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Heterosis and Combining Ability in Some Watermelon (*Citrullus lanatus*)Hybrids.

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ABSTRACT

This study was achieved during the first of March 2021, 2022 and 2023 seasonsin Kaha Farm, Horticultural Research Institute, Agriculture Research Center at the QalyobiyaGovernorate, Egypt. The purpose of this investigate was to estimate hybrid vigor and combining ability of some watermelon hybrids. A total five watermelon inbred lines (genotypes) crossed in a half diallel mating design to obtain 10 cross combinations (F_1 hybrid). All genotypes were prepared at Randomized Complete Block Design with three ereplication. The data showed that significantly differences between the crosses and their parents for traits.The data exhibited that some F_1hybrids recorded highly significant to mid and better parent'sheterosis for traits. The best crosses for most studied characters were P_1 x P_2, P_1 x $P_4$and P_4 x P_5, Thus these promising crosses to improve the yield and quality in watermelon. GCA and SCA influences were significant for plant traits. GCA/SCA ratio were lower than unity for plant length and TSS traits, indicating that dominance types of gene effect were higher importance in the inheritance of traits and seems to be predominant with a possibility of exploiting heterosis to boost the yield. The evaluation of combining abilities revealed that the parents P_1, $P_2$and P_4were identified as the ideal general combiners for generality traits and the F_1hybrids P_1x P_2 and P_1x P_4 were the better specific combinations for total yield and associated traits. Therefore, these F_1 hybrids are promising crosses with high yield and quality which can be recommended for commercial cultivation.

Keywords: Watermelon-Heterosis- General and Specific combining ability.

INTRODUCTION

The genetic improvement of qualitative and quantitative traits is the basic interest of vegetable breeders. Cucurbitaceae family is one of the economically most significant families, supplying edible, nutritious seeds and fruits to humanity, watermelon (*Citrulluslanatus*Thunb.) has major economic importance and grown for ripe juicy fruits that are rich in sugars, it is a source of vitamins, easily digestible calcium, iron salts, some essential amino acids and mineral salts, easy consumption and low caloric content (Bisognin, 2002). Watermelon 2n = 22 chromosome) is an important horticultural crop worldwide. Watermelon is one of the most widespread grown vegetable crops in the world following tomato and onions (Wehner and Lou, 2016).According to FAO (2018) the main watermelon production countries are China (70.3%), Turkey (4.7%), USA (2.2%) and Egypt (1.7%). New watermelon varieties and hybrids allow for a 15- 20% increase in total fruit yield without additional costs (Saediman et al., 2020 andVinhas et al., 2021).

Breeding for new hybrids has so far achieved limited success in Egypt. It is therefore important to develop the productivity of the watermelon per unit area to satisfy the demands of dietary needs through vigorous breeding programs. Decline of excellent watermelon seeds causes the price of watermelon seeds to be very expensive so that it is not profitable for farmers in Egypt. The assembly of hybrid watermelon with favorable traits is an effort to meet the requirements of watermelon seeds in Egypt and reduce the dependence on of watermelon crop seeds imports from abroad. As regards, current requirements of both producers and consumers it is an important component of watermelon breeding programme, especially for yield and fruit quality traits, such as similarity of features, TSS and high fruit yield (Adjoumani et al., 2016). These purposes can be solved by using heterosis, which has been widely used in watermelon crop breeding (Samadia and Haldhar, 2020). Analyzing successes in the breeding of commercial hybrids, it should be noted that it depends on the availability of a wide variety of specific lines, which allows for a faster response to market changes now and also in response to the climate changes that the world is witnessing now. The inbred lines are important component in the production of high yield and quality of cross combinations (Agah et al. ,2021).

Diallel crosses as reported provided early information on the genetic behaviors of parental genotypes and their crosses. Half diallel mating design is one of the various biometrical techniques available for vegetable breeders to achieve the aforementioned data in the crop species (Fasahat et al., 2016).Assessment of general and specific combining ability is the first step in development and evaluation of crosses. General combining ability is closed as the total magnitude of the heterosis in the compounds all cross, which is get in this form. Specific combining ability is defined by the value of heterogeneity in affirmation cross combination and when the parent is crossed with another distinctive form.The estimation of general combining ability, specific combining ability and gene effect were all addressed by the half diallel mating design (Queiroz et al., 2017). Watermelon breeders can take advantage from such data on combining abilities for developing high yielding lines and crosses. Success of any breeding procedure is estimated by a beneficial hybridization disposed in the form of high combining inbred and hybrid vigor in their crosses. The genetic improvement of yield and quality traits is largely depending on the study of GCA of the parents and SCA of the F_1 hybrids. It is a confirmed fact that the dominance is a component of non-additive gene effect and helps in the selection of excellent parents and hybrids to further benefit from heterosis (Naroui et al., 2023). Nascimento et al. (2019)illustrated thatthe behavior of F_1 hybrids assists to estimate general combining ability (GCA) and specific combining ability. GCA is connected with the additive gene effect due to additive by additive. The general combining ability (GCA) of a line due to its behavior with another lines to product offspring with a favorable specification (Sprague and Tatum 1942). (Santos et al. 2017andNascimento et al. 2019) illustrated that prevalence of non-additive (dominance) gene effect for days to first female flower, average fruit weight and total yield traits. The superiority of additive gene effect noticed for average fruit weight and TSS (Alabboud et al. 2020 andKundua et al. ,2021).

Hence, this investigation aimed for breeding new promising local Egyptian F_1hybrids based on Egyptian genetic sources versus mainstream commercial crosses.

MATERIALS AND METHODS

The experiment was planned in Kaha Farm, Horticultural Research Institute, Agriculture Research Center at the Qalyobiya Governorate, Egypt. The genetic materials under this investigate were 5 genotypes of watermelon that were prescribed from a previous breeding program by Noura (2017). These parent’s constant of 4 inbred lines selected for high resistance to Fusarium wilt and Crimson sweet variety. The 5 genotypes were planted on the first of March 2021 and self-pollinated to get enough quantity seeds from every genotype. In the season of 2022, the inbred lines (genotypes) crossed in a half diallel pattern to obtain 10 cross combinations (F_1 hybrid). In the planting season of 2023, all 15 genotypes (five genotypes and their F_1 hybrids) were grown. A randomized complete block design (RCBD) with three replicates was used in the study to examine the combining ability and hybrid vigor of watermelon hybrids. All the 15 genotypes were sown in plots. Each plot was 5 m in length and 2 m width; therefore, the net plot area was 10 m^2, the plants were spaced0.75 m apart. Standard agricultural practices and plant protection procedures were laid out for good healthy watermelon. Insects and diseases were controlled by regular use of insecticides and fungicides.

The following yield and agronomic data were observed on five randomly chosen plants in relation to different traits: plant length (P.L. (cm)), number of branches/plant (No.B./P), days for the anthesis of the first female flowers (D.F.F.F. (days)), rind thickness (R.T. (cm)), total soluble solid (TSS%), average fruit weight (A.F.W. kg), and total yield per plant (T.Y./P.(kg)). Data were collected during the harvest of each replication, omitting the border plants, from five randomly chosen plants and five fruits. Their average was then obtained for statistical analysis of all plant attributes.

Genetic analysis:

The genetic analysis for the data of the 15 genotypes (parents and F_1 hybrid) was made according to Griffing, (1956) fixed model 1 method 2 as follows:

a- Estimating sum of squares:

1- Genteral combining ability sum of squares (ss**GCA).**

$$SS_g = \frac{1}{n+\ 2}\,[\sum_{i=}^{n}(Y_{i.} + Y_{ii})^{2} \ -\ \frac{4}{n}Y^2..]$$

2- Specific combining ability sum of squares (ss**SCA)**

$$SS_s = \ \underset{i\leq j}{\Sigma\Sigma} Y^2{}_{ij} - \frac{1}{n\ +\ 2}\underset{i}{\Sigma}\,(Y_{i.} + Y_{ii})^2 + \frac{2}{(n+1)(n+2)}Y^2..$$

b- Estimating general combining effects (*gi*):**

$$\text{gi} = \frac{1}{n+2}(Y_{i.} + Y_{ii}) - \frac{2}{n}Y^2..$$

c- Estimating specific combining ability effects (*S*ij):

$$S_{ij} \ = \ Y_{ii} - \frac{1}{n+2}(yi. + yii\ +\ \ y.i\ +\ yii) + \frac{2}{(n+1)(n+2)}Y^2..$$

Where:

i = number of rows

j = number of columns

gi = the general combining ability of ith parent.

Sij = the specific combining ability of ith and jth parents.

yi = sum of rows

yii = value of F_1's

y.. = Σ (yi + yii) /2

n = number of parents.

Heterosis over mid-parent (MP) and the best parent (BP) were estimated and expressed as percentages (Mather and Jinks, 1971) as the following:

a. Mid-parent heterosis (MP) = [(F_1-MP)/MP] × 100

b. Better parent heterosis (BP) = [(F_1-BP)/BP] ×100.

RESULTS AND DISCUSSION

Analysis of variance:

The results in **Table (1)** recorded that the mean squares of all genotypes were highly significant for all traits expect number of fruits/plant. The present data reflect that all genotypes were the main component variation in total phenotypic variation and indicating the sufficient genetic variation to be exploited in breeding program. The significant differences among all genotypes are attributed to the various genetic resources utilized this study. In general, half diallel mating pattern can be used for divide genetic variance into its components. The given data are similar with those previously results reported by Choudhary et al. (2012), Adjoumani et al. (2016) and Costa et al. (2019).

Table (1). The analysis of variance and mean sum of square for studied traits of watermelon.

Traits		**Traits**						
Para.	**Df**	**P. L. (cm)**	**No. B./P**	**D.F.F.F. (days)**	**R. T. (cm)**	**T.S. S. %**	**A. F. W. (kg)**	**T.Y. P. (kg)**
Replicates	2	1318.02	1.4	10.29	0.013	0.87	0.94	0.63
Genotypes	14	2365.64^{**}	2.18^{**}	9.41^{*}	0.24^{*}	4.09^{**}	6.26^{**}	32.82^{**}
Error	28	397.5	0.49	2.86	0.09	0.58	0.78	1.02

P.L.= plant length, No. B./P.=number of branches/plant, D.F.F.F.= days to anthesis first female flower, R.T. = rind thickness, TSS%= total soluble solid, A.F.W.= average fruit weight, T.Y./P.= total yield/plant and *, **= significant at 0.05 and 0.01 levels of probabilities.

Mean performances:

Data in **Table (2)** exhibited highly significant differences among parents and their crosses concerning yield and its component in watermelon. Therefore, the findings result illustrated that the differences between the mean performances of the lowest and highest parents were significant indicating the existence of genetic variability among the five used parents for plant traits. These obtained results exhibited differences for plant length in the estimated watermelon genotypes. The plant length of parents varied from 192.33 cm (P_5) to 236.00 cm (P_2) while the F_1hybrids ranged from 215.00 cm P_3 x P_5 to 296.67 cm P_4 x P_5. Between parental lines, P_2 recorded the tallest parent while P_5 was the shortest one. With regard to crosses, P_3 x P_5 had the shortest plants. Also, number of branches, between parents varied from 4.00 (P_2 & P_5) to 5.33 (P_4). Regarding to F_1 hybrids, P_3 x P_4 (6.33) recorded the highest number of branches, while (P_2 x P_5) 4.33 recorded the lowest number of branches. These results are in accordance to Hatem 2009; Choudhary et al. 2012. As for days to anthesis of first female flower trait,the results exhibited that parents widely varied ranging from 51.33 (P_5) to 57.33 (P_4), while the F_1 crosses ranged from 53.67 (P_1x P_2) to 58.00 (P_4x P_5). These results are in agreement with Rabou and El-Sayd (2021).For rind thickness trait, the results exhibited that the parents ranged from 0.67 (P_3 & P_5) to 1.17 cm (P_1), while the F_1hybrids ranged from 0.50 (P_3 x P_5 & P_4 x P_5) to 1.33 cm (P_1 x P_3 & P_2 x P_3). For TSS, the parent ranged from 6.33 (P_4) to 10.33 % (P_2). While, the F_1 hybrid P_1 x P_4 was the highest means in this trait. The results exhibited that, the parents for average fruit weight were varied from 4.02 kg (P_5) to 7.43 kg (P_1). Whereas, the F_1 hybrid P_1 x P_4 (7.26) had the greatest significantly for average fruit weight between all estimated genotypes except P_1 x P_2 which was significantly equal with. With regard to, total yield / plant most important trait for farmers and watermelon breeders.Both $P_4$and P_1 parental genotypes gave the highest magnitude over all estimated genotypes with no significant differences between them. F_1 hybrid (P_1 x P_4) gave the greatest mean magnitude compared to other crosses followed by both hybrids of P_1 x P_2 (earliest cross)andP_3x P_4 (late cross) with no significant differences between them. In contrast, F_1 hybrid P_1 X P_5 recorded the lowest value. These obtained results are in accordance to Saediman et al. (2020).

For ten F_1 hybrids the results showed that there was no single cross superiority versus other cross combinations for all characters. The best F_1 hybrids for most studied characters were (P_1 x P_2), (P_1 x P_4), (P_3 x P_5) and (P_4 x P_5). Thus, these promising crosses can be used for support breeding program to improve the yield and quality in watermelon.Similar results were quoted byWehner and Lou (2016) and Vinhas et al. (2021).

Table (2). The mean performance for the five parental varieties and their F_1 hybrids for studied traits in watermelon.

Traits / Genotypes		P. L. (cm)	No. B./P.	D.F.F.F. (days)	R. T. (cm)	T.S.S. %	A.F.W. (kg)	T.Y.P. (kg)
Parents								
P_1		223.33	4.33	55.33	1.17	7.33	7.43	14.86
P_2		236.00	4.00	55.67	0.93	10.33	5.10	9.69
P_3		225.33	4.33	57.00	0.67	7.33	4.60	11.82
P_4		213.33	5.33	57.33	0.83	6.33	4.93	14.94
P_5		192.33	4.00	51.33	0.67	8.67	4.02	6.15
F_1 hybrids								
P_1 x P_2		243.33	4.67	53.67	1.27	7.33	6.15	17.22
P_1 x P_3		275.00	6.00	56.33	1.33	9.00	5.73	15.47
P_1 x P_4		273.33	6.00	55.33	0.83	10.00	7.26	18.88
P_1 x P_5		258.33	6.00	57.00	0.77	8.00	4.03	10.88
P_2 x P_3		238.33	5.00	54.33	1.33	9.67	4.80	14.88
P_2 x P_4		238.33	6.00	57.00	0.67	8.67	4.40	14.21
P_2 x P_5		273.33	4.33	57.00	1.00	9.33	5.10	11.22
P_3 x P_4		236.67	6.33	57.67	0.87	9.67	5.63	16.50
P_3 x P_5		215.00	4.67	55.33	0.50	8.67	4.17	11.26
P_4 x P_5		296.67	6.00	58.00	0.50	7.67	4.33	15.16
LSD	**5%**	**33.35**	**1.18**	**2.83**	**0.51**	**1.27**	**1.48**	**1.50**
	1%	**44.98**	**1.59**	**3.82**	**0.69**	**1.72**	**1.99**	**2.18**

P.L.= plant length, No. B./P.= number of branches/plant, D.F.F.F.= days to anthesis first female flower, R.T.= rind thickness, TSS%= total soluble solid, A.F.W.= average fruit weight and T.Y./P.= total yield/plant.

Heterosis:-

Heterosis depends on the origin of parental lines included in hybridization. Heterosis breeding purveys a chance for achieving unequaled improvement in quality and traits. The hybrid effects are computed as a deviation of the mid - parents magnitude and better parents. It was showed that a significant negative and positive heterosis for studied traits. None of the crosses in this study reported high heterosis for all studied traits. However, a significant and desirable magnitude of heterosis over mid and better parent was recorded in several F_1hybrids. Therefore, in the breeding programme the superiority of the new cross combinations must be warranted. The estimation of heterosis versus mid parents and better parent for studied traits has been listed in Table 3. The higher significant and positive versus mid parent and better parent heterosis is recorded in F_1hybrid P_4 x P_5 and P_2 x P_5 for plant length**.**Range of the heterosis versus mid parent was 2.95 % for P_3 x P_5 to 46.27 % for P_4 xP_5; in addition, heterosis versus better parent was ranged from - 4.58 for (P_3 x P_5) to 39.07 % for F_1hybrid P_4 x P_5. Whereas, P_1 x P_3 and P_1 x P_5exhibited the best positive heterosis versus mid and better parent for number of branches /plant.Similar results are in agreement with(Esmaeili et al. 2022; Serhiienko et al. 2023).

The negative amount of heterosis for days to anthesis female flower were considered to be desirable, as it demonstrate earliness, where early flowering may be contributed to quick incorporation of commercial hybrids and their accelerated growth and development. In case of watermelon, for earliness traits like days to anthesis female flower heterosis, the negative direction is desirable to catch up with early market. Range of the heterosis versus mid parent was –3.30 for P_1 x P_2 to 6.88 % for P_1x P_5. Also, the results showed that significant desirable negative heterosis versus mid parent was recorded in three crosses P_2 x P_3 (-3.57), P_1 x P_2 (-3.30) and P_1 x P_4 (-1.78). Negative magnitudes of heterosis over better parents obtained by these hybrids indicate their precocity in comparison with their better parents. The negative value of heterosis for this character reported that the F_1 hybrids are early maturing than their parents. The heterosis of hybrids versus better parents reported ranged from -3.00 for P_1 x P_2 to 12.99 % for P_4 x P_5. Significant desirable negative heterosis versus better parent was noticed in P_1 x P_2 (-3.00) and P_2 x P_3 (-2.41).The results are in full accordance to the views conveyed by Abd El-Hadi et al. (2020) and Badr et al. (2021).

As regard to rind thickness, P_4 x P_5 (-33.33 %) recorded high and negative desirable mid parent heterosis which ranged from - 33.33 % to 66.25% for cross P_3 x P_5. Whilst, P_3 x P_5 and P_4 x P_5 (-25.37%) exhibited high and negative heterosis value (desirable) over better parent and varied from to -25.37 to 98.51 % (P_1 x P_3 and P_2 x P_3). P_1 x P_4 showed significant highest positive heterosis versus mid parent for TSS whichranged from -16.99 % (P_1 x P_2) to 46.41 % (P_1 x P_4). Out of ten hybrids, significantly higher positive heterosis was registered in F_1hybrid P_1 x P_4 followed by P_3 x P_4. Also, P_1 x P_4 revealed significantly positive heterosis versus better parents and ranged from -29.04 (P_1 x P_2) to 36.43 % (P_1 x P_4).These results are in accordance to those of (Singh et al. 2020).

Concerning the yield related traits, F_1 hybrids had significantly and positive magnitudes of heterosis versus the mid parents for average fruit weight and ranging from – 29.61 % for P_1 x P_5 to 18.15 % for P_3 x P_4. Significantly higher positive heterosis was registered in F_1hybrid P_3 x P_4 followed by F_1hybrid P_1 x P_4. While, P_3 x P_4 exhibited significant highest positive heterosis versus better parents. Naroui et al. (2023)reported the useful heterosis for fruit weight. Ogbu et al. (2016) and Nascimento et al. (2018) found desirable heterosis values for average fruit weight versus the mid-parents and better parents.

As regard to, total yield / plant there was the useful heterosis magnitudes versus the mid- parents and better (high) parents P_4 x P_5 (43.70 %), P_2x P_5 (41.67%) and P_1 x P_2 (40.29 %). The negative better parent’s heterosis reported in total fruit yield / plant for crosses exhibited that none of the F_1 hybrids had fruits that yielded greater than the best parent. Jalal et al. (2023) found desirable heterosis values for total yield versus the mid parents and better parents (24.67 and 12.90%, respectively). Generally, the values of heterosis over the mid-parents for crosses were higher than their corresponding better parent heterosis evaluates for plant characters.

Table (3). Estimates of heterosis based on mid parents and better parent of yield and its component for F_1 hybrids in watermelon.

Traits Genotypes	Traits													
	P. L. (cm)		**No. B. / P.**		**D. F. F. F. (days)**		**R.T. (cm)**		**TSS %**		**A.F.W. (kg)**		**T.Y./P. (kg)**	
	MP	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**
P_1 x P_2	5.95	3.11	11.99**	7.85**	-3.30**	-3.00*	20.95**	36.56**	-16.99**	-29.04**	-4.13**	-17.23**	40.29**	15.88**
P_1 x P_3	22.59	22.04	38.57**	38.57**	0.28	1.81	44.57**	98.51**	22.78**	22.78**	-4.74**	-22.88**	15.97**	4.10**
P_1 x P_4	25.19*	22.39	24.22**	12.57**	-1.78	0.00	-17.00**	0.00	46.41**	36.43**	17.48**	-2.29**	26.71**	26.37**
P_1 x P_5	24.30*	15.67	44.06**	38.57**	6.88**	11.05**	-16.30**	14.93**	0.00	-7.73**	-29.61**	-45.76**	3.57**	-26.78**
P_2 x P_3	3.32	0.99	20.05**	15.47**	-3.57**	-2.41*	66.25**	98.51**	9.51**	-6.39**	-1.03	-5.88**	38.29**	25.89**
P_2 x P_4	6.08	0.99	28.62**	12.57**	0.88	2.39*	-23.86**	-19.28**	4.08**	-16.07**	-12.26**	-13.73**	15.39**	-4.89**
P_2 x P_5	27.62*	15.82	8.25**	8.25**	6.54**	11.05**	25.00**	49.25**	-1.79**	-9.68**	11.84**	0.00	41.67**	15.79**
P_3 x P_4	7.91	5.03	31.06**	18.76**	0.87	1.18	16.00**	29.85**	41.58**	31.92**	18.15**	14.20**	23.32**	10.44**
P_3 x P_5	2.95	-4.58	12.12**	7.85**	2.14*	7.79**	-25.37**	-25.37**	8.38**	0.00	-3.25**	-9.35**	25.25**	-4.74**
P_4 x P_5	46.27**	39.07*	28.62**	12.57**	6.76**	12.99**	-33.33**	-25.37**	2.27**	-11.53**	-3.24**	-12.17**	43.70**	1.47*

P.L.= plant length, No. B. / P. = number of branches / plant, D.F.F.F. = days to anthesis first female flower, R.T.= rind thickness, TSS%= total soluble solid, A.F.W.= average fruit weight, T.Y. /P.= total yield per plant and *, ** = significant at 0.05 and 0.01 levels of probabilities, respectively.

Analysis of general and specific combining abilities:

Analysis of variance for combining abilities **(Table 4)** divided genetic variation into GCA and SCA.The obtained results in Table 4 reported that highly significant effects of GCA and SCA obtained for most traits suggesting the emergence of additive genetic effects and non-additive genetic effects in the inheritance of traits. Mean squares of general and specific combining ability actions for plant traits were significantly different. The values of GCA variance were greater than SCA variance for all traits expect for plant length and TSS traits, refering that additive gene effect played a major role in the expression of most characters. These data are partially in accordance to those previously published recorded Ferreira et al. (2002). Also, Abd El-Hadi et al. (2020)found that general combining ability effects were greater important than specific combining ability effects for average fruit weight, TSS and days to anthesis first female flower traits, indicating the predominance of additive gene actions was recorded. GCA/SCA ratios were reported to be higher than one for all traits expect for plant length and TSS, revealing that the additive and additive by additive types of gene action were more importance in the inheritance of all traits except both plant length and TSS. Therefore, it could be planned that the existence of great values of additive actions suggests the possibilities for improving number of branches/plant, days to anthesis first female flower, rind thickness,average fruit weight, and total yield/plant by selection in the segregating generations. Also, GCA/SCA ratio were lower than unity for plant length and TSS, indicating that dominance types of gene effect were higher importance in the inheritance of both traits and seems to be predominant with a possibility of exploiting heterosis to boost both traits, so delaying selection would be important to improve the above traits.Costa et al. (2019) reported that the GCA/SCA ratio of plant length, rind thickness and TSS was lower than one.Abd El-Hadi et al. (2020) found that plant length and TSS were mainly governed by dominance gene actions in squash. The present findings are in confidence with of Tiago et al. (2019) and Amandeep et al. (2022).

Information on the percentage increase in cross combination over the mid parent and better parent simply helps identify the better hybrids by allowing one to score them out, but it does not provide insight into the potential causes of hybrid superiority. The general methods of choosing the parents based on per se adaptation and performance, genetic variation does not necessarily lead to beneficial results. This is dramatically because of differential combining abilities of parental lines which depends on the complex interactions between the genes and cannot be controlled by the per se performance alone (Allard, 1960**).** However, to effect ameliorate in polygenic inherited traits such as yield and quality traits, information about the combining abilities of parents and their cross combinations, the evaluates of genetic units of variance and the type of gene effect involved are of great importance to the vegetable breeders. Combining abilities studies estimate the parents based on of their GCA effect and the performance of these genotypes in SCA effects. GCA variance, being connected to additive gene effect, typifies the fixable components of genetic variability and are used to classify the parental lines for the breeding behavior in cross combinations, whereas, SCA actions are connected to non - fixable component of genetic variation Hayman, (1957). These results were in agreement with Amandeep et al. (2022). Kouakou et al. (2019) reported that dominance gene effects were predominant in the inheritance of characters referring to potential of the heterosis utilization to subsequent generations to improving genetically aforementioned traits. Mean squares from the analysis of GCA and SCA showed significant for most traits (Table 5).

Traits Para.	d.f	P. L. (cm)	No. B./P.	D.F.F.F.(days)	R. T.(cm)	TSS %	A. F.W(kg)	T.Y. /P.(kg)
GCA	**4**	156.96^{ns}	1.03^{**}	3.47^{**}	0.15^{**}	1.12^{**}	3.84^{**}	20.49^{**}
SCA	**10**	3123.55^{**}	0.60^{**}	3.01^{**}	0.05^{ns}	1.46^{**}	1.39^{**}	4.39^{**}
Error	**28**	132.50	0.17	0.95	0.03	0.19	0.26	0.34
GCA / SCA		0.05	1.72	1.15	3.00	0.77	2.76	4.67

Table (4). Analysis of combining abilities and the mean squares of F_1 hybrids for traits in watermelon.
P.L.= plant length, No. B./P.= number of branches/plant, D.F.F.F.= days to anthesis first female flower, R.T.= rind thickness, TSS%= total soluble solid, A.F.W.= average fruit weight and T.Y. /P= total yield per plant. **: significant at 0.01 level of probability.

General combining ability effects (*gi*):

The results in **Table (5)** revealed that, parent (P_1) might be the best general combiner for plant length (5.90) and average fruit weight (1.10), suggesting that the parent when recombined subscribed to the development of productive crosses, exhibition potential to use in genetic breeding programmes aiming at the development of genotypes. Parent (P_2) is good combiner for TSS (0.64). Another parent P_4 is the most effectivegeneral combiner for number of branches/plant (0.60), and total yield/plant (1.34). P_5 is the greatest general combiner for days to anthesis first female flower (- 0.76) and rind thickness(- 0.18) which showed negative magnitudes for GCA effects. The results shows their potential usage in breeding program which aims to production hybrids that meet the needs of consumers demand for fruits. The obtained results completely according to Omran et al. (2012), Singh et al. (2017) and Tiago et al. (2019).

Specific combining ability effects (S_{ij})

Among all F_1 hybrids, P_1xP_2had significant and favorable SCA effects for plant length (93.83), days to anthesis first female flower (-1.60) and yield (2.74) whereasP_1x P_4 had significant and desirable SCA effects for plant length

(22.54), days to anthesis first female flower (-1.27), TSS (2.14), average fruit weight (1.76) and total yield / plant (4.74). Also, P_2x P_4 followed by P_3 x P_5 indicated the highest favorable SCA effects for rind thickness. Generally, hybrids P_1xP_4& P_1xP_2 were a best combination for the most traits and included parents that are best general combiners. Therefore, these cross combinations could be elected and used in breeding program to improving the yield and quality in watermelon. The results showed that some of the superior crosses had one of the two parents with desirable GCA effect, suggesting that participation of one best general combiner reveals to be essential to get best specific combination. Nascimento et al. (2019) identified best general combiners and excellent crosses in watermelon, SCA effect refers to dominance, additive by dominance, dominance by dominance and has positive related with heterosis. Naroui et al. (2023) elucidate that the promising F_1 hybrids with significant SCA effects (*Sij*) could be advanced support to the isolate of transgressivesegregants to ameliorate ideal genotypes and utilized in the breeding program to improving studied traits.

Table(5). Estimates of GCA and SCA effects for studied traits for parents and their crosses in watermelon.

Traits Geno.	P. L. (cm)	No. B./P.	D.F.F.F. (days)	R. T. (cm)	TSS %	A. F. W. (kg)	T.Y. / P. (kg)
GCA							
P_1	5.90^{**}	0.08	0.33^{*}	0.17^{**}	-0.32^{**}	1.10^{**}	0.99^{**}
P_2	1.43	-0.40^{**}	-0.28	0.11^{**}	0.64^{**}	0.18^{*}	-0.05
P_3	-5.72^{*}	-0.03	0.33^{*}	0.01	0.07	0.02	0.64^{**}
P_4	2.33	0.60^{**}	1.05^{**}	-0.12^{**}	-0.36^{**}	-0.41^{**}	1.34^{**}
P_5	-3.91^{*}	-0.26^{**}	-0.76^{**}	-0.18^{**}	-0.03	-0.89^{**}	-2.92^{**}
SE(gi)	**3.89**	**0.137**	**0.330**	**0.060**	**0.129**	**0.172**	**0.343**
SE(gi – gj)	**6.15**	**0.217**	**0.522**	**0.094**	**0.204**	**0.273**	**0.542**
SCA							
P_1X P_2	93.83^{**}	-0.14	-1.60^{**}	0.10	$- 1.53^{**}$	- 0.44	2.74^{**}
P_1 x P_3	32.21^{**}	0.81^{**}	0.44	0.26^{**}	0.72^{**}	$- 0.70^{**}$	0.30
P_1 X P_4	22.54^{**}	0.20	-1.27^{**}	- 0.12	2.14^{**}	1.76^{**}	4.74^{**}
P_1 X P_5	13.78^{**}	1.05^{**}	2.21^{**}	- 0.18	- 0.19	$- 1.50^{**}$	-0.73
P_2X P_3	0.02	0.29	-1.61^{**}	0.32^{**}	0.43^{*}	-1.20^{**}	-0.99^{*}
P_2 X P_4	-7.98	0.67^{**}	0.35	$- 0.22^{**}$	- 0.14	$- 0.68^{**}$	-0.62
P_2X P_5	33.25^{**}	-0.14	2.16^{**}	0.17^{*}	0.19	0.50^{*}	0.65
P_3X P_4	-2.50	0.62^{**}	0.40	1.39^{**}	1.43^{**}	0.44	0.98^{*}
P_3X P_5	-17.93^{**}	-0.18	-0.13	$- 0.20^{*}$	0.10	- 0.27	-4.26^{**}
P_4X P_5	55.69^{**}	0.53^{**}	1.83^{**}	- 0.08	$- 0.48^{**}$	0.31	3.20^{**}
SE(sii- sij)	**10.66**	**0.376**	**0.904**	**0.163**	**0.354**	**0.472**	**0.940**
SE(sij- ski)	**13.76**	**0.486**	**1.167**	**0.210**	**0.457**	**0.609**	**1.213**

P.L.= plant length, No. B. / P.= number of branches / plant, D.F.F.F.= days to anthesis first female flower, R.T.= rind thickness, TSS%= total soluble solid, A.F.W.= average fruit weight and T.Y. /P = total yield per plant.

To determine the most significant crossings, it was also necessary to compare the performance of the cross combinations based on mean yield, desired heterotic response, SCA impacts of crosses, and GCA effects of the parents. **Table (6)** and **Fig. (1)**displays the best crosses that have been categorized using these criteria. Parent (P_4), apparent rated above as an excellent general combiner for plant length, number of branches/plant, rind thickness and total yield/plant, produced the first best cross($P_1 \times P_4$). Thus, in genetic advancement, this parent (P_4) may serve as a promising progenitor for the aforementioned qualities. Furthermore, this cross (P_1 x P_4) showed the highest mean yield, highest real heterosis and highest SCA effects for yield and was formed from high x high general combiner parents for yield per plant. Additionally, it demonstrated considerable or extremely significant favorable SCA impacts for four crucial traits: plant length, earliness, TSS%, and average fruit weight. Once more, these findings show that, out of the ten crosses examined in the current study, this cross can be regarded as the optimal combination. The second-best cross, P_1 x P_2, had high mean yield per plant and extremely substantial SCA effects for at least two key contributing features. It was created from parents with high x low general combiner scores. Crosses with high SCA that incorporate both lines which are also strong general combiners might also be used to create new varieties. However, if crosses with high SCA contain only one good combiner, these combinations would eliminate desirable transgressive segregates as long as the good combiner's additive genetic system and the crosses' complementary and epistatic effects work together to minimize undesired plant traits and maximize the desired trait (Habeeb 1998). According to El-Hosary (1987), a hybrid with high SCA effects did not always result from parents with high GCA effects and vice versa.

Table (6). The best crosses chosen for yield on the basis of mean performance, heterosis and SCA along with GCA effects of the involved parents.

Cross	Yield	Heterosis		SCA	GCA		Desirable significant SCA for other traits
		MP	BP		1st parent	2nd parent	
P_1x P_4	18.88	26.7^{**}	26.4^{**}	4.7^{**}	0.99^{**}	1.34^{**}	P.L., D.F.F.F, TSS %, A.F.W. and T.Y./P.
P_1x P_2	17.22	40.3^{**}	15.9^{**}	2.7^{**}	0.99^{**}	-0.05	P.L. and D.F.F.F.

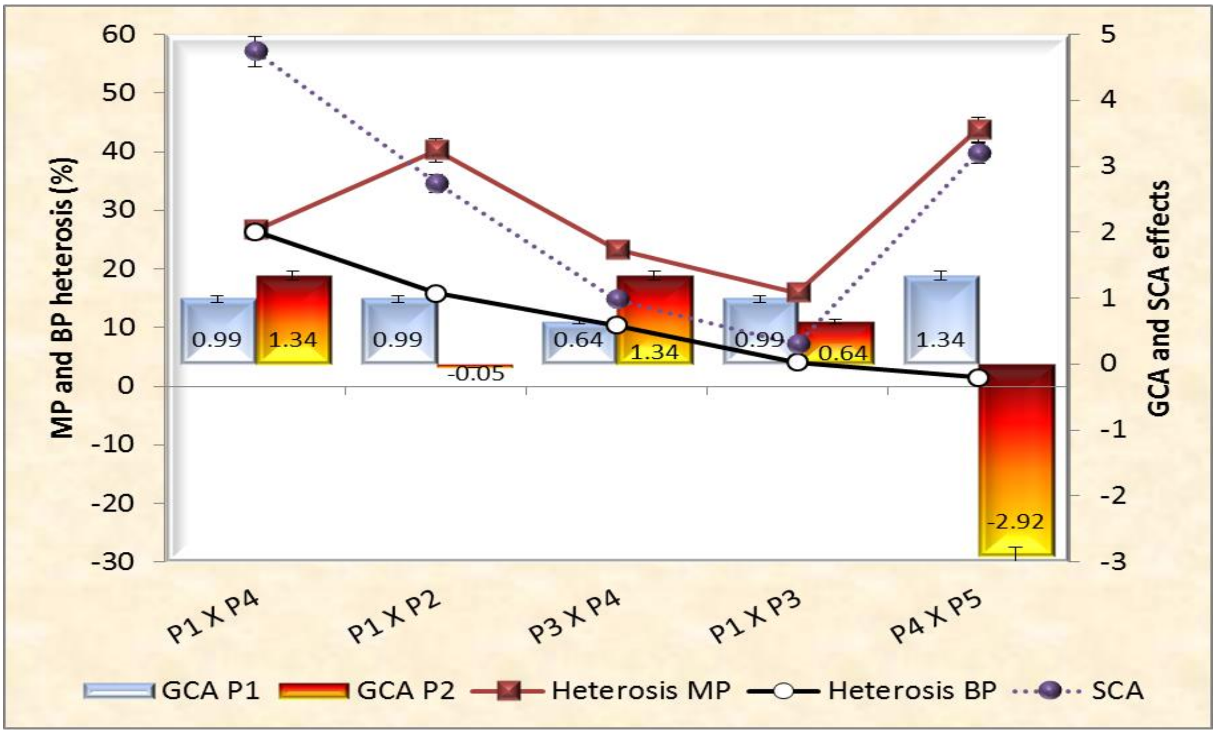

Fig.1: The best crosses chosen for yield on the basis of heterosis and SCA along with GCA effects of the involved parents

Conclusion

The results of heterosis reported that F_1 hybrid (P_1 x P_4) exceeded the performance of mid and better parents and F_1 hybrid (P_1 x P_2) revealed significant mid-parent heterosis for plant length and earliness. The results showed that the importance of additive and dominance gene action which proposes the use of incorporated breeding strategics which can efficiently use the additive next to non-additive genetic variation. GCA estimates showed that none of the parents and cross combinations reveled best combining abilities effects for all studied traits. The assessment of combining abilities illustrated that parents P_1, P_2 and P_4 were identified as the good combiners and the P_1 x P_2 and P_1 x P_4 were the better specific combinations for total yield and associated traits. However, these genotypes could be used as parents in genetic enhancing program directing to development the yield and related traits. Finally, by more selection based on best SCA and heterotic effect in the passing generation and can develop a best hybrids watermelon which will contribute towards the total watermelon production in Egypt and meet the requirements of agronomist and reduce the amount of costs annually spend to purchase the foreign hybrid seeds.

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قوة الهجين والقدرة على التآلف فى بعض هجن البطيخ.

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الملخص العربى

أجريت تجربة حقلية بمزرعة قها - معهد بحوث البساتين – مركز البحوث الزراعية بمحافظة القليوبية - مصر خلال المواسم 2021، 2022، 2023 وقد أستخدمت فى هذة الدراسة خمسة سلالات من البطيخ وقد أجرى التهجين بين هذة السلالات بنظام التهجين النصف دائرى وذلك فى قطاعات كاملة العشوائية فى ثلاث مكررات. وقد أشارت نتائج تحليل التباين للأباء والهجن الي وجود إختلافات عالية المعنوية لجميع الصفات. لا يوجد هجين ذات قيمة عالية لجميع الصفات. كانت أعلي قيم معنويه مرغوبه لقوه الهجين مقارنه بمتوسط الأبوين وأعلى الآباء للهجن(P_4 x P_5وP_1 x P_4وP_1 x P_2) لمعظم الصفات.كما أشارت النتائج الى وجود إختلافات معنوية عالية لكلاً من تباين القدرة العامة والخاصة على التآلف لكل الصفات محل الدراسةمما يؤكد على أهمية الفعل الجينى الإضافى والغير إضافى فى وراثة تلك الصفات. وأن النسبة المحسوبة بين متوسط مربعات الإنحرافات للقدرة العامة والخاصة على التآلف تؤكد أن الفعل الجينى الإضافى كان يلعب دوراً هاماً عن الفعل الجينى الغير إضافى فى وراثة معظم الصفات. وأن القدرة العامة على التآلف كانت أعلي من القدرة الخاصة على التآلفلجميع الصفات ما عدا صفات طول النبات و السكريات الكلية الذائبة. كما أظهرت سلالات الآباء أن الأب الأول والرابع ذو قوة تآلف عامة عالية لمعظم الصفات.كماأشارت تقديرات القدرة الخاصة على التآلف للهجن الناتجة أن أفضل التوليفات لصفة المحصول الكلى والصفات المرتبطة به كان للهجنP_1 x P_2 وP_1 x P_4 حيث أظهرت تأثيرات معنوية عالية لمعظم الصفات المدروسة حيث أن هذة الهجن دخل فى تكوينها أحد الآباء الذى أعطى قيم معنوية عالية فى القدرة العامة على التآلف.

الخلاصة: أنه يمكن إستخدام هذه السلالات كآباء في برامج التحسين الوراثي لصفات المحصول ومكوناتة وذلك عن طريق الإنتخاب فى الأجيال الإنعزالية المتقدمة و التي توجه لتحسين صفات المحصول ومكوناته في البطيخ ويمكن التوصية بها تجارياً.