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The Effect of Gene Action and Heterosis in Cucumber Yield under Low Temperature

Aboshanady, A.M.A., Maamoun, M.K. and Tahany R. Elsayed

Department of Vegetable, Medicinal and Aromatic Plant Breeding, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt

ABSTRACT

Five promising inbred lines were selected to cross as females among four testers used as males of cucumbers (*Cucumis sativus* L.) which generated by self-pollination for six generations under greenhouse at Research farm, Sakha Village, Kafr Elshikh governorate between 2021 and 2023. Twenty F1 hybrids were produced in a Line × Tester scheme between parents during early summer of 2024, Nine parents, their ten F_1 hybrids, and the commercially hybrid (Rafal F1) were evaluated during winter season of 2024 in a randomized complete block design with three replications to estimate some genetic parameters. Four crosses $P_3 \times P_6$, $P_4 \times P_6$, $P_4 \times P_7$ and $P_4 \times P_8$ had positive significant heterotic value over the better parent for early yield weight, the cross $P_3 \times P_9$ had great highly significant positive values of heterosis over (M.P) for total yield weight. Non-additive gene played the main role in all traits. The line Cu14 and tester Cu2e consider excellent combiners for early yield weight, whereas, Cu12, Cu14 and Cu2e cultivars were best parents for total yield weight. The crosses $P_1 \times P_7$ and $P_3 \times P_9$ had great (SCA) effects for early yield, while the crosses $P_3 \times P_9$ and $P_5 \times P_9$ had the greatest (SCA) effects for total yield.

Keywords: Cucumber- *Cucumis sativus* L.- Heterosis- Combining ability- Line × Tester.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) (2n=2x=14) is considered an important vegetable crops, returns to to the gourd family, which include many of genera and species (Gopalakrishnan, 2007). Cucumber is originated from Africa and India since several thousand years ago, cucumber grown in many area of the world, according to (Wehner and Horton, 1986). There are two main varieties of cucumbers: the fresh and pickled cucumber (Staub and Bacher, 1997). Cucumber has high percentage of water and a few calories and sodium, it is rich in nutrients and it is antioxidant, anti-cancer, reduces stress and aids digestion (Jat et al., 2021). Cucumber area in Egypt was nearly 26.7 thousand hectares, with a total production of 626,9 thousand tonnes (FAOSTAT, 2023). It has the property of cross-pollinated; it is almost monoecious with various sex ratio (Bairagi et al., 2002). In Line × Tester design, we depend on many testers to test (GCA) of lines (Kemothorne, 1957). It is important to know good parents and suitable breeding programe by estimate (GCA) and (SCA) variances and its effects, (GCA) is fixable because it controlled by the additive gene action. Whereas (SCA) is non- fixable and controlled by non-additive gene action. Estimated of heterosis can measured by dominance (Kumar et al., 2017). Several studied estimated heterosis and reported the combining ability in family of cucurbetiace (Ahmed et al., 2004, Al-Araby, 2004, Moradipur et al., 2016 and Tiwari and Singh, 2016).

Egypt faces great challenges due to the huge population. In Egypt the farmer unable, utilize on only local seeds of cucumber so we use the imported hybrid seeds to product cucumber. Therefore, the main aim of vegetable breeding enhancing cucumber yield and quality. This experiment aimed to study the various performance of nine inbred lines of cucumber, to estimate the amount of heteroic effect between them, and assess (GCA) and specific combining ability (SCA), through Line × Tester mating design for cucumber crop and fruit characters.

MATERIALS AND METHODS

This investigation was conduct at Research farm, Sakha Village, Kafr Elshikh governorate belongs to Agriculture Research Center-Egypt between 2021 to 2024.

Plant materials.

The materials which used in our experiment content of five advanced inbred lines, viz., cu 12, cu14, cu15, cu16 and cu17 and four cultivars (cu2e, cu5e, cu7e and cu8e) as testers, which created through self-pollination for six consecutive seasons (to ensure homogeneity). These lines were crossed at early summer season of 2024 to obtain twenty F_1 hybrids by Line x tester breeding programme. In the winter season of 2024, the nine parents, their 20 F_1 hybrids, and check variety were planted in the greenhouse under drip irrigation. We use a randomized complete block design and three replicates.

Table (1). Genotypes of cucumber inbred lines used in the study.

	Lines					Testers			
Code	P1	P2	P3	P4	P5	P6	P7	P8	P9
genotype	Cu12	Cu14	Cu15	Cu16	Cu17	Cu2e	Cu5e	Cu7e	Cu8e

Experimental design

Means traits and statistical variances were done according to Cochran and Cox (1957). The comparison between genotype means calculated by Duncan (1955).

Estimates of heterosis

a) Heterosis over the mid-parent parent ($\overline{M.P.}$)

$\% = \frac{\overline{F_1} - \overline{M.P.}}{\overline{M.P.}} \times 100$

b) Heterosis over the better parent ($\overline{B.P.}$) %

$= \frac{\overline{F_1} - \overline{B.P.}}{\overline{B.P}} \times 100$

c) Heterosis over the commercial hybrid ($\overline{C.H.}$)

$\% = \frac{\overline{F_1} - \overline{C.H.}}{\overline{C.H.}} \times 100$

Potence ratio (P): were done by Wigan (1944).

Line x tester analysis: proposed by Kempthorne (1957).

Proportional contribution of lines, testers and their interaction in F_1 top crosses

Contribution of lines = $\frac{s.s. \text{ of Lines}}{s.s. \text{ of crosses}}$ x 100

Contribution of testers = $\frac{s.s. \text{ of testers}}{s.s. \text{ of crosses}}$ x 100

Contribution of lines x testers = $\frac{s.s. \text{ of lines x testers}}{s.s. \text{ of crosses}}$ x 100

Where: *S.S.* mean sum square for lines, testers and lines x testers.

RESULTS AND DISCUSSION

Test of significant and mean performances

Table (2) showed analysis of variance and highly significant mean squares for all traits; indicating that variability genetic could be calculated Brar and Sukhija (1977).

Table (2). Analysis of variance and means squares for all traits of the parents and their F_1 hybrids of cucumber plants grown under greenhouse during the winter season of (2024-2025).

S.O.V.	d.f.	Average fruit weight (gm)	Average fruit length (cm)	Early yield weight (gm)	Early yield number	Total yield weight (kg)	Total yield number
Replications	2	1.28	1.39	500.7	0.14	0.0019	0.59
Genotypes	28	756.88**	17.03**	121023**	18.91**	1.39**	275.64**
Error	56	1.39	0.71	9111.2	1.33	0.002	0.58

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

The performance of parents and their F_1 hybrids

Table (3) showed high mean of F_1 than the corresponding value of testers, lines and parents mean for average fruit weight. Concerning parents, the P_2 produced the heaviest fruit (91 gm), whereas the P_7 was the lightest one. The crosses $P_1 \times P_6$, $P_1 \times P_7$ and $P_2 \times P_7$ had the heaviest fruit, while genotypes $P_1 \times P_9$ and $P_5 \times P_8$ had the lower value than all other genotypes. In order to length of fruit, the parent 1 cv. was the tallest one and exceeded parents and crosses means, while 6 cultivar had the shortest one. Concerning the crosses, the genotypes $P_1 \times P_7$ and $P_2 \times P_7$ had the longest fruits and exceeded parents, F_1 mean and check hybrid following by $P_1 \times P_6$, whilst the genotypes $P_4 \times P_6$ and $P_4 \times P_7$ had the shortest fruits.

Regarding early yield (weight of fruits/plant), check hybrid exceeded all genotypes means. The P_1 was the highest parent for this trait; meanwhile the P_6 was the lowest one. From 20 crosses, the cross P_1 x P_7 has higher value than other crosses. While, the lowest one was the cross P_5 x P_9. Concerning fruit number of early yield, the lines mean exceeded the check hybrid, parents and F_1 hybrids means in early fruit number / plant, whereas 1 cultivar produced the largest early fruit number / plant and almost equal the highest early fruit number which produced by the crosses P_1 x P_9 and P_4 x P_9. On the other hand, the lowest number presented by the cross P_5 x P_9.

Table (3). Means performance for all traits of 9 parents, 20 crosses, and the check hybrid (Rafal F_1) of cucumber plants grown under greenhouse during the winter season of (2024-2025).

Genotype	Average fruit weight (gm).	Average fruit length (cm)	Early yield / plant		Total yield / plant	
			Fruit weight (gm)	No. of fruits	Fruit weight (kg)	No. of fruits
Lines						
P_1	84 hi	17 bc	978 a	11.64 a	4.44 j	48.04 g
P_2	91 de	14 def	889.34 b	9.77 c	5.29a	58.13c
P_3	80 j	13.34 ef	400.34 o	5.00 n	4.05 ij	50.67 f
P_4	89 ef	13.67 ef	312.34 q	3.51 p	4.24 ef	47.66 g
P_5	87.34 fg	15 cde	814.34 c	9.33 d	4.05 ij	46.39 hi
Average of lines	86.26	14.6	678.86	7.85	4.33	50.18
Testers						
P_6	76.67 k	12.67 fg	165 s	2.15 r	3.61 l	47.12 gh
P_7	72 m	13efg	314.67 q	4.37 o	4.16 gh	57.85c
P_8	73 lm	13 efg	352 p	4.82 n	4.62 b	63.34a
P_9	76.34 k	15.67 cd	758.34 e	9.94 c	2.65 q	34.69 n
Average of testers	74.50	13.58	397.5	5.32	3.76	50.74
Average of parents	81.04	14.15	538.18	6.73	4.03	50.43
F_1 Crosses						
P_1 x P_6	132 a	19 ab	717.34 f	5.48 lm	4.23 efg	32.33 o
P_1 x P_7	112 b	20 a	812.67 c	7.32 ij	4.12 hi	37.15 m
P_1 x P_8	71 m	12 fgh	323.67 q	4.62 o	4.24 ef	60.62b
P_1 x P_9	55 p	15 cde	628.34 j	11.29 ab	3.15 p	56.59 d
P_2 x P_6	83 hij	10 h	811.34 c	9.78 c	4.46 d	53.77 e
P_2 x P_7	112 b	20 a	581.67 l	5.21 mn	4.34 de	38.87 l
P_2 x P_8	102 c	16 cd	785.67 d	7.70 h	4.52 c	44.33 jk
P_2 x P_9	85 ghi	15 cde	686.67	7.99 g	2.90 q	33.76 n
P_3 x P_6	102 c	17 bc	570.67 l	5.63 l	3.41 m	33.65 n
P_3 x P_7	83 hij	12 fgh	438 n	6.42 j	3.31 n	39.45 l
P_3 x P_8	71 m	15 cde	464.34 n	6.54 k	3.22 o	45.35 ij
P_3 x P_9	83 hij	16 cd	714.67 fg	8.51 ef	4.06 j	48.27 g
P_4 x P_6	94 d	10 h	599 k	6.31 k	4.29 def	45.21 ij
P_4 x P_7	76 kl	11 gh	655.67 j	8.52 ef	3.38 mn	43.93 k
P_4 x P_8	82 ij	14 def	542.34 m	6.70 k	4.18 gh	51.61 f
P_4 x P_9	64 n	14 def	719	11.06 b	2.43 r	37.32 m
P_5 x P_6	91 de	13 efg	675 i	7.39 hi	3.42m	37.44 m
P_5 x P_7	80 j	14 def	699 gh	8.60 e	2.45 r	30.08 p
P_5 x P_8	60 o	13 efg	591 l	9.59 c	3.95 k	64.02a
P_5 x P_9	86 fgh	14 def	260.67 r	3.07 q	3.68 l	43.29 k
Average of crosses	86.40	14.50	613.87	7.39	3.69	43.85
Rafal Con	93 d	14 def	671.66 de	7.14 fg	4.08 j	43.42 k

Means followed by an alphabetical letter in common within each column are not significantly different at 5% level according to Duncan's Multiple Range Test.

Whereas for total yield (weight of fruits/plant), the check hybrid exceeded the means of both testers and F_1 hybrids, but it seems to be lower than the lines mean. The parent 2 had the largest value (5.29 kg /plant) followed by 8cv. with a value of 4.62 Kg/plant. Concerning crosses, the genotype P_2 x P_8 had the largest value (4.52 Kg/plant) followed by the genotype P_2 x P_6 with a value of (4.46 Kg/plant). On the contrary, P_4 x P_9 had the lowest one with (2.43 Kg/plant). The check hybrid produced (4.08 Kg/plant). Regarding fruits number for a total yield the testers mean exceeded the means of lines, check hybrid and F_1hybrids. The parent P_9 was the lowest value while P_8 was the highest one. Concerning the crosses, the highest cross was P_5 x P_8, whereas the lowest cross was P_5 x P_7 (**Table 3**).Regarding the previous traits, Ahmed *et al* (2004), Moradipur et al (2016), Kumar *et al* (2017), Sharma et al. (2017), Thakur et al.

(2017), Kumar et al. (2018), Al-Araby et al. (2019), Abd Rabou (2020) and Nahla A. EL-Magawry and Nasef (2024) noted variation between parents and crosses. However, it is necessary to educate the execution of genotypes it is not favorable to rely mainly on the mean performances of the paternal genotypes of the crosses Allard (1960), so, combining ability was more credibility for us to appreciate the genetic parameters like heterosis, Kumar et al. (2017).

HETROSIS:

Concerning average fruit weight, **Table (4)** show that, 10 cross out from 20 revealed significant or highly significant positive values for heterosis over the mid-parents ranged from (5.08% to 64.31%) for crosses $P_5 \times P_9$ and $P_1 \times P_6$, respectively. In order to heterosis over the better parent, 9 crosses reflected highly significant positive values ranged from (57.14% to 3.75%) for the genotypes $P_1 \times P_6$ and both of ($P_3 \times P_7$, $P_3 \times P_9$), respectively. The average heterosis over the mid-parents was significant with positive value (7.28%), where as it was absent over the better parent. Partial dominance was found in 5crosses and over-dominance in remained crosses, but it was absent effect (P= 0) in the cross $P_4 \times P_8$, suggesting that the additive effect may be play the main effect about inheritance for this trait. In this concern, Abd-Rabou and Zaid (2013) and Kumar et al. (2017) on cucumber, reflected over dominance towards average fruit weight. Concerning heterosis over the check hybrid, 5 crosses revealed highly significant positive values. The values ranged from (9.68 %) reflected by 2 crosses $P_2 \times P_8$ and $P_3 \times P_6$ to (41.94 %) reflected by cross $P_1 \times P_6$. The average was absent (-7.31%). Same results noted by Airina et al. (2013) on cucumber observed negative heterosis. Whereas, Sudhakar et al. (2005), Hanchinamani and Patil (2009), Kaur and Dhall (2017), and Thakur et al. (2017), on cucumber, found positive value for this trait.

As concern to heterosis over the mid-parents for length of fruit, **Table (4)** show that seven crosses had highly significant positive values. Over-dominance was found in 16 crosses, complete dominance in one cross and partial dominance in 3 crosses. Further, potence ratio Kumar et al. (2017), Al-Araby et al. (2019) and Abd Rabou. (2020) on cucumber noted the same results towards over dominance.

Table (4). Percentage of Heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) of 20 crosses for Average fruit traits of Cucumber evaluated during winter season of 2024-2025.

Crosses	Average fruit weight (g)				Average fruit length (cm)			
	M.p	B.p	C.H	P	M.p	B.p	C.H	P
$P_1 \times P_6$	64.31**	57.14**	41.94**	13.81	28.08**	11.76**	35.71**	1.61
$P_1 \times P_7$	43.59**	33.33**	20.43**	5.5	33.33**	17.65**	42.86**	2
$P_1 \times P_8$	-9.55**	-15.48**	-23.66**	-1.54	-20.00**	-29.41**	-14.29**	-1.8
$P_1 \times P_9$	-31.40**	-34.52**	-40.86**	-6.39	-8.17**	-11.76**	7.14	-2.5
$P_2 \times P_6$	-1.00	-8.79**	-10.75**	-0.12	-25.01**	-28.57**	-28.57**	-4.5
$P_2 \times P_7$	37.42**	23.08**	20.43**	3.18	48.15**	42.86**	42.86**	11
$P_2 \times P_8$	24.39**	12.09**	9.68**	2.22	18.52**	14.29**	14.29**	3.6
$P_2 \times P_9$	1.59	-6.59**	-8.60**	0.32	1.11	-4.28	7.14	1
$P_3 \times P_6$	30.21**	27.50**	9.68**	13.8	30.72**	27.44**	21.43**	15
$P_3 \times P_7$	9.21**	3.75**	-10.75**	2.0	-8.88**	-10.04	-14.29**	-9
$P_3 \times P_8$	-7.19**	-11.25**	-23.66**	-1.6	13.90**	12.44*	7.14	5
$P_3 \times P_9$	6.18**	3.75**	-10.75**	3.2	10.31**	2.11	14.29**	15
$P_4 \times P_6$	13.48**	5.62**	1.08	1.97	-24.07**	-26.85**	-28.57**	-5.67
$P_4 \times P_7$	-5.59**	-14.61**	-18.28**	-0.41	-17.51**	-19.53**	-21.43**	-8.00
$P_4 \times P_8$	1.23	-7.87**	-11.83**	0.00	4.99	2.41	0.00	3.00
$P_4 \times P_9$	-22.58**	-28.09**	-31.18**	-2.79	-4.57	-10.66*	0.00	-1.67
$P_5 \times P_6$	10.97**	4.19**	-2.15*	1.75	-6.04*	-13.33**	-7.14	-0.43
$P_5 \times P_7$	0.41	-8.40**	-13.98**	0.22	0.00	-6.67	0.00	-0.33
$P_5 \times P_8$	-25.16**	-31.30**	-35.48**	-2.58	-7.14**	-13.33**	-7.14	-0.67
$P_5 \times P_9$	5.08**	-1.53	-7.53**	0.58	-8.71**	-10.66*	0.00	-5.00
Average	7.28**	0.10	-7.31**		2.95**	2.71**	3.57	

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Regarding heterotic effect over the better parent, only six crosses had significant or highly significant positive value $P_1 \times P_7$, $P_2 \times P_7$ and $P_3 \times P_6$; it means that the previous crosses had length of fruit more than the better parent. Six crosses had highly significant positive values of heterosis over the check hybrid, ranged from 42.86% by both genotypes $P_1 \times P_6$ and $P_2 \times P_6$, to 14.29% by the genotypes $P_3 \times P_9$ and $P_2 \times P_8$. The average heterosis was significant with positive values in both of (M.P and B.P) and it was absent in (C.H). The same results obtained by Hanchinamani and Patil (2009) and Kaur and Dhall (2017) on cucumber. As regard to early yield weight of fruit, **Table (5)** presented 12 crosses out of 20 had significant or highly significant positive heterotic value over (M.P), whereas only four crosses $P_3 \times P_6$, $P_4 \times P_6$, $P_4 \times P_7$ and $P_4 \times P_8$ had significant or highly significant positive heterotic value 42.55%, 73.29%, 89.68% and 54.07% over (B.P) respectively.

The presence of heterosis was due to partial dominance in ten genotypes, whereas over-dominance found in the other genotypes. Regarding heterosis over (C.H) four crosses had a negative value. The average heterosis was absent over the mid parent, the better parent and the check hybrid. However, the absence of significant heterosis over the better parent did not imply the absence of superior F_1 crosses, i.e., $P_3 \times P_6$, $P_4 \times P_6$, $P_4 \times P_7$ and $P_4 \times P_8$.

Concerning early fruit number, **Table (5)** showed that 11 crosses had significant or highly significant positive values of heterosis over (M.P). The higher and the lower value presented in the genotypes $P_4 \times P_6$ (122.97 %) and $P_5 \times P_7$ (25.55 %) respectively. Over-dominance found in 11 crosses, but it was partial in 8 genotypes and complete dominance in one cross. Regarding heterosis over (B.P), 3 crosses had significant or highly significant positive value, they were $P_4 \times P_6$, $P_4 \times P_7$ and $P_4 \times P_8$, which had values 79.77%, 94.97 and 39 %; it means that the previous crosses had early number of fruit more than the better parent. Only four cross-had significant or highly significant positive value over (C.H), ranged from 34.31% to 58.12% for the genotypes $P_5 \times P_8$ and $P_1 \times P_9$, respectively. It means that the previous crosses had early number of fruit more than any crosses or than the (C.H).

Table (5). Percentage of Heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) of 20 crosses for early yield weight and number traits of Cucumber evaluated during winter season of 2024-2025.

Crosses	Early yield weight				Early yield number			
	M.p	B.p	C.H	p	M.p	B.p	C.H	P
$P_1 \times P_6$	25.52*	-26.65**	6.80	0.36	-20.52	-52.92**	-23.25	-0.30
$P_1 \times P_7$	25.74*	-16.90*	20.99	0.50	-8.56	-37.11**	2.52	-0.18
$P_1 \times P_8$	-51.33**	-66.90**	-51.81**	-1.09	-43.86**	-60.31**	-35.29*	-1.06
$P_1 \times P_9$	-27.62**	-35.75**	-6.45	-2.18	4.63	-3.01	58.12**	0.58
$P_2 \times P_6$	53.90**	-8.77	20.80	0.78	64.09**	0.10	36.85*	1.00
$P_2 \times P_7$	-3.38	-34.60**	-13.40	-0.07	-26.31*	-46.67**	-27.03*	-0.69
$P_2 \times P_8$	26.58*	-11.66	16.97	0.61	5.55	-21.19*	7.84	0.16
$P_2 \times P_9$	-16.65*	-22.79	2.23	-2.09	-18.92*	-19.62*	11.90	-22.91
$P_3 \times P_6$	101.89**	42.55*	-15.04	2.44	57.48*	12.60	-21.15	1.44
$P_3 \times P_7$	22.52	9.41	-34.79**	5.1	37.03*	28.40	-10.08	6.52
$P_3 \times P_8$	23.44	15.99	-30.87**	3.64	33.20*	30.80	-8.40	17.82
$P_3 \times P_9$	23.36*	-5.76	6.40	0.75	13.92	-14.39	19.19	0.42
$P_4 \times P_6$	150.97**	91.78**	-10.82	4.89	122.97**	79.77**	-11.62	5.12
$P_4 \times P_7$	109.14**	108.37**	-2.38	293.29	116.24**	94.97**	19.33	10.61
$P_4 \times P_8$	63.27**	54.07*	-19.25	10.60	60.86**	39.00*	-6.16	3.85
$P_4 \times P_9$	34.31**	-5.19	7.05	0.82	64.46**	11.27	54.90**	1.35
$P_5 \times P_6$	37.85**	-17.11	0.50	0.57	28.75*	-20.79*	3.50	0.46
$P_5 \times P_7$	23.83*	-14.16	4.07	0.53	25.55*	-7.82	20.45	0.70
$P_5 \times P_8$	1.34	-27.43**	-12.01	0.03	35.55**	2.79	34.31*	1.11
$P_5 \times P_9$	-66.85**	-67.99**	-61.19**	-18.77	-68.14**	-69.11**	-57.00**	-21.59
Average	27.89	-1.97	-8.61		24.20**	-2.66*	3.45	

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

The average heterosis over (M.P) was highly significant positive value but it was absent for (B.P) and (C.H). Various results found by Al-Araby (2004), Bairagi et al. (2002), Mule et al. (2012) Al-Araby et al. (2019) and Abd Rabou. (2020) in cucumber for these traits.

Concerning weight of total yield, **Table (6)** show that 4 genotypes, had highly significant positive values of heterosis over (M.P), ranging from 5.09 % for the genotype P_1 x P_6 to 21.18 % for the genotype P_3 x P_9. The presence of heterosis was over-dominance in 13 crosses, but it was partial in 6 genotypes and only one was complete dominance. In this concern, Abd-Rabou and Zaid (2013) and Kumar et al. (2017) on cucumber estimated over dominance in most genotypes. Concerning heterosis over (B.H), no cross-had highly significant positive value. Regarding heterosis based on (C.H) 7 crosses showed highly significant positive values, ranged from 2.45% to 10.78% reflected by crosses P_4 x P_8 and P_2 x P_8. The average heterosis over (M.P), (B.P) and (C.H) had negative values. This is in agreement with Kumbhar et al. (2005), Sudhakar *et al*. (2005) Hanchinamani and Patil (2009), Araina et al. (2013), Kaur and Dhall (2017), Thakur et al. (2017), Abd Rabou et al. (2019) and Al-Araby et al. (2019) on cucumber.

As regard of total yield number **Table (6)** presented that five cross had significant or highly significant positive values of heterosis over (M.P). The genotypes P_1 x P_9 and P_5 x P_9 had large and low value respectively. The presence of heterosis was over-dominance in most crosses and partial in 6 crosses. The same results obtained by Abd-Rabou and Zaid (2013) and Kumar et al. (2017) on cucumber. Regarding heterosis over the better parent, only one cross P_1 x P_9 had highly significant positive value 17.80 %. It means that the previous cross-had total number of fruit more than the better parent. The average heterosis over (M.P), (B.P) and (C.H) was absent.

Table (6). Percentage of Heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) of 20 crosses for total yield weight and number traits of Cucumber evaluated during winter season of 2024-2025.

Crosses	total yield weight %				total yield number			
	M.p	B.p	C.H	p	M.p	B.p	C.H	P
P_1 x P_6	5.09**	-4.73**	3.68**	0.50	-32.05**	-32.70**	-25.54**	-32.94
P_1 x P_7	-4.19**	-7.21**	0.98	-1.30	-29.83**	-35.78**	-14.44**	-3.22
P_1 x P_8	-6.40**	-8.23**	3.92**	-3.18	8.85**	-4.29**	39.61**	0.64
P_1 x P_9	-11.14**	-29.05**	-22.79**	-0.44	36.81**	17.80**	30.33**	2.28
P_2 x P_6	0.22	-15.69**	9.31**	0.338	2.18	-7.50**	23.84**	0.21
P_2 x P_7	-8.15**	-17.96**	6.37**	-0.511	-32.97**	-33.13**	-10.48**	-133.55
P_2 x P_8	-8.78**	-14.56**	10.78**	-1.779	-27.01**	-30.01**	2.10	-6.30
P_2 x P_9	-26.95**	-45.18**	-28.92**	-0.770	-27.26**	-41.92**	-22.25**	-1.08
P_3 x P_6	-10.97**	-15.80**	-16.42**	-1.92	-31.18**	-33.59**	-22.50**	-8.57
P_3 x P_7	-19.37**	-20.43**	-18.87**	-14.29	-27.29**	-31.81**	-9.14**	-4.13
P_3 x P_8	-25.72**	-30.30**	-21.08**	-3.92	-20.45**	-28.40**	4.44**	-1.84
P_3 x P_9	21.19**	0.25	-0.49	1.00	13.10**	-4.74**	11.17**	0.70
P_4 x P_6	9.30**	1.18	5.15**	1.167	-4.60**	-5.14**	4.12**	-7.96
P_4 x P_7	-19.52**	-20.28**	-17.16**	-21.338	-16.73**	-24.06**	1.17	-1.73
P_4 x P_8	-5.64**	-9.52**	2.45**	-1.321	-7.01**	-18.52**	18.86**	-0.50
P_4 x P_9	-29.46**	-42.69**	-40.44**	-1.278	-9.36**	-21.70**	-14.05**	-0.59
P_5 x P_6	-10.70**	-15.56**	-16.18**	-1.88	-19.92**	-20.54**	-13.77**	-25.62
P_5 x P_7	-40.32**	-41.11**	-39.95**	-28.98	-42.29**	-48.00**	-30.72**	-3.85
P_5 x P_8	-8.88**	-14.50**	-3.19**	-1.36	16.69**	1.07	47.44**	1.08
P_5 x P_9	9.85**	-9.14**	-9.80**	0.47	6.78**	-6.68**	-0.30	0.47
Average	-9.53**	-18.03**	-9.63**		-12.18**	-20.48**	0.99	

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Concerning heterosis over the check hybrid, eight crosses had positive heterotic effects. It ranged from 4.44% to 47.44% reflected by genotypes P_3 x P_8 and P_5 x P_8, respectively. Various results obtained in cucumber by Al-Araby (2004), Yadav *et al* (2007), Hanchinamani and Patil (2009), Kushwaha et al. (2011), Airina et al. (2013), Tiwari and Singh (2016), Kumar et al. (2017), Thakur et al. (2017) Abd Rabou et al. (2020) and Nahla A. EL-Magawry and Nasef (2024) significant differences among all genotypes for all traits presented in **Table (7).** Means square for both GCA and SCA were highly significant for most of traits under study; (gca / sca ratio) indicated that, both additive and non-additive gene effect in the inheritance of all experiment traits.

Table (7). The analysis of variance and mean squares of the factorial mating design (line x tester analysis) for all traits in Cucumber during winter season of (2024-2025).

Genotype	df	Average fruit weight	Average fruit length	Early yield weight	Early yield number	Total yield weight	Total yield number
Reps	2	1.40	1.21	93.11	0.079	0.002	0.97
Treatment	28	756.89**	17.03**	121023**	18.91**	1.39**	275.59**
PARENTS	8	149.87**	6.34**	265713**	33.88**	1.52**	213.63**
Crosses	19	1024.1**	22.43**	63022.8**	13.25**	1.25**	273.75**
Par.vs. crosses	1	535.6**	0.09**	65504**	6.63**	2.86**	806.27**
Lines	4	626.3**	25.69**	44908**	3.06**	1.04**	43.44**
Testers	3	2252.5**	3.39**	57238**	6.65**	2.07**	670.03**
Line x Tester	12	849.6**	26.1**	70506**	18.30**	1.12**	251.5**
Error	56	1.38	0.71	91111.2	1.33	0.002	0.58
Total	86	21272.9	519.68	3899873.6	604.4	39.09	7750.4
G.C.A.	__	5.09	0.107	302.79	0.27	0.0038	0.65
S.C.A.	__	282.74	8.46	9841.9	6.43	0.375	83.66
GCA / SCA	__	0.018	0.012	0.030	0.041	0.01	0.007

** = significant at 0.01, probability levels.

The analysis of variance for combining.

In all traits (gca/sca ratio) low than one, means that the dominance genes more effect than additive genes, to enhance these traits we would be make hybridization or crossing between parents. In this concern Al-Araby (2004), Dogra and Kanwar (2011), Airina (2013), Malav et al. (2018), Abd Rabou *et al.* (2019), Al-Araby et al. (2019), Ene et al. (2019), Abd Rabou et al. (2020) and Nahla A. EL-Magawry and Nasef (2024) found same results. Meanwhile, Al-Araby (2004), Moushumi and Sirohi (2010), Dogra and Kanwar (2011), Al-Araby et al. (2019) and Abd Rabou et al.(2020) reported that (gca / sca ratio) more than one in some traits.

Combining ability:

Table (8) presented that, four parents P_1, P_2, P_6 and P_7 could be considered excellent combiners for average weight of fruit, the tester Cu2e was the best parent for GCA effects. For average length of fruit, P_1, P_2 and P_7 cultivars were the best combiners. The line Cu14 and tester Cu2e were excellent combiners for weight of early yield, whereas the line Cu16 and tester Cu8e were good combiners for number of early yield. Regading weight of total yield P_1, P_2, P_6 and P_8 cultivars could be considered as good combiners, while 3 parents P_1, P_4 and P_8 cultivars were the best combiner with highly significant positive value for number of total yield. In this concern, different results reported for effects of (GCA) in all traits by Yadav *et al*. (2007), Dogra and Kanwar (2011), Golabadi *et al.* (2015), El-Eslamboly and Mohamed (2018), Ene et al. (2019), Al-Araby et al. (2019), Abd Rabou et al. (2020) , El-Remaly et al. (2021) and Nahla A. EL-Magawry and Nasef (2024)**.**

Regarding SCA effects, **Table (9)** showed that ten genotypes had significant or highly significant positive values of SCA effects for average weight of fruit, whereas, five genotypes exhibited highly significant values of SCA effects for average length of fruit, suggesting that, these crosses had tallest fruits than the other crosses. Furthermore, the genotypes viz., $P_1 \times P_7$, $P_2 \times P_8$, $P_3 \times P_9$ and $P_5 \times P_8$ had significant or highly significant positive values for early yield weight, indicated that the previous genotypes had earlier yield than the other crosses, while 5 genotypes viz., $P_1 \times P_9$, $P_2 \times P_6$, $P_4 \times P_9$, $P_5 \times P_7$ and $P_5 \times P_8$ had significant or highly significant positive values of SCA effects for early yield number. Concerning total yield weight, nine crosses had highly significant value, whereas 10 genotypes had highly significant positive values. In this concern, many investigation presented desirable effect of SCA Singh and Sharma (2006), Kushwaha et al. (2011), Airina (2013), Naik et al. (2018). Al-Araby et al. (2019), Ene et al. (2019) Abd Rabou et al. (2020) and Nahla A. EL-Magawry and Nasef (2024), as well as, Al-Araby (2010), El-Adl et al. (2014) on summer squash and El-Tahawey et al. (2015) on pumpkin.

Table (8). Estimates of general combining ability effects of all traits for the parents of cucumber during the winter season of (2024-2025).

Genotype	Average fruit weight.	Average fruit length.	Early yield weight.	Early yield number	Total yield weight.	Total yield number.
Lines						
P_1	5.52**	1.62**	-0.03	-0.24	0.25**	2.82**
P_2	9.27**	0.87**	95.80**	0.27	0.37**	-1.17**
P_3	-1.32**	0.37	-40.12	-0.53	-0.19**	-2.17**
P_4	-6.90**	-2.13**	8.47	0.74*	-0.12**	0.66**
P_5	-6.57**	-0.72**	-64.12*	-0.24	-0.31**	-0.14
SE gcs	0.314	0.245	27.81	0.337	0.012	0.197
Testers						
P_6	13.93**	--0.15	54.13*	-0.48	0.28**	-3.38**
P_7	6.60**	0.58*	43.67	-0.11	-0.17**	-5.95**
P_8	-9.27**	-0.55*	-79.13**	-0.37	0.34**	9.34**
P_9	-11.27**	0.12	-18.67	0.97**	-0.44**	-0.01
SE gca	0.281	0.219	24.87	0.302	0.011	0.177

*, ** significant at 0.05 and 0.01 levels, of probability, respectively.

Table (9). Estimates of specific combining ability effects of all studied traits for 20 F1 crosses of cucumber during winter season of (2024-2025).

Crosses	Average fruit weight.	Average fruit length.	Early yield weight.	Early yield number	Total yield weight.	Total yield number
P_1 x P_6 P_1 x	25.15**	2.65**	42.70	-1.21	0.02	10.97**
P_7	12.48**	2.58**	148.50*	0.26	0.35**	-3.57**
P_1 x P_8 P_1 x	-12.65**	-3.95**	-217.70**	-2.18**	-0.03	4.61**
P_9	-24.98**	-1.28*	26.50	3.13**	-0.34**	9.93**
P_2 x P_6 P_2 x	-26.60**	-4.60**	40.87	2.59**	0.13 **	14.46**
P_7	9.40**	3.33**	-178.33**	-2.35**	0.45**	2.14**
P_2 x P_8 P_2 x	15.60**	0.80	148.47*	0.41	0.13**	-7.68**
P_9	1.60*	0.47	-11.00	-0.65	-0.71**	-8.91**
P_3 x P_6 P_3 x	2.32**	3.57**	-63.88	-0.75	-0.37**	-4.66**
P_7	-7.68**	-3.50**	-52.08	0.06	-0.02	3.73**
P_3 x P_8 P_3 x	-4.82**	-0.03	-36.95	0.04	-0.61**	-5.66**
P_9	10.18**	-0.03	152.92**	0.66	1.00**	6.60**
P_4 x P_6 P_4 x	1.57*	-1.60**	-84.13	-1.35	0.45**	4.07**
P_7	-9.10**	-2.00**	-17.00	0.49	-0.02	5.37**
P_4 x P_8 P_4 x	10.77**	2.80**	-7.53	-1.07	0.27**	-2.24**
P_9	-3.23**	0.80	108.67	1.93**	-0.70**	-7.20**
P_5 x P_6 P_5 x	-2.43**	-0.02	64.45	0.72	-0.23**	-2.90**
P_7	-5.10**	-0.42	98.92	1.54*	-0.76**	-7.67**
P_5 x P_8 P_5 x	-8.90**	0.38	113.72*	2.81**	0.24**	10.97**
P_9	16.43**	0.05	-277.08**	-5.06**	0.75**	-0.41
SE sca	0.629	0.491	55.63	0.675	0.025	0.395

*, ** significant at 0.05 and 0.01 levels, of probability, respectively.

The proportional contribution

The value of contribution for lines ranged from 3.34% for total yield number to 24.11% for average fruit length. Whereas, the contribution value for testers excuded contribution of lines for average fruit weight per plant, early yield number, total yield weight and number with values (34.73%,7.93%, 25.97% and 38.65%) respectively.

Table (10). Percentage of Proportional contribution (%) for lines, testers and lines x testers relative to total variations for all traits of Cucumber during winter season (2024 –2025).

Traits	Genotypes		
	Line %	Tester %	Line x tester %
Average fruit weight	12.87	34.73	52.40
Average fruit length	24.11	2.39	73.50
Early yield weight	15	14.34	70.66
Early yield number	4.87	7.93	87.20
Total yield weight	17.42	25.97	56.60
Total yield number	3.34	38.65	58.01

The contribution of L × T interactions for different traits ranged from 52.40% for average fruit weight to 87.20% for number of early yield, it also recorded greater proportion for studied traits than both lines and testers. From these results, we suggested that, the higher contribution of L × T interactions than the individual contribution of lines and testers due to the interaction between lines and testers for the previous traits Table 10. As regard of proportional contribution **v**arious results obtained by Hanchinamani (2006), Sharma (2010), Dogra and Kanwar (2011), Golabadi et al. (2012) and Al-Araby et al. (2019) on cucumber.

CONCLUSIONS:

This experiment estimated the heterosis and combining ability for nine inbreed lines crossed in 5 × 4 Line × Tester design, genetic variability was found between genotypes. It could be concluded that, the lines Cu12, Cu14, and the tester Cu2e, were the best parents for most traits. P_4 and P_9 were a promising parent inbred line due to high early yield number. The cross $P_3 \times P_9$ has a big value of SCA effects for total yield, the cross $P_4 \times P_7$ had the best heterotic and superiority values for weight and number of early yield over (B.P), since, the genotype $P_1 \times P_9$ had great values over (C.H) for early yield number, in addition to the crosses $P_2 \times P_8$ and $P_5 \times P_8$ were superiority over (C.H) for total weight and number of fruits respectively.

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الملخص العربى

تأثير الفعل الجينى وقوة الهجين على المحصول في الخيار تحت ظروف البرودة

أحمد محمد عبد الباقى أبوشنادى، مسعد خيرى مأمون، تهانى رشاد السيد

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

يعد الخيار واحداً من أهم محاصيل الخضر في مصر تم التهجين بين خمسة سلالات من الخيار مرباة داخلياً مع أربعة سلالات أخرى بطريقة السلالةx الكشاف لإنتاج 20 هجين بينهم. تم زراعة التسعة آباء مع 20 هجين بالإضافة إلى الهجين الأول التجارى Rafal F1 الذى استخدم للمقارنة، وتم تقييم الصفات الثمرية ومكونات المحصول الكلى والمبكر في تجربة تحت ظروف الصوب البلاستيكية في ثلاثة مكررات بتصميم القطاعات كاملة العشوائية بالمزرعة البحثية في منطقة سخا بمحافظة كفر الشيخ خلال الموسم الشتوى 2024/2025، وذلك لقياس قوة الهجين والقدرة على التآلف لسلالات الآباء. أظهرت النتائج أن متوسط مربعات التباين الخاص بالسلالات والآباء والهجن الناتجة منهما كانت معنوية لكل الصفات المدروسة. وكانت الهجن $P_4 \times P_6$ و $P_4 \times P_7$ و $P_4 \times P_8$ متفوقة واعطت قيمة معنوية موجبة نسبة الى الأب الأعلى لصفة وزن المحصول المبكر، بينما أعطى الهجين $P_1 \times P_6$ قيمة معنوية موجبة نسبة للأب الأعلى فى صفة الوزن الكلى للمحصول. وكانت السلالة CU14والكشاف CU2e ذات قدرة عامة عالية على التآلف بالنسبة لوزن المحصول المبكر ، بينما كانت السلالتانCU14 و CU12والكشافCU2e وCU7e أفضل قدرة عامة على التألف بالنسبة لصفة الوزن الكلى للمحصول، بالنسبة للقدرة الخاصة على التآلف أعطت الهجن $P_1 \times P_7$،$P_3 \times P_9$ أعلى قيم بالنسبة للمحصول المبكر والهجن$P_5 \times P_9$، $P_3 \times P_9$ أعلى قيم للمحصول الكلى.