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COMBINING ABILITY STUDIES IN WATERMELON (*Citrullus lanatus*).

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ABSTRACT

Five watermelon cultivars and 10 F_1 hybrids as well as the reciprocal crosses F_{1r} were used to study the general and specific combining ability effects (GCA and SCA) for number of morphological, yield and fruit quality traits.

The results showed that:

1. The GCA was significant for all studied traits except branches number and leaves number, the SCA was significant for days to female flower, fruit number, fruit weight, TSS and rind thickness. The other traits were insignificant. The reciprocal was insignificant for stem length, branches number, total yield and fruit number, but was significant for other studied traits.
2. The additive gene effects were the most important in the inheritance of all studied traits.
3. The parental cultivar Giza-1 was the best general combinor for most morphological characters. The parent Giza-21 and Charleston Gray were best general combinor for most yield and fruit characters.
4. The highest desirable SCA effects resulted from the crosses "Giza-1 x Charleston Gray", "Giza-1 x Dulzera" and "Crimson sweet x Dulzera".

INTRODUCTION

I. Vegetative growth:

I.1. Stem length:

Abd El- Raheem *et al.* (1986a) showed that both general and specific combining ability variances were significant for stem length of cantaloupe. They also reported that the effect due to general combining ability was more important than those specific combining ability. Delany and Lower (1987) showed that the stem length of cucumber genotypes under studying were complexly inherited, they concluded that stem length was controlled by large number of genes with no clear major gene segregation. In the same investigation, they reported that the negative estimate of dominance effects indicated that dominance was performed for lower stem length. Awny *et al.* (1992) recorded highest values for both general combining ability and specific combining ability on cucumber.

I.2. Number of branches / plant:

Abd El-Raheem *et al.* (1986a) found over dominance for this trait in cantaloupe. They also found that general combining ability / specific combining ability ratio was 1.05. Linda and Staub (1989) found that the parental lines (WI 2963, 84H2 61) had a highest general combining ability effects for primary lateral branches number on cucumber. El-Mighawry (1998) showed highly significant general and specific combining abilities for number of branches per plant on summer squash. This finding indicated the importance of both additive and non additive gene effects. Abd El-Salam (1998) recorded moderate heritability in narrow sense on watermelon and he found at least 1-2 group of genes controlled this trait.

I.3. Number of leaves / plant:

El-Mighawry (1998) showed highly significant for general and specific combining ability variance of leaves number on summer squash, indicating the important of both additive and non-additive variance in the inheritance of this trait. He also found that the ratio between general and specific combining abilities was 1.013. Awny *et al.* (1992) revealed highly significant for specific combining ability variance for leaves number on cucumber, suggesting the predominant role of non-additive gene action. They also showed over dominance for this trait, and the narrow sense heritability was low.

II. Flowering and yield traits:

II.1. Days to the first male and female flowers:

El-Shawaf (1979) reported that the general combining ability for the male flowering time was significant and it was insignificant for the female flowering time of cucumber. Thomas and Davis (1984) reported highly significant for general combining ability variance for days to first female flower of muskmelon greater than those specific combining ability variance indicating the importance of additive gene effects. Linda and Staub (1989) showed highest general combining ability effects for early male and female flowering for cucumber lines (WI 2712 and 2 HI 853). Awny *et al.* (1992) reported that the days to male and female flowering on cucumber had highly significant for general combining ability. Abd El-Hafez *et al.* (1997) showed highly significant for general and specific combining ability for anthesis of the first female flower on cucumber. On the other hand, the ratio between general and specific combining ability was about 1:1, indicating the importance of both additive and non-additive gene action in the inheritance of this trait.

II.2. Number of fruits / plant:

Singh and Joshi (1980) showed high general combining ability value for fruits number in bitter gourd. Li and Shu (1985) found significant effect general combining ability for fruits number in watermelon. Abd El-Raheem *et al.* (1986b) mentioned that general and specific combining abilities were non-significant for this character in cantaloupe. Sirohi *et al.* (1986) recorded great specific combining ability effect in some pumpkin crosses for this character. El-Mighawry (1998) recorded that general and specific combining abilities showed highly significant for number of fruit / plant in summer squash. Abd El-Hafez *et al.* (1997) showed highly significant effects for general and specific combining ability in fruits number of cucumber. They also found that the ratio between general and specific combining ability was 2:3 for this trait.

II.3. Yield / plant:

El-Shawaf and Bater (1981) revealed that general combining ability was more important than specific combining ability for total yield of pickling cucumber. Abd El-Raheem *et al.* (1986a) showed that the general and specific combining abilities were significant for this character in cantaloupe. The analysis of variance for general and specific combining ability were highly significant in summer squash and muskmelon by El-Meghawry (1991) and Awny (1992), respectively. Arora *et al.* (1996) found significant general and specific combining ability for yield / plant in summer squash.

III. Fruit traits:

III.1. Fruit weight:

Abd El-Raheem *et al.* (1986a) found that the mean squares of general and specific combining ability were highly significant on cantaloupes, similar results were obtained by Abd El-Hafez *et al.* (1997) and El-Mighawry (1998) on cucumber and muskmelon, respectively; Kamooh *et al.* (2000) found a inverse result on cucumber.

III.2. Total soluble solids:

om *et al.* (1987) revealed that the general combining ability was more importance for TSS on muskmelon. El-Mighawry (1998) found that the general and specific combining ability both importance in heritance of TSS.

III.3. Rind thickness:

Thomas and Davis (1984) recorded significant of general combining ability on muskmelon. Awny (1992) reported the importance of both general and specific combining ability on muskmelon.

MATERIALS AND METHODS

Five inbred lines of watermelon from the cultivars: Giza-1, Giza-21, Charleston gray, Crimson sweet and Dulzera were used in this study. This study was carried out during the two summer seasons of 1999 and 2000 in the Farm of Faculty of Agriculture, Ismaiellia.

The seeds of the five inbred lines were sown in April, 1999. At the flowering stage, hybridization in a complete diallel crosses mating design among five lines was constructed to produce the F_1 hybrids. The crossing technique was carried out by tying the male and female flowers by cotton filaments in the afternoon and crossing was made from 8-10 am. The pollinated flowers were tied by the cotton and tagged. At mature stage, seeds were removed from the fruits, washed and spread for drying.

In April 2000, the parents and F_1 hybrids were arranged in randomized complete blocks design experiment with three replicates. The experimental unit was 25 rows (10 m long, 3m weadth and 0.5 m between plants). In every block, five rows for parents and 20 rows for F_1 hybrids.

All the agriculture practices were carried out according to the recommendations of the Ministry of Agriculture, Egypt.

Data were recorded on individual plants basis from 10 plants of each parent and F_1 hybrids of the three replicates as follows:-

1. Vegetative growth:

- Stem length - Branches number. - Leaves number.

2. Flowering and yield traits:

- Days to male flowers. - Days to female flowers.
- Number of fruits / plant. - Total yield / plant.

3. Fruit characteristics:

- Fruit weight. - Total soluble solids (TSS) %.
- Rind thickness. - Number of seeds.

Statistical procedures:

The data analysis of variance for combining ability and extension of the various effects were done according to method (1) model (1) of Griffing (1956), as shown in Table (1) to compare combining ability of parents and to identify better combination for characters under study, i.e. general, specific and reciprocal combining ability effects.

Table 1: Expected mean squares for general, specific and reciprocal combining ability.

Source of variance	D.F.	S.S.	M.S.	E (M.S.)
General combining ability g.c.a	P–1	Sg	Mg	$\sigma^2 e + \frac{2(n-1)^2}{n} \sigma^2 s + 2n\sigma^2 g$
Specific combining ability s.c.a	P(p-1) / 2	Ss	Ms	$\sigma^2 e + \frac{2(n^2-n+1)}{n^2} \sigma^2 s$
Reciprocal combining ability r.c.a	P(p-1) / 2	Sr	Mr	$\sigma^2 e + 2\sigma^2 r$
Error	M	Se	Me	$\sigma^2 e$

Where: Mg: Mean square of g.c.a.
Ms: Mean square of s.c.a.
Mr: Mean square of reciprocal.
Me: Mean square of error.
M: Degrees of freedom of error.
P: Number of parents.

RESULTS AND DISCUSSION

1. Vegetative growth:

The analysis of variances (Table 2) showed that the mean squares for general and specific combining ability insignificant for the studied vegetative traits, except stem length which showed significant value for general combining ability. This finding indicated the predominant role for additive variance of that trait. Results of Abd El-Raheem *et al.* (1986a) on cantaloupe and Awny *et al.* (1992) on cucumber were otherwise.

Table 2: Analysis of variance for combininh ability for vegetative traits.

Source of variation	d.f.	Traits M.S.		
		Main stem length	Number of branches per plants	Number of leaves per plant
G.c.a.	4	3751.64*	8.166	2917.166
S.c.a.	10	973.002	7.435	1761.908
R.c.a.	10	1824.575	0.66	13.129
Error	48	1263.504	8.168	1232.081
G.c.a. / S.c.a.		3.855	1.088	1.655

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

Table 3: Estimates of g.c.a. and s.c.a. effects for vegetative traits.

Parents and crosses	Traits		
	Main stem length	Number of branches per plants	Number of leaves per plant
G.c.a.			
1. Giza-1	21.820*	-0.620	28.953*
2. Giza-21	15.270	0.280	-5.163
3. Charleston gray	0.553	1.313	-15,397
4. Crimson sweet	-12.397	0.063	-8.047
5. Dulzera	-25.747*	-1.037	-0.347
S.E. (gi) ±	31.793	2.556	31.395
Crosses S.c.a.			
Giza-1 x Giza-21	-17.370	-0.447	-23.137
Giza-1 x Charleston gray	19.013	3.520*	35.763
Giza-1 x Crimson sweet	15.297	0.937	-8.253
Giza-1 x Dulzera	-24.687	-1.630	11.713
Giza-21 x Charleston gray	-3.603	-0.547	-18.703
Giza-21 x Crimson sweet	-23.987	0.203	-7.470
Giza-21 x Dulzera	35.780	0.637	-16.837
Charleston gray x Crimson sweet	-3.437	1.170	-28.070
Charleston gray x Dulzera	-32.253	-2.230	28.397
Crimson sweet x Dulzera	7.613	1.103	25.880
$S_{ij} + S_{ki}$	55.067	4.428	54.378

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

The estimates of general combining ability effect are presented in Table (3). The results revealed that the most desirable general combining ability was shown by Giza-1 for stem length and number of leaves / plant, in same table. The results also revealed that the all crosses having non-significant values of specific combining ability for vegetative traits under study, except (Giza-1 x Charleston gray) for number of branches / plant.

Estimation of reciprocal combining ability are given in Table (4). The results revealed that the all crosses of vegetative studied traits were unimportance. The crosse (Charleston gray x Giza-1) for stem length and number of branches / plant and (Crimson sweet x Giza-21) for number of branches / plant were significant with negative sign.

Table 4: Estimates of reciprocal combining ability effects for vegetative traits.

Characters / Crosses	Traits		
	Main stem length	Number of branches per plants	Number of leaves per plant
Giza-21 x Giza-1	30.00	2.833	-47.167
Charleston gray x Giza-1	-41.167*	-4.167*	-14.167
Crimson sweet x Giza-1	-61.667	-1.667	24.167
Dulzera x Giza-1	-32.167	-4.000	-33.167
Charleston gray x Giza-21	-4.167	0.667	-17.250
Crimson sweet x Giza-21	-0.833	-4.167*	17.500
Dulzera x Giza-21	-12.750	-1.500	12.500
Crimson sweet x Charleston gray	35.00	-0.500	8.333
Dulzera x Charleston gray	-3.333	0.00	0.833
Dulzera x Crimson sweet	15.250	1.083	30.00
$r_{ij} + r_{ki}$	71.092	5.716	70.202

* Significant at 0.05 level of probability. ** Significant at 0.01 level of probability.

2. Flowering and yield traits:

From Table (5), the results showed that the variances due to general and specific combining ability effects were highly significant for female flowering and number of fruit / plant. Moreover, general combining ability variance for male flowering and total yield / plant were higher in magnitude than those specific combining ability varience, suggesting the predominant role for additive variance of these traits. Similar conclusion was reported bt Thomas and Davis (1984) on muskmelon, Linda and Staub (1989) and Awny *et al.* (1992) on cucumber, El-Meghawry (1998) on muskmelon, and Kamooh *et al.* (2000) on cucumber.

The estimates of combining ability effects showed that Dulzera cultivar gave significant negative general combining ability effect for female flowering. It was earlier than the other parents. Giza-21 and Dulzera also gave significant positive general combining ability effect for number of fruits / plant and total yield / plant, general combining ability effect of Giza-1 was significantly positive only for number of fruits / plant. As for as specific combining ability effect is concerned only one cross, i.e. (Crimson sweet x Dulzera), showed significantly positive effect for number of fruits / plant (Table 6). The cross combinations (Giza-21 x Dulzera) and (Crimson sweet x Dulzera) were found to be significantly late for female flowering. Estimation of reciprocal combining ability effect (Table 7) showed that the crosses (Charleston x Giza-1), (Crimson sweet x Giza-1), (Dulzera x Giza-1), (Crimson sweet x Giza-21), (Crimson sweet x Charleston gray) and (Dulzera x Charleston gray) had negative significant values for male and female flowering, indicating that traits were influenced by reciprocal cross effects. On the contrary, the results of crosses in Table (7) exhibited absence of reciprocal cross effects both number of fruits / plant and total yield / plant traits.

Table 5: Analysis of variance for combininh ability for days to male and female flowering and yield traits.

Source of variation	d.f.	Traits M.S.			
		Days to flowering		Yield	
		Male flowering	Female flowering	Number of fruits	Total yield
G.c.a.	4	2.317**	4.318**	2.829**	27337280**
S.c.a.	10	0.203	1.772**	0.323**	16737470
R.c.a.	10	3.208**	4.312**	0.185	6241773
Error	48	0.499	0.354	0.094	6504624
G.c.a. / S.c.a.		8.187	2.43	8.758	1.633

* Significant at 0.05 level of probability. ** Significant at 0.01 level of probability.

Table 6: Estimates of G.c.a. and S.c.a. effects for days to male and female flowering and yield traits.

Parents and crosses	Traits			
	Days to flowering		Yield	
	Male floweing	Female floweing	Number of fruits	Total yield
G.c.a.				
1. Giza-1	-0.058	0.084	0.266**	-1176.153
2. Giza-21	-0.375	0.245	0.593**	1822.646*
3. Charleston gray	-0.066	-0.143	-0.544**	-0.203.487
4. Crimson sweet	0.819**	0.885**	-0.584**	-1966.519**
5. Dulzera	-0.328	-0.876**	0.269**	1523.513*
S.E. (gi) ±	0.632	0.532	0.274	2281.162
Crosses S.c.a.				
Giza-1 x Giza-21	-0.33	0.430	0.084	-1202.854
Giza-1 x Charleston gray	0.198	-0.043	-0.179	-3804.345*
Giza-1 x Crimson sweet	-0.277	-0.605	-0.306	1156.186
Giza-1 x Dulzera	0.429	0.510	-0.343	2918.645
Giza-21 x Charleston gray	-0.043	-0.550	-0.189	-686.479
Giza-21 x Crimson sweet	0.540	0.180	-0.399	-2.781
Giza-21 x Dulzera	-0.666	1.646**	0.081	257.354
Charleston gray x Crimson sweet	0.038	-0.309	0.154	746.021
Charleston gray x Dulzera	0.227	-0.115	-0.516**	-4373.179**
Crimson sweet x Dulzera	-0.054	1.620**	0.374*	-846.814
$S_{ij} + S_{ki}$	1.094	0.922	0.475	3951.088

* Significant at 0.05 level of probability ** Significant at 0.01 level of probability.

Table 7: Estimates of reciprocal combining ability effects for days to male and female flowering and yield traits.

Parents and crosses	Traits			
	Days to flowering		Yield	
	Male floweing	Female floweing	Number of fruits	Total yield
Giza-21 x Giza-1	0.847	0.863*	0.333	-1008.334
Charleston gray x Giza-1	-0.305	-1.255**	0.267	8.333
Crimson sweet x Giza-1	-1.815**	-1.572**	0.300	414.167
Dulzera x Giza-1	-1.917**	-2.052**	-0.483*	-3341.667
Charleston gray x Giza-21	-0.490	-0.688	0.083	-2158.333
Crimson sweet x Giza-21	-0.338	-1.437**	0.033	291.666
Dulzera x Giza-21	0.625	0.162	0.000	-470.833
Crimson sweet x Charleston gray	-1.817**	-2.440**	0.450*	1608.333
Dulzera x Charleston gray	-1.656**	-1.952**	-0.400	274.500
Dulzera x Crimson sweet	1.216	-0.485	-0.217	-3342.500
$r_{ij} + r_{ki}$	1.413	1.191	0.613	5100.833

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

3. Fruit traits:

The variances due to general and specific combining ability effects were highly significant for all studied fruit traits (Table (8). Moreover, general combining ability variance for most studied traits were higher in magnitude than those specific combining ability variance, suggesting the predominant role for additive variance of these traits, except the number of seeds. Similar conclusion was reported by Awny (1992), Abd El-Hafez *et al.* (1997) and El-Mighawry (1988) on muskmelon, cucumber and muskmelon, respectively. The variance due to reciprocal effects were significant for all studied traits.

Table 8. Analysis of variance for combininh ability for fruit traits.

Source of variation	d.f.	Traits M.S.		
		Fruit weight	TSS	Rind thickness
G.c.a.	4	3.002**	5.925**	0.058**
S.c.a.	10	0.804**	1.444**	0.029**
R.c.a.	10	0.570*	2.006**	0.047**
Error	48	0.202	0.201	0.006
G.c.a. / S.c.a.		3.733	5.179	2

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

The estimates of combining ability effects showed that Charleston gray gave significant positive general combining ability effect for fruit weight and rind thickness (Table 9). Crimson sweet cultivar also gave significant positive general combining ability effect for fruit weight and total soluble solids. General combining ability of Dulzera was significantly positive only for total soluble solids (TSS).

Table 9: Estimates of G.c.a. and S.c.a. effects for fruit traits.

Parents and crosses	Traits		
	Fruit weight	TSS	Rind thickness
G.c.a.			-0.033
1. Giza-1	-0.692**	-0.988**	-0.045*
2. Giza-21	-0.282*	-0.418**	0.155**
3. Charleston gray	0.664**	-0.072	-0.073**
4. Crimson sweet	0.432**	0.495**	0.037
5. Dulzera	-0.123	0.984**	0.068
S.E. (gi) ±	0.402	0.401	
Crosses S.c.a.			
Giza-1 x Giza-21	0.213	-0.752**	-0.005
Giza-1 x Charleston gray	-0.825**	0.343	0.035
Giza-1 x Crimson sweet	0.649*	-0.524*	-0.127**
Giza-1 x Dulzera	0.850**	0.021	0.113*
Giza-21 x Charleston gray	0.048	-0.210	0.055
Giza-21 x Crimson sweet	0.497	0.506*	0.102*
Giza-21 x Dulzera	-0.035	-0.582*	-0.225**
Charleston gray x Crimson sweet	0.435	0.893**	-0.158**
Charleston gray x Dulzera	-0.060	-0.737**	0.032
Crimson sweet x Dulzera	-0.830**	-0.436	0.003
$S_{ij} + S_{kl}$	0.697	0.694	0.118

* Significant at 0.05 level of probability. ** Significant at 0.01 level of probability.

Table 10. Estimates of reciprocal combining ability effects for fruit traits.

Characters / Crosses	Traits		
	Fruit weight	TSS	Rind thickness
Giza-21 x Giza-1	-0.575	-1,675**	-0.200**
Charleston gray x Giza-1	-0.400	1.117**	-0.033
Crimson sweet x Giza-1	-0.442	-0.350	0.017
Dulzera x Giza-1	-0.546	-0.517	0.200**
Charleston gray x Giza-21	-0.667*	0.367	0.125*
Crimson sweet x Giza-21	0.192	-2.183**	-0.233**
Dulzera x Giza-21	-0.071	-0.583	-0.017
Crimson sweet x Charleston gray	-0.567	0.183	0.267**
Dulzera x Charleston gray	0.850*	0.242	-.0.100
Dulzera x Crimson sweet	-0.582	-0.507	-0.050
$r_{ij} + r_{ki}$	0.900	0.896	0.152

* Significant at 0.05 level of probability. ** Significant at 0.01 level of probability.

As for specific combining ability effect is considered only one cross, i.e., Giza-1 x Charleston gray, showed significantly positive effect for number of seeds (Table 9). The cross combination Giza-1 x Crimson sweet further exhibited significantly positive specific combining ability effect for fruit weight. The cross combination (Giza-1 x Dulzera) also showed significant and positive specific combining ability for three important traits, fruit weight, rind thickness and number of seeds. Giza-21 x Crimson sweet and Charleston gray x Crimson sweet, showed significantly positive effect for total soluble solids, Giza-21 x Crimson sweet showed also some effect for rind thickness. The crosses combination Crimson sweet x Dulzera and Giza-21 x Charlestin gray showed significantly positive specific combining ability effect for number of seeds. Both of the fruit weight and total soluble solids were influenced by one reciprocal cross effect (Table 10), rind thickness and number of seeds were also influenced by three reciprocal cross effects.

It is evident from the foregoing results that the crosses showed high specific combining ability effects were not always involving the two parents with good general combining ability effects were obtained from crosses involved one parent with good general combining ability effects. These result indicated that selection program could be executed in order to select and develop superior varieties in the advanced segregating generations from promising F_1 hybrids. However, some of the crosses including parents with high general combining ability did not exhibit high specific good combination in some traits, it may be due to the lack of genetic diversity of the parental varieties of the crosses.

High specific combining ability estimates were also obtained in crosses among parents with low general combining ability, which might be due to the presence of interaction between genes. Furthermore, high specific combining ability estimates were obtained between high x low general combining ability, this might be due to the gene interaction involved in these crosses may be low of unfixable type. These results coincide with the findings of Bhagchandani *et al.* (1980) in summer squash, who reported that the best specific combining ability was sometimes obtained in cross between parents with good and poor or moderate general combining ability.

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دراسات عن القدرة على التآلف فى البطيخ

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إستخدم فى هذا البحث خمسة أصناف من البطيخ تم التهجين فيما بينها والحصول على ١٠ هجن والهجن العكسية لها وذلك طبقا لنظام التهجينات الدائرية ، تم دراسة القدرة العامة والخاصة على التآلف لبعض الصفات الخضرية (طول النبات - عدد الأفرع - عدد الأوراق) والصفات الزهرية والمحصول (عدد الأيام لظهور الأزهار المذكرة والمؤنثة - عدد الثمار - المحصول الكلى) والصفات الثمرية (متوسط وزن الثمرة - نسبة المواد الصلبة الذائبة - سمك القشرة). وتلخصت أهم النتائج فى الآتى:-

١- التأثير المعنوى للقدرة العامة على التآلف فى صفات طول الساق وظهور الأزهار والمحصول الكلى ومتوسط وزن الثمرة وعدد الثمار ونسبة المواد الصلبة الذائبة (TSS) وسمك القشرة وكانت القدرة الخاصة على التآلف معنويه لصفات عدد الأيام للتزهير المذكر والمؤنث وعدد الثمار ووزن الثمرة ونسبة المواد الصلبة الذائبة وسمك القشرة. وأوضحت التهجينات العكسية أن طول الساق ، عدد الأفرع ، المحصول الكلى ، عدد الثمار كانت غير معنوية.

٢- ظهر التأثير الإضافى للجينات فى وراثة كل الصفات المدروسة .

٣- كان الأب المحلى جيزه ١ ذا قدرة عامه على التآلف مع كل الأصناف المستخدمة فى الصفات الخضرية ، بينما الصنف جيزة ٢١ وشارلستون جراى ذا قدرة عامة على التآلف لصفات المحصول والصفات الثمرية.

٤- القدرة الخاصة على التآلف كانت عالية للهجن جيزة ١ × شارلستون جراى ، جيزه ١ × ديلازورا وأخيرا ديلازورا × كرمسون سويت.