.009
(1x6)(2x4)	-1.167	0.152	-0.440	0.111	0.556	1.449	64.815
(1x6)(2x5)	5.333	0.020	0.424	0.889	-0.778	-4.648	-272.824
(1x6)(3x4)	5.333	0.020	0.424	0.889	-0.778	-4.648	-272.824
(1x6)(3x5)	-1.167	0.152	-0.440	0.111	0.556	1.449	64.815
(1x6)(4x5)	-4.167	-0.172	0.016	-1.000	0.222	3.199	208.009
(2x3)(4x5)	-4.167	-0.172	0.016	-1.000	0.222	3.199	208.009
(2x3)(4x6)	-5.167	-0.201	0.696	0.056	-0.500	-1.825	-48.130
(2x3)(5x6)	9.333	0.373	-0.712	0.944	0.278	-1.374	-159.880
(2x4)(3x5)	-1.167	0.152	-0.440	0.111	0.556	1.449	64.815
(2x4)(3x6)	-1.000	-0.076	-0.076	-0.278	-0.500	-0.779	-96.630
(2x4)(5x6)	2.167	-0.076	0.516	0.167	-0.056	-0.670	31.815
(2x5)(3x4)	5.333	0.020	0.424	0.889	-0.778	-4.648	-272.824
(2x5)(3x6)	-8.333	-0.191	-0.762	-1.167	-0.111	2.408	226.315
(2x5)(4x6)	3.000	0.171	0.338	0.278	0.889	2.241	46.509
(2x6)(3x4)	6.167	0.277	-0.620	0.222	1.000	2.604	144.759
(2x6)(3x5)	-1.000	-0.182	1.474	0.222	-0.167	-1.033	-66.435
(2x6)(4x5)	-5.167	-0.095	-0.854	-0.444	-0.833	-1.571	-78.324
(3x4)(5x6)	-11.500	-0.297	0.196	-1.111	-0.222	2.044	128.065
(3x5)(4x6)	2.167	0.029	-1.034	-0.333	-0.389	-0.416	1.620
(3x6)(4x5)	9.333	0.268	0.838	1.444	0.611	-1.629	-129.685
S.E.	0.900	0.030	0.106	0.110	0.084	0.322	20.532

Table 7. Estimates of the effects of the specific combining ability of the four strains of the order t(ij)(kl) for each double cross hybrid for the traits studied

Traits	**Phenotypic variance**					
	σ^2A	$\sigma^2\Delta$	σ^2AA	$\sigma^2A\Delta$	$\sigma^2\Delta\Delta$	**σ^2AAA**
Plant height	-1155	1854	-978	-16430	20495	**10953**
Fruit diameter	-4.420	3.688	2.320	-21.472	22.605	**14.315**
Fruit length	-38.000	-5.733	50.127	-124.170	277.101	**82.780**
No. of female	-64.750	27.375	56.261	-217.004	279.740	**144.669**
No. of fruit set	-48.842	-20.246	84.266	-17.282	140.858	**11.521**
Rate of fruit set	-150.3	663.5	-436.9	-3067.9	2499.1	**2045.3**
Plant yield	-1202286	825102	817716	-6988853	9971275	**4659236**

Table 8. Types of genetic action of double-crosses in the studied traits.

Discussion

It is noted that there are significant differences for the sources mentioned above, which infer from the presence of the effects of the additive gene, as well as the presence of the dominance effect and the interaction effect of this type. This indicates the importance of all types of superiority effects components (additive, dominant, and the interactions between them), which are (additive x additive, dominant x dominant, additive x additive x additive, dominant x dominant x dominant), all of which were involved in the gene expression of the studied traits. These results agree with [11].

Inbred[12] line 1 gave the highest positive combining effect on the length of the fruit (0.553) and the plant yield with a value of 130.704, and Inbred line 3 gave the highest positive combining effect on the number of flowers set with a value of 0.322. This indicates the large size of its participation in the inheritance of these traits and its increase due to the action of the additive gene, while the inbred lines that gave low positive values or high negative values in these traits mean their little contribution to the inheritance of these traits., These results agree with[3], and accordingly, the best parents can be taken advantage of by entering them into the breeding and improvement program to transfer the trait in zucchini squash plants[13.] Estimates of the effects of the specific combining ability of the two inbred line Sijfor the traits studied are presented in Table 3. It is noted that S1x2 showed the highest values in plant height and plant yield, with 2.11 and 72.93, respectively.S1x4 also showed the highest positive values for the effects of the specific combining ability in the fruit diameter (0.083), and S1x6 showed the highest positive values for the effect of the specific combining ability on the fruit length (0.285). While S3x6 showed the highest positive values for the effects of the specific combining ability in the number of female flowers (0.429) and the number of flowers set (0.356).S1x5 showed the highest positive values for the effects of specific combining ability in the fruit set ratio (0.506). The effects of the specific combining ability did not have anything to do with the values of the effects of the general combining ability, or it may contain one parent who has a high ability to combine. It is unnecessary for the two parents with the general combining ability concerning the specific combining ability for the studied trait[15].

Conclusions

The results showed the epistasis gene action of the type (dominant × dominant) responsible for the inheritance of all the traits studied.

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