Horticulture Research Journal, 3(4), 103 :109 - June 2025, ISSN 2974/4474

Heterosis and Combining Ability for Some Promising Inbred Lines of Squash

Amr Ahmed EL- Sayed and Mossad Khairy maamoun

Department of Vegetables, Medicinal and Aromatic Plant Breeding, Horti. Res. Inst., Agric. Res. Cen., Giza, Egypt.

ABSTRACT

The current research was conducted between 2023 and 2025 at the Kaha Vegetable Research Farm, affiliated with the Horticulture Research Institute in the Kaliobia Governorate. This investigation involved six inbred lines of summer squash (*C. pepo* L.). Results showed that the fruit weight of the hybrids ranged from 85.00 g (P1×P2) to 106.00 g (P2×P5), with the hybrid (P2×P5) achieving the highest fruit weight compared to all other evaluated genotypes and the control. Furthermore, the duration until the first female flower appeared significantly differed among the hybrids when compared to the commercial hybrid Yara, with hybrids (P1×P2 and P2×P4) outperforming others by producing the first female flower in fewer days. The parent line P4 recorded the highest total yield among the parental genotypes, while hybrids (P1×P4 and P3×P4) yielded the most. The mid-parent heterosis for all traits examined indicated a highly advantageous heterosis for total yield across all hybrid combinations. The analysis of potence ratio values revealed that most F1 crosses displayed a positive tendency regarding average fruit length, and total yield, indicating a dominance effect towards the superior parent in these characteristics (including partial, complete, and over dominance). Line 1 was recognized as an excellent general combiner, providing significant and positive GCA values for fruit weight and total yield. In contrast, Line 6 excelled as a general combiner for fruit length and total yield.

Key words: *Cucurbita pepo*- Gca- Heterosis- Squash- Potence ratio.

INTRODUCTION

Summer squash (*Cucurbita pepo* L.), characterized by a diploid chromosome number of 40 (2n=40), is a crop that thrives in warm seasons and is classified within the Cucurbitaceae family. The commercial production of squash hybrids has seen significant growth, attributed to the advantageous traits exhibited by hybrids, particularly the phenomenon of heterosis, which enhances vegetative growth, yield, and other essential characteristics López-Anido et al. (2004). In a study conducted by César et al. (2013) a total of 56 hybrids of summer squash were developed through a complete diallel crossing design involving eight distinct varieties. The researchers identified heterosis in total yield, fruit diameter, fruit length, and the emergence of the first female flower. Tamilselvi et al. (2015) assessed heterosis and combining ability related to earliness and yield traits in pumpkin through a line x tester mating design. Abd El-Hadi et al. (2014) demonstrated that heterosis compared to mid-parents showed highly significant values for all traits examined, while the heterosis relative to the better parent also revealed significant magnitudes for the majority of the traits studied. According to Soliman (2018), the heterosis observed over the mid-parental values was significantly negative for the duration until the first female flower blooms. Jasim and Esho (2021) reported that a positive general combining ability (GCA) signifies that these parental lines play a crucial role in enhancing certain traits and contribute to the genetic yield potential in their progeny. This suggests their applicability in crossbreeding initiatives aimed at improving yield efficiency and component enhancement. The high GCA values of these parents indicate their considerable influence in passing on this trait to hybrids, due to the substantial additive genetic effects present. This outcome corroborates earlier findings by El

Sharkawy et al. (2018). Furthermore, Hussein et al. (2013) indicated that the GCA/SCA ratio was greater than one for most traits, underscoring the relevance of additive and additive x additive gene effects. Out of the 15 crosses studied, nine showed significant positive SCA effects on yield and one or more other important traits. In the research conducted by Soliman (2022), six parental genotypes and their fifteen hybrids were assessed in an open field over two consecutive summer seasons. The results revealed significant variations among the genotypes in terms of average performance across all examined traits. Additionally, highly significant differences were noted for both general and specific combining abilities for all traits studied. The primary aims of this study were to evaluate the extent of heterosis for the traits analyzed in a half diallel cross design, to identify favorable parent combinations as genetic resources, and to determine suitable materials for breeding programs aimed at improving hybrid production and quality.

MATERIALS AND METHODS

This research was undertaken from 2023 to 2025 at the Kaha Vegetable Research Farm, which is part of the Horticulture Research Institute located in the Kaliobia Governorate. The investigation centered on six inbred lines of summer squash (*C. pepo*, L.), referred to as Line-98 (P1), Line-65 (P2), Line-77 (P3), Line-101 (P4), Line-99 (P5), and Line-Q15 (P6) these genetic materials were developed by author. These lines were employed as parental lines in a half diallel cross mating design. The six parental lines were planted in an unheated plastic greenhouse, and all possible crosses, without reciprocals. Seeds from 21 genotypes, including 15 F1 hybrids and their 6 parental lines, were sown in seedling trays on February 5th, 2024, and 2025, within an unheated plastic greenhouse. On February 20th of those years, the seedlings were transplanted into the field to assess their performance in a field experiment. The study utilized a randomized complete block design with three replications. Each plot was organized with four rows, spaced 50 cm apart, and measured 4 meters in length and 1 meter in width. All agricultural techniques were executed following the directives of the Ministry of Agriculture, Egypt. Data were gathered from ten individual plants of each parent and F1 hybrid, focusing on metrics such as average days to anthesis of female flowers (DTF), fruit length (FL) in centimeters, average fruit diameter (FD) in centimeters, average fruit weight (AFW) in grams, and total yield per plant (TY) in grams.

Biometrical analyses involved the computation of means and variances for each treatment, with statistical comparisons of the means conducted to identify significant differences, following the methodology outlined by Snedecor and Cochran (1990). The analysis of general and specific combining abilities (GCA and SCA) were calculated according to Griffing (1956) method 2 model 1. The average degree of heterosis (ADH%) was determined as the percentage increase or decrease in F1 performance relative to the mid-parent (MP), in accordance with the approach described by Sinha and Khanna (1975).

RESULTS AND DISCUSSION

Performance of parents and their F_1 hybrids:

The average performance of inbred lines and their 15 F1 hybrids concerning various growth and fruit yield characteristics is summarized in **Table (1).** The findings revealed differences in Fruit Length (FL) among the assessed genotypes. The parental lines exhibited lengths between 12.67 cm (P6) and 14.67 cm (P2), while the hybrids showed a range from 14.00 cm (P3×P6) to 15.50 cm (P2×P5, P4×P6). Among the parental lines, P2 produced the longest fruits, whereas P6 yielded the shortest. In terms of hybrid crosses, the combinations (P2×P5, P4×P6) resulted in the longest fruits, while (P3×P6) produced the shortest plants in comparison to the control. Additionally, the parental lines for fruit weight varied from 70.00 g (P1) to 99.67 g (P2). The hybrids exhibited an average fruit weight that varied between 85.00 g for P1×P2 and 106.00 g for P2×P5. Notably, the P2×P5 hybrid demonstrated a significantly greater average fruit weight compared to all other genotypes assessed, including the control. The fruit diameter among the hybrids showed a narrow range, spanning from 3.00 cm to 3.96 cm, with P2×P6 recording the lowest measurement and P1×P5 the highest. The number of days until the first female flower appears is a crucial parameter for breeders, as it plays a significant role in enhancing the early yield of the hybrids produced. The analysis revealed a notable distinction between all hybrids and the commercial hybrid Yara. Specifically, the hybrid (P1×P2, P2×P4) demonstrated superiority over the other hybrids, producing the first female flower in fewer days compared to the control. Conversely, the hybrid (P3×P6) exhibited the longest duration before the appearance of the first female flower. The total yield trait holds significant importance for both breeders and growers. Among the evaluated parental genotypes, parent P4 exhibited the highest yield, while P5 demonstrated the lowest. Additionally, the hybrids P1×P4 and P3×P4 achieved the greatest yield. These findings are somewhat consistent with the results reported by Soliman (2022) and Hussein (2013).

Table (1). Mean performance of 15 summer squash F_1's and their six parents for fruit length (FL), fruit weight (FW), fruit diameter (FD), number of days till flowering (DTF) and total yield (TY) (combined of 2024/2025).

Genotype	FL **(cm)**	FW **(g)**	FD **(cm)**	DTF	TY **(g/plant)**
(P_1)	14.00	70.00	3.23	37.00	900.00
(P_2)	14.67	99.67	3.33	37.67	866.67
(P_3)	13.50	88.33	3.50	38.67	933.00
(P_4)	13.33	81.00	3.93	38.67	963.33
(P_5)	13.50	82.67	3.27	39.67	800.00
(P_6)	12.67	84.00	3.60	40.33	830.00
P_1×P_2	14.83	85.00	3.16	37.67	1133.33
P_1×P_3	15.39	105.89	3.39	38.33	1233.33
P_1×P_4	14.50	96.11	3.50	39.00	1256.67
P_1×P_5	14.28	93.67	3.96	39.67	1133.33
P_1×P_6	14.50	91.89	3.24	39.67	1116.67
P_2×P_3	14.22	94.67	3.73	40.00	1163.33
P_2×P_4	15.17	86.67	3.67	37.67	1150.00
P_2×P_5	15.50	106.00	3.17	37.89	1100.00
P_2×P_6	14.83	100.00	3.00	38.56	1166.33
P_3×P_4	14.83	96.67	3.73	37.89	1256.67
P_3×P_5	14.83	93.33	3.43	39.56	1083.33
P_3×P_6	14.00	90.00	3.57	40.11	1083.33
P_4×P_5	15.17	91.67	3.83	38.67	1116.67
P_4×P_6	15.50	98.33	3.47	39.00	1066.67
P_5×P_6	14.83	98.33	3.50	39.67	1100.00
Control (yara)	12.83	79.00	3.40	39.67	1063.33
LSD at 0.05%	0.62	8.70	0.57	1.50	153.02

Heterosis over mid-parent (MP-heterosis):

The mid-parent heterosis for all traits examined is summarized in **Table (2).** The findings indicate that all crosses exhibited highly significant heterosis, with the exception of the cross (P2×P3), which did not demonstrate significant heterosis for fruit length. Similarly, the data reveal that all crosses displayed highly favorable heterosis, except for the crosses (P1×P2 and P2×P3), which showed non-significant heterosis for fruit weight. In terms of fruit diameter, the crosses (P1×P3, P2×P4, P3×P4, P3×P5, P3×P6, and P5×P6) exhibited non-significant heterosis, while the crosses (P1×P2, P1×P4, P1×P5, P1×P6, P2×P3, P2×P6, and P4×P5) demonstrated positive or negative heterosis as genetic material is ready according to the breeder's desire. However, both positive and negative heterosis can be valuable for crop improvement, depending on the breeding objectives and ultimate goal of the breeder is to achieve heterosis in the direction that aligns with their desired outcomes. The crosses involving P1×P4, P1×P5, P1×P6, and P2×P3 exhibited significant positive heterosis for the number of days to flowering while both P2xP5 and P3xP4 exhibited significant desirable heterosis for earliness. In terms of total yield, all crosses demonstrated highly favorable heterosis for this characteristic. These findings are somewhat consistent with the results reported by Soliman (2022) and Hussein (2013). The potence ratio values presented in Table 3 indicate that the majority of F1 crosses displayed a positive trend for average fruit length and total yield, suggesting a dominance effect favoring the superior parent in these traits (including partial, complete, and over dominance). Alternatively, the estimated potency ratios for most F1 hybrids were found to be negative in relation to the number of days to flowering which indicated that varying degrees of recessiveness (partial to under-recessiveness) were involved. This outcome is consistent with the research conducted by Hussein (2013).

Table (2). Relative Heterosis values over mid-parents (MP) of 15 F_1 hybrids for some summer squash characters.

Crosses	FL **(cm)**	FW **(g)**	FD **(cm)**	DTF	TY **(g/plant)**
$P_1×P_2$	**3.49***	**0.20**	**-3.89****	**0.89**	**28.30****
$P_1×P_3$	**11.92****	**33.75****	**0.66**	**1.32**	**34.57****
$P_1×P_4$	**6.10****	**27.30****	**-2.33***	**3.08****	**34.88****
$P_1×P_5$	**3.84***	**22.71****	**21.71****	**3.48****	**33.33****
$P_1×P_6$	**8.75****	**19.34****	**-5.04****	**2.59****	**29.09****
$P_2×P_3$	**0.99**	**0.71**	**9.27****	**4.80****	**29.28****
$P_2×P_4$	**8.33****	**-4.06***	**0.92**	**-1.31**	**25.68****
$P_2×P_5$	**10.06****	**16.27****	**-4.04***	**-2.01***	**32.00****
$P_2×P_6$	**8.54****	**8.89****	**-13.46****	**-1.14**	**37.49****
$P_3×P_4$	**10.56****	**14.17****	**0.45**	**-2.01***	**32.54****
$P_3×P_5$	**9.88****	**9.16****	**1.48**	**0.99**	**25.02****
$P_3×P_6$	**7.01****	**4.45***	**0.47**	**1.55***	**22.90****
$P_4×P_5$	**13.04****	**12.02****	**6.48****	**-1.28**	**26.65****
$P_4×P_6$	**19.23****	**19.19****	**-7.96****	**-1.27**	**18.96****
$P_5×P_6$	**13.38****	**18.00****	**1.94**	**-0.83**	**34.97****

NS,*,: insignificant and significant at 0.05and 0.01 % probability levels.**

Table (3). Potence ratio (P) for 15 F_1's for studied traits summer squash characters.

Crosses	FL **(cm)**	FW **(g)**	FD **(cm)**	DTF	TY **(g/plant)**
$P_1×P_2$	1.50	0.01	-2.56	1.00	15.00
$P_1×P_3$	6.56	2.92	0.17	0.60	19.20
$P_1×P_4$	2.50	3.75	-0.24	1.40	10.26
$P_1×P_5$	2.11	2.74	42.33	1.00	5.67
$P_1×P_6$	1.75	2.13	-0.94	0.60	7.19
$P_2×P_3$	0.24	0.12	3.80	3.67	7.94
$P_2×P_4$	1.75	-0.39	0.11	1.00	4.86
$P_2×P_5$	2.43	1.75	-4.00	0.78	8.00
$P_2×P_6$	1.17	1.04	-3.50	0.33	17.35
$P_3×P_4$	-17.00	3.27	0.08	0.04	20.34
$P_3×P_5$	-0.31	2.76	0.43	0.78	3.26
$P_3×P_6$	2.20	1.77	0.33	0.73	3.92
$P_4×P_5$	21.00	11.80	0.70	1.01	2.88
$P_4×P_6$	7.50	10.56	-1.80	0.60	-2.55
$P_5×P_6$	4.20	-22.50	0.40	1.00	19.00

General combining ability (GCA) effects:

It is widely recognized that General Combining Ability (GCA) is influenced by additive gene effects and the additive components of epistatic variance, whereas Specific Combining Ability (SCA) arises from non-additive gene effects and the remaining epistatic variance (Matzinger et al., 1959). The assessment of GCA effects across various lines indicated that certain individual lines demonstrated strong general combining ability across all traits **(Table 4).** Within this study, Line 1 was identified as an effective general combiner for earliness as well as smaller weight and diameter of fruit (according to the plant breeder's point of view), showing significant and negative GCA values for fruit weight, fruit diameter, and number of days, but total yield was positive, although it did not perform well in terms of fruit length. On the other hand, Line 2 also proved to be a competent general combiner, achieving significant and positive GCA values for fruit length but it fell short regarding total yield. Line 3 served as a competent general combiner specifically for total yield. Line 4 was recognized for its general combining ability across total yield traits. Line 5 was effective in combining the traits of total yield. Line 6 demonstrated strong general combining ability for fruit length and total yield traits. These observations are consistent with the research conducted by Hussein and Selim (2014), who assessed the GCA effects of individual parental genotypes in the F'1 generation, finding significant or highly significant results for most traits. Furthermore, Soliman (2022) noted that significant and positive GCA values are beneficial for the majority of the traits studied.

Table (4). Estimates of general combining ability effects of six summer squash inbred lines for some characters.

Crosses	FL **(cm)**	FW **(g)**	FD **(cm)**	DTF	TY **(g/plant)**
(P_1)	**0.06**	**-12.03****	**-0.26****	**-1.29****	**70.92****
(P_2)	**0.95****	**10.14****	**-0.38****	**-1.75****	**-14.21**
(P_3)	**-0.40**	**4.72**	**0.17**	**0.54**	**75.67****
(P_4)	**0.18**	**-4.94**	**0.62****	**-0.83****	**108.42****
(P_5)	**0.10**	**1.39**	**0.01**	**1.13****	**-131.58****
(P_6)	**-0.88****	**0.72**	**-0.16**	**2.21****	**-109.21****
S.E. (ĝi- ĝj)	**0.62**	**6.65**	**0.22**	**0.64**	**68.25**

Specific combining ability effect:

The potential for crossing between specific parents plants was assessed by evaluating the specific combining ability (SCA) effects of each F1 cross combination across all examined traits (see **Table 5**). It was observed that the most favorable combinations, which demonstrated highly positive and significant SCA effects for all traits, originated from the cross (P1×P3). The data indicated that the F1 crosses (P3×P5, P3×P6, and P4×P5) did not yield favorable combinations across all traits. These results align with the findings of Hussein and Selim (2014), who noted that all studied crosses showed significant positive SCA effects for total yield, as well as those reported by Soliman (2022).

Table (5). Estimates of specific combining ability (SCA) effects of 15 F_1hybrids for some summer squash characters

Crosses	FL (cm)	FW (g)	FD (cm)	DTF	TY (g/plant)
$P_1 \times P_2$	0.06	-19.38**	-0.35	-0.43	135.77
$P_1 \times P_3$	3.08**	48.70**	-0.20	-0.73	345.89**
$P_1 \times P_4$	-0.17	29.04**	-0.32	2.65**	383.14**
$P_1 \times P_5$	-0.76	15.37	1.66**	2.69**	253.14
$P_1 \times P_6$	0.89	10.70	-0.31	1.61	180.77
$P_2 \times P_3$	-1.32	-7.13	0.95**	4.73**	221.02
$P_2 \times P_4$	0.93	-21.46**	0.30	-0.89	148.27
$P_2 \times P_5$	2.01**	30.20**	-0.59	-2.18**	238.27
$P_2 \times P_6$	0.99	12.87	-0.92**	-1.27	414.89**
$P_3 \times P_4$	1.29	13.95	-0.05	-2.52**	378.39**
$P_3 \times P_5$	1.37	-2.38	-0.34	0.52	98.39
$P_3 \times P_6$	-0.15	-11.71	0.23	1.11	76.02
$P_4 \times P_5$	1.79**	2.29	0.41	-0.77	165.64
$P_4 \times P_6$	3.76**	22.95**	-0.52	-0.85	-6.73
$P_5 \times P_6$	1.85**	16.62	0.19	-0.81	333.27**
SE (Sij-Skl)	1.70	18.25	0.60	1.77	278.03

CONCLUSION

The current research concludes that Line 1 was identified as an effective general combiner. Therefore, may be utilized in future breeding strategies.

REFERENCES

Abd El- Hadi, A.H., El- Adl, A. M., Horeya M. Fathy and Abdein, M. A. (2014). Heterosis and genetic behavior of some yield and yield component traits in squash (*Cucurbita pepo*, L.) Alexandria Science Exchange Journal, 35 (3) : 178 – 189.

César Sánchez - Hernández C. Villanueva - Verduzco; Sahagún Castellanos, J., JLegaria - Solano . P., Martínez-Solís, J. and Sánchez-Hernández, M. Á. (2013). Heterosis en híbridos de calabacita tipo grey zucchini. Revista Chapingo Serie Horticultura, 19 (1):99-115.

Elsharkawy, S. E. M, Badr, L.A.A., Shams, A. S. and Khalil, E. M. (2018). Heterosis and combining ability studies for fruit yield and quality characters in squash (*Cucurbita pepo* L.). Annals of Agric. Sci., Moshtohor,56 (3): 731-740.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci., 9: 463-493.

Hussein, A. H., Abd Rabou, A. M., Haggag, S. Zein and Zaid, N.A. (2013). Inheritance of some economic characters and powdery mildew resistance in summer squash. Arab J. Biotech., 16 (2): 225-242.

Hussein, A. H. and Selim, M. A. M. (2014). Breeding for improving quality and yield characteristics in cantaloupe under high temperature conditions. Egypt. J. Plant Breed.,18 (2):243-264.

Jasim -Esraa Abd, Al-h. and Esho, K. B. (2021). Study the line × tester hybridization, [II] Seeds yield and its component in (*Cucurbita pepo* L.). Plant Archives , 21(1): 1-5

López Anido, F, Cravero, V., Asprelli, P., Firpo,T., García, S. M. and Cointry, E. (2004). Heterotic patterns in hybrids involving cultivar-groups of summer squash, Cucurbita pepo L. Euphytica , 135(3): 355–360

Matzinger, D.F., G.F. Sprague and C.C. Cockerham (1959). Diallel crosses of maize in experiments repeated over locations and years. J. Agron, 51: 346-350.

Sinha, S.K. and Khanna, R. (1975). Physiological, biochemical and genetic basis of heterosis. Advan.Agron. 27: 123-174.

Snedecor, G. W. and Cochran, W.G. (1990). "Statistical Method". 7th ed. The Iowa State Univ. Ames. USA.

Soliman- Abeer, A. El. K. (2018). Types of gene action and hybrid vigour for yield and yield components in summer squash (*Cucurbita pepo* L.). Egypt. J. Plant Breed, 22 (5): 989– 1002.

Soliman- Abeer, A. El. K. (2022). Genetics analysis, combining ability and heterosis of some yield and yield component traits in summer squash (c*ucurbita pepo* L.) Menoufia J. Plant Prod., Vol. 7 December (2022): 181 – 191.

Tamilselvi, N. A., Jansirani, P. and Pugalendhi, L. (2015). Estimation of heterosis and combining ability for earliness and yield characters in pumpkin (*Cucurbita moschata* Duch. Ex. Poir). African Journal of Agricultural Research, 10(16): 1904-1912.

الملخص العربى

قوة الهجين والقدرة علي التآلف لبعض السلالات الواعدة من الكوسة

عمرو أحمد السيد و مسعد خيري مأمون

-قسم بحوث تربية الخضر والنباتات الطبية والعطرية - معهد بحوث البساتين –مركز البحوث الزراعية. الجيزة. مصر.

تم إجراء البحث الحالي خلال الفترة من 2023 إلى 2025، في مزرعة التجارب الزراعية بقها بمحافظه القليوبيه ، معهد بحوث البساتين. ستة سلالات متجانسة من الكوسة (*C. pepo*, L.) كشفت البيانات أن وزن ثمار الهجن يتراوح من 85.00 جم (P1 × P2) إلى 106.00 جم (P2 × P5). كان للهجن (P2 × P5) أعلى وزن ثمار معنوي بين جميع الأنماط الجينية التي تم تقييمها مقارنةً بهجين المقارنة. أظهر عدد الأيام حتى أول زهرة مؤنثة الفرق المعنوي بين جميع الهجن والهجين التجاري يارا، وقد وجد أن الهجين (P1 × P2،P2 × P4) كان متفوقًا على جميع الهجن وأعطى أول زهرة أنثوية في عدد قليل من الأيام. أعطى الاب P4 أكبر محصول إجمالي على جميع الأنماط الجينية الأبوية التي تم تقييمها، وكذلك أعطى الهجين (P1 × P4،P3 × P4) أعلى محصول. تم تقييم قوة الهجين لجميع الصفات المدروسة حيث أظهرت جميع التهجينات قوة عاليه وموجبه لمعظم الصفات. أظهرت القيم المقدرة للسيادة العامة أن معظم التهجينات F1 كانت ذات طبيعة موجبة لمتوسط طول الثمرة والمحصول الكلي مما يشير إلى سيادة تجاه أعلى اب في الصفة (سيادة جزئية وكاملة وسيادية متفوقه). الاب P1 كانا أفضل الأباء حيث اعطى قدرة عامة على الائتلافGCA موجبة ومعنوية لوزن الثمرة والمحصول الكلي و الاب P6 ايضا كان أفضل الأباء حيث اعطى قدرة عامة على الائتلافGCA لطول الثمرة وخصائص المحصول الكلي.