Egypt. J. Plant Breed. 28(3): 317-341 (2024)

TRADITIONAL BREEDING OF GREENHOUSE CUCUMBER TO DEVELOPE INBRED LINES AND HYBRIDS WITH HIGH PRODUCTIVITY, QUALITY AND LONG POSTHARVEST SHELF LIFE

I.N. Nasef
Horticulture Dept., Faculty of Agriculture, Suez Canal University, 41522, Ismailia, Egypt.
E-mail: innasef@hotmail.com.

ABSTRACT

This study was conducted on greenhouse cucumber to generate inbred lines by self-pollination across six generations between 2016 and 2021ina private farm at 10th Ramadan association, Ismailia, Egypt. Ten F_1 hybrids were produced by half-diallel crossings between the five inbred lines during 2021/2022 season. The genotypes and a check variety were evaluated during the two consecutive winter seasons 2022/2023 and 2023/2024.Main stem length, internode length, branches number, days until the first female flowering, node of the first female flower, number of female flowers per node, fruit weight, diameter, length and color, fruits number/plant, total yield/plant and weight loss during postharvest shelf-life traits were measured. The results showed highly significant differences among genotypes in all studied traits. Also, highly significant variances were observed for GCA and SCA for all traits during both seasons, which suggested that both additive and non-additive gene action were important in the expression of all characters. Furthermore, the cross P_2 × P_4 and P_4 × P_5 exhibited desirable values of SCA effects and heterosis for all studied traits. Mostly, the parentsP_2, P_4 and P_5 could be used in breeding programs to produce parthenocarpicgynoecious hybrids of greenhouse cucumber.

Key words: ***Cucumis sativus,combining ability, heterosis, storability, yield quality***.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important vegetables in *Cucurbitaceae* family. It has a chromosome number 2n = 2X = 14 (Swamy 2023).It has been studied as a model crop for genomic research in cucurbitaceous vegetables because it has a smaller genome size (367 Mbp) (Huang *et al* 2011).It is native to Africa and India. Cucumber is cultivated world wide to consume fresh relished mostly as salad and processed as pickled cucumber. Cucumber has high water content and low calories, chlolesterol, fat and sodium, and is a good source for mineral nutrients (P, K, Ca and Mg). In addition, it has medicinal properties such as anti-inflammatory, antioxidant and anti-cancer benefits. Also, cucumber is used for digestive benefits and mood stability by modulating stress. Furthermore, cucumber may slow age-related cellular deteriorations by fortifying cells (Akhtar *et al* 2020).The cultivated cucumber is very low in available genetic diversity, which is impediment in improving the genetics of various market classes of cucumber. So, the increase of genetic diversity in cultivated cucumber is considered a major task in the public sector research. Earliness, uniform it of fruit color, shape and size, high yield, better quality, postharvest shelf life, parthenocarpic and gynoecious are desirable traits for production of greenhouse cucumber and are important objectives in cucumber breeding (Jat *et al* 2021).Cucurbits can be improved by exploiting heterosis breeding and combining ability estimates. Therefore, an appropriate selection for parents in the program of breeding is vital for success. The superior trait identified in the parent cannot be guaranteed in their progeny if trait cannot be transferred. So, it has become imperative to screen germplasm of cucumber to isolate desirable cross combinations and potential combining lines either to obtain new recombinants or to exploit heterosis. Therefore, the method that can help breeders to choose the desirable parent and crosses will be interested. Genetic analysis is a guide line for identifying best combiners and assessing relative breeding potential of parents in crop, which could be used to exploit heterosis in F_1 hybrid or for accumulating fixable genes to new variety. Heterosis and combining ability analysis studies are indispensable tools in any program of breeding. They provide the desired genetic description concerning heterosis exploitation or improvement of variety for commercial gains. Diallel analysis had been used to give adequate information about heterosis and combining ability of parents in crosses to segregate desirable population (Ene *et al* 2019).Developing cultivar with high yield and better quality is a major goal of breeding program in cucumber. Parthenocarpy discovery in cucumber led to the production of seedless fruit with gynoecious trait. Parthenocarpy coupled with gynoecy is better parameter for yield and quality suited for protected cultivation. Because the fruit of these cultivars don't require pollination to set. Fortunately, greenhouse parthenocarpic cucumber fruit are seedless, mild in flavor and doesn't require peeling because it has a thin skin. Therefore, using one or more gynoecious lines as parents in breeding program has made possible to produce good hybrids with high yield and quality. Traditional breeding can benefit in cucumber by exploiting gynoecious along with parthenocarpic traits. Several methods of breeding have been employed for improving genetics of cucumber such as single seed descent method, single plant selection, mass selection, pedigree selection, simple backcross breeding, hybridization, population improvement, extraction of inbred lines and use of sex inheritance and chemicals in breeding (Jat *et al* 2021).Egypt makes significant efforts to increase the protected cultivation area to cover local market requirements and for exporting of vegetables. Many studies wereconducted to improve the yield and quality of cucumber. But there is lack in cucumber breeding to exploit heterosis and combining ability to obtain better cultivars. Therefore, the objectives of the current study were to develope local inbred lines and hybrids of greenhouse cucumber with high productivity, quality and long postharvest shelf life under room conditions by estimating combining ability and heterosis in traditional breeding using half diallel mating design.

MATERIAL AND METHODS

Five inbred lines, as shown in Table (1), were generated by self-pollination across six generations under greenhouse from 2016 to 2021 in a private farm at 10th Ramadan association, Ismailia, Egypt. Ten F_1 hybrids were produced by crossing the five inbred lines in a half-diallel mating design during 2021/2022 season. The genotypes (5 inbred lines, their 10 F_1 hybrids, and the commercial hybrid (Kassab F_1)) were evaluated under greenhouse conditions, during the two consecutive winter seasons 2022/2023 and 2023/2024. The male flowers in parthenocarpic gynoecious lines P_4 and P_5 were induced by spraying silver nitrate, first at 2-3 leaf stage (Beyer 1976).

Table 1. List of the cucumber inbred lines used in the breeding program.

Inbred lines	Code	Sex expression	Origin
CAIN	P_1	Monoecious	Egypt
C7IN	P_2	Monoecious	Egypt
C6IN	P_3	Monoecious	Egypt
CSIN	P_4	Parthenocarpicgynoecious	Egypt
CWIN	P_5	Parthenocarpicgynoecious	Egypt

Field evaluation

The five inbred lines, their 10 F_1 hybrids, and the check variety (Kassab F_1) were planted in the greenhouse under drip irrigation system during the winter seasons 2022/2023 and 2023/2024, in a randomized complete blocks design with three replications. The soil of the greenhouse was cleared, ploughed and harrowed. Then, organic manure was added at rate of 30 m^3/feddan. The width of row was 1.5 m and its length was 4 m. Seeds of genotypes under study were directly sown in hills spaced 50 cm apart on both sides of the row, on the 7^{th} and 15^{th} of October in the seasons of 2022/2023 and 2023/2024, respectively. The normal agricultural managements such as fertilization, control of insects and fungi as well as weed control were performed according to the recommendations of the Egyptian Ministry of Agriculture for cucumber production under greenhouse conditions.

Recorded data

1- **Vegetative growth, flowering and yield:** Four plants from each plot were used to record the following data: Main stem length (m), internode length (cm), branches number, days until the first female flowering, node of the first female flower, number of female flowers per node, fruit weight (g), diameter (cm) and length (cm), fruits number/plant, and total yield/plant(kg) traits were measured.

2- Weight loss (%): The weight loss of cucumber fruits in each replicate were weighed (g) before the storage as an initial weight and then were weighed after three days of postharvest shelf life at room conditions. The weight loss was calculated as a percentage from the initial weight.

3- **Color:** Fruit color was evaluated using a Hunter colorimeter (Hunter Instrument DP-9000, Japan) which measures L* indicate lightness (‘100L’ indicates white, ‘0L’ indicates black), a* (+a* indicates redness, −a* indicates greenness) b* (+b* indicates yellow, −b* indicates blue) (Nasef 2018).

Statistical analysis

Data were statistically analyzed, using analysis of variance (ANOVA) with Co Stat version 6.303 1998-2004, Co Hort software,798 Lighthouse Ave, PMP320, Monterey, CA 93940, USA. Duncan’s test was performed at $P \leq 0.05$ significance level to compare the means.

Genetic analyses

Combining abilities

General and specific combining abilities were estimated using ADG-R program according to Method 2, Model 1 of Griffing (1956).

Heterosis

The heterosis based on mid-parent and better-parent was calculated manually in Microsoft Excel-2010 as percentages as per the formula given by Mather and Jinkes (1982), in each cross as follows:

a. Mid-parent heterosis (M.P.H.) = [(F_1-M.P)/M.P] ×100

b. Better parent heterosis (B.P.H.) = [(F_1-B.P)/B.P] ×100

Where, F_1 = Mean of the F_1 hybrid, M.P. = mean of the two parents involved in F_1 cross i.e., ($P_1 + P_2$)/2, B.P. is the mean value of better parent. Significance of the estimated heterosis was tested with "t" test according to Chaudhary *et al* (1978), as follows:

$tM.P.H. = (F1 - M.P.)/\sqrt{\frac{3}{2} \times \frac{MSe}{r}}$ and $tB.P.H. = (F1 - B.P.)/\sqrt{2 \times \frac{MSe}{r}}$

Where, MSe = Error mean squares,r = Number of replications, tM.P.H.= t for heterosis over mid-parents value, tB.P.H.=t for heterosis over better parent value.

RESULTS

Performance of genotypes

1- Vegetative growth characters

The results presented in Table (2) show the mean performance of 5 cucumber parental inbred lines and their10 F_1 hybrids for main stem length, internode length, branches number, day until flowering, node of the first female flower and number of female flowers per node traits during 2022/2023 and 2023/2024 seasons. Significant differences were found among the 5 parents and 10 hybrids for vegetative growth characters (main stem length, internode length and branches number). $P_2 \times P_4$ recorded the highest value followed by $P_4 \times P_5$ for vegetative growth traits. The shortest period for appearing the first female flower was recorded with $P_2 \times P_5$in both seasons, followed by $P_4 \times P_5$, in the first season, and by $P_1 \times P_5$ in the second season, however no significant differences were observed between $P_4 \times P_5$ and the check variety in both seasons. $P_2 \times P_4$ and $P_4 \times P_5$ gave the highest number of female flowers per node in both seasons. $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_4$, $P_2 \times P_5$, $P_3 \times P_4$, $P_3 \times P_5$, $P_4 \times P_5$ and check variety had the lowest node of the first female flower.

Table 2. Mean performance of 5 cucumber parental inbred lines and their 10 F_1 hybrids in addition to the check cultivar (Kassab F_1) for the traits main stem length (MSL), internode length (INL) and branches number, days until first female flowering (DUF), node of the first female flower (NFFF), number of female flowers per node (NFFN), during 2022/2023 and 2023/2024 seasons

Genotypes	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022-2023 season					
P_1	3.10g	5.33gh	8.00fg	41.67b	21.33c	1.67c
P_2	3.87abc	6.53abc	9.33cdef	42.67b	22.33bc	1.67c
P_3	3.75cde	6.83a	8.33fg	44.00a	21.33c	1.67c
P_4	3.30f	5.67efg	10.67bc	40.00c	1.00d	2.00bc
P_5	3.17fg	5.83defg	10.00cde	39.00cd	1.00d	2.00bc
$P_1\times P_2$	3.60e	6.20bcde	7.67g	40.00c	24.00a	1.67c
$P_1\times P_3$	3.87abc	6.57ab	7.67g	39.00cd	24.00a	1.67c
$P_1\times P_4$	3.67de	6.17bcde	8.67efg	38.00de	1.00d	2.67ab
$P_1\times P_5$	3.62e	6.33abcd	9.33cdef	38.00de	1.00d	2.33abc
$P_2\times P_3$	3.70cde	6.83a	9.00defg	45.00a	23.00ab	2.00bc
$P_2\times P_4$	4.00a	6.00cdef	13.33a	38.33d	1.00d	3.00a
$P_2\times P_5$	3.80bcd	5.60fg	12.00ab	36.00f	1.00d	2.67ab
$P_3\times P_4$	3.80bcd	6.00cdef	12.00ab	39.00cd	1.00d	2.33abc
$P_3\times P_5$	3.87abc	5.83defg	12.33a	40.00c	1.00d	2.00bc
$P_4\times P_5$	3.97ab	5.03h	13.00a	36.67ef	1.00d	3.00a
Check Var	3.70cde	5.93def	10.33cd	38.00de	1.00d	2.00bc
Genotypes	2023-2024 season					
P_1	3.10g	5.17de	8.00e	40.00cd	21.67c	2.00bcd
P_2	3.87abc	6.17abc	9.33cd	42.00ab	22.33bc	1.67cd
P_3	3.73cde	6.67a	8.33de	42.67a	21.67c	1.67cd
P_4	3.30f	6.17abc	10.67b	40.00cd	1.00d	2.00bcd
P_5	3.13g	5.50cde	10.00bc	39.00de	1.00d	2.00bcd
$P_1\times P_2$	3.63e	6.67a	8.00e	40.33c	23.67a	1.33d
$P_1\times P_3$	3.83bcd	6.33ab	8.00e	39.33cd	23.67a	1.67cd
$P_1\times P_4$	3.70de	5.83bcd	9.00cde	37.67fg	1.00d	2.67ab
$P_1\times P_5$	3.63e	5.50cde	9.33cd	37.67fg	1.00d	2.00bcd
$P_2\times P_3$	3.70de	6.67a	9.33cd	41.33b	22.33ab	1.67cd
$P_2\times P_4$	4.00a	5.50cde	13.33a	38.00fg	1.00d	2.67ab
$P_2\times P_5$	3.87abc	5.67bcde	12.33a	37.00g	1.00d	2.00bcd
$P_3\times P_4$	3.80cd	5.33de	12.33a	39.67cd	1.00d	2.33abc
$P_3\times P_5$	3.83bcd	5.50cde	12.33a	39.67cd	1.00d	2.67ab
$P_4\times P_5$	3.97ab	5.00e	13.00a	37.00g	1.00d	3.00a
Check Var	3.70de	5.83bcd	10.00bc	38.33ef	1.00d	2.00bcd

Means in the same column with the same letters are not significantly different at $P\leq 0.05$ according to Duncan's multiple range test.MSL = main stem length, INL = internode length, BN = branches number, days until first female flowering (DUF), NFFF = node of the first female flower and NFFN = number of female flowers per node.

2- Fruit characters

There are significant differences among all studied genotypes of cucumber for fruit characters (fruit weight, length, diameter and color) and fruits number per plant as shown in Table 3, however, $P_2 \times P_4$ and $P_4 \times P_5$ exhibited an appropriate character for Egyptian market for weight, length and diameter and gave the lowest value of L and b, and high negative value of -a which means more green color of fruit than other genotypes. Additionally, the highest number of fruits per plant was obtained with $P_2 \times P_4$ and $P_4 \times P_5$ followed by the check variety.

Table 3. Mean performance of 5 cucumber parental inbred lines and their 10 F_1 hybrids in addition to the check cultivar (Kassab F_1) for fruit weight (FW), fruit length (FL) and fruit diameter (FD) ,fruits color (-a and +b), fruit numbers per plant (FNP), yield per plant (YP) and weight loss (WL) after three days at room temperature during 2022/2023 and 2023/2024 seasons.

Genotypes	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season								
P_1	84.48h	11.33h	3.30bcd	33.28d	-8.30bc	16.23c	48.33f	4.04h	11.13b
P_2	123.55a	15.17ef	3.47bcd	39.90a	-7.47a	20.63ab	37.67i	4.27h	8.79de
P_3	124.07a	15.17ef	3.57b	36.60b	-7.97b	21.67a	39.67i	4.28h	9.42cd
P_4	99.27g	15.17ef	3.17cd	31.63e	-8.50c	16.27c	56.00de	5.68ef	8.67e
P_5	99.13g	17.00ab	3.13d	31.07ef	-8.57c	16.23c	58.00cd	5.90de	8.86de
$P_1 \times P_2$	104.26f	15.83cde	3.33bcd	31.13ef	-8.40bc	16.30c	44.67g	4.84g	8.33e
$P_1 \times P_3$	112.04cd	15.33def	3.23bcd	34.60c	-9.37e	20.47ab	42.00h	5.27fg	8.89de
$P_1 \times P_4$	109.31d	14.17g	3.17cd	31.07ef	-9.63ef	14.10de	58.67c	6.00cde	8.84de
$P_1 \times P_5$	114.26bc	14.50fg	3.27bcd	30.37ef	-10.10fgh	14.10de	58.00cd	6.42bcd	13.23a
$P_2 \times P_3$	109.58d	17.00ab	4.13a	36.77b	-9.17de	19.80b	37.67i	5.95cde	6.94f
$P_2 \times P_4$	108.80de	17.17a	3.30bcd	30.07fg	-10.40gh	13.73e	65.00a	6.91ab	7.34f
$P_2 \times P_5$	114.95bc	16.83ab	3.27bcd	31.27ef	-10.22gh	14.27de	55.33e	5.97cde	8.91de
$P_3 \times P_4$	117.30b	16.17bcd	3.23bcd	32.93d	-8.77cd	14.50de	56.33cde	6.33cd	9.69c
$P_3 \times P_5$	109.91d	16.50abc	3.50bc	32.10d	-8.33bc	15.43cd	57.00cde	6.26cd	9.66c
$P_4 \times P_5$	109.08d	17.33a	3.27bcd	28.93g	-10.50h	12.43f	66.00a	7.08a	7.40f
Check Var	105.84ef	16.67abc	3.27bcd	30.00fg	-9.90fg	13.50ef	61.00b	6.45abc	9.36cd

Table 3. Cont.

Genotypes	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2023/2024 season								
P_1	84.58g	11.67g	3.33cd	33.93d	-8.63bcde	16.43c	47.33f	4.11h	11.59b
P_2	125.67a	15.50de	3.53bc	40.43a	-7.73a	20.93ab	38.67i	4.43h	8.62efg
P_3	126.00a	15.50de	3.63b	36.20b	-7.87a	21.87a	40.00hi	4.40h	9.58cd
P_4	100.07ef	15.17ef	3.23d	33.23de	-8.47bc	16.53c	55.00e	5.80f	8.37g
P_5	97.33f	16.83abc	3.13d	32.77e	-8.50bcd	16.43c	57.33cd	6.18cde	8.55efg
$P_1 \times P_2$	110.41cd	16.07cd	3.37cd	32.47e	-8.17ab	16.87c	44.33g	4.99g	8.63efg
$P_1 \times P_3$	109.18d	15.50de	3.27d	35.17c	-8.63bcde	21.00ab	41.67h	5.15g	9.73cd
$P_1 \times P_4$	113.66b	14.33f	3.23d	30.67fg	-9.43fgh	14.40de	57.67cd	5.95ef	8.47fg
$P_1 \times P_5$	111.00bcd	14.83ef	3.30cd	30.17gh	-9.73hi	14.60de	58.33c	6.49bc	14.11a
$P_2 \times P_3$	109.67d	16.67abc	4.20a	36.23b	-9.10efg	20.27b	39.00i	5.92ef	6.58h
$P_2 \times P_4$	109.33d	17.33ab	3.33cd	29.90gh	-10.17i	14.03de	65.67a	7.00a	7.06h
$P_2 \times P_5$	113.71b	17.00ab	3.33cd	31.37f	-9.90hi	14.67de	56.00d	6.13def	9.22def
$P_3 \times P_4$	111.97bcd	16.50bc	3.23d	33.03de	-9.00def	14.20de	57.00cde	6.02def	10.12c
$P_3 \times P_5$	113.03bc	16.50bc	3.40bcd	30.80fg	-8.90cde	14.93d	57.67cd	6.34bcd	9.76cd
$P_4 \times P_5$	109.16d	17.50a	3.30cd	29.53h	-10.13hi	12.73f	65.00a	7.05a	6.91h
Check Var	102.66e	17.00ab	3.30cd	29.97gh	-9.53gh	13.80e	61.33b	6.53b	9.35cde

Means in the same column with the same letters are not significantly differed at $P \leq 0.05$ according to Duncan's multiple range test. FW = fruit weight, FD = fruit diameter and FL = fruit length, L = lightness,-a = indicates blue and +b = indicates yellow, FNP = fruit number per plant, YP = yield per plant and WL = weight loss percentage after 3 days at room temperature.

3- Yield and weight loss during postharvest shelf life

The results showed that $P_2 \times P_4$ and $P_4 \times P_5$ gave the highest yield per plant followed by check variety compared with other genotypes of cucumber under study in both seasons under greenhouse conditions (Table 3). Concerning the weight loss during postharvest shelf life of genotypes, significant differences were observed, where $P_2 \times P_4$ had the lowest weight loss followed by $P_2 \times P_4$ and $P_4 \times P_5$ with no significant difference between them

Genetic analysis

The analysis of variance for combining ability showed significant differences among the genotypes for all studied traits under study (Tables 4 and 5). The mean squares due to general combining ability GCA and specific combining ability (SCA) exhibited highly significant for all parameters in both seasons. Regarding GCA/SCA ratio, the ratio was more than unity for all parameters, except for -a trait in both seasons.

Table 4. Mean squares of analysis of variance for general and specific combining ability (GCA and SCA) for main stem length (MSL), internode length (INL), branches number (BN), days until first female flowering (DUF), node of the first female flower (NFFF) and number of female flowers per node (NFFN) of cucumber in a half-diallel cross during 2022/2023 and 2023/2024 seasons.

SOV	df	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022/2023 season						
GCA	4	0.09***	0.57***	8.29***	11.87***	321.98***	0.34**
SCA	10	0.07***	0.18***	2.21***	4.38***	40.94***	0.19*
Error	28	0.003	0.03	0.24	0.17	0.26	0.07
GCA/SCA		1.24	3.14	3.76	2.71	7.86	1.79
SOV	2023/2024 season						
GCA	4	0.088***	0.52***	7.83***	5.94***	323.59***	0.35**
SCA	10	0.075***	0.23***	2.20***	1.88***	40.88***	0.18*
Error	28	0.002	0.05	0.14	0.10	0.14	0.07
GCA/SCA		1.167	2.24	3.56	3.16	7.91	1.89

***, **, *** significance at 0.05, 0.01 and 0.001, probability levels, respectively. SOV = Source of variances, df = Degree of freedom, MSL = Main stem length, INL= Internode length, BN = Branch numbers, DUF= days until the first female flowering, NFFF = Node of the first female flower, NFFN = Number of female flowers per node.**

Table 5. Mean squares of analysis of variance for general and specific combining ability (GCA and SCA) for fruit weight (FW), fruit length (FL)), fruit diameter (FD), fruit color (L, -a and +b), fruit number per plant (FNP), yield per plant (YP) and weight loss (WL) after three days at room temperature in a half-diallel cross during 2022/2023 and 2023/2024 seasons.

SOV	df	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season									
GCA	4	178.05***	6.14***	0.11***	20.75***	0.60***	17.71***	236.29***	1.54***	3.56***
SCA	10	68.32***	0.96***	0.04**	4.20***	1.02***	4.55***	33.74***	0.64***	1.94***
Error	28	0.70	0.09	0.01	0.18	0.03	0.17	0.54	0.03	0.04
GCA/SCA		2.61	6.41	2.82	4.95	0.59	3.89	7.00	2.40	1.84
SOV	2023/2024 season									
GCA	4	185.95***	5.40***	0.12***	15.81***	0.51***	17.75***	211.09***	1.64***	5.70***
SCA	10	70.41***	0.88***	0.04***	6.12***	0.65***	5.11***	37.23***	0.52***	2.76***
Error	28	0.98	0.08	0.01	0.10	0.03	0.12	0.55	0.01	0.07
GCA/SCA		2.64	6.14	2.78	2.58	0.78	3.48	5.67	3.16	2.07

**** and *** significance at 0.01 and 0.001 probability levels, respectively. S.O.V.= Source of variances, df = Degree of freedom, FW= Fruit weight, FD= Fruit diameter, FL = Fruit length, L= lightness, -a = indicates blue, +b = indicates yellow, FNP= Fruit number per plant, YP= Yield per plant and WL= weight loss.**

General combining ability effects

The results in Tables (6 and 7), showed that P_2 gave the highest positive value with highly significant level for MSL, while P_1 gave the highest negative value in both seasons. The GCA of INL trait of P_3had the highest positive value with highly significant level in both seasons, while P_4 had the highest negative value followed by P_5 in the first season, however P_5had the highest negative value followed by P_4 in the second season. The line P_4gave the highly significant and positive GCA effects followed by line P_5 in both seasons for BN trait.P_5 parent exhibited highest negative value of GCA effect with high significant level followed by P_4 parent for DUF trait in both seasons. Both $P_4$and P_5gave highest negative value of GCA for NFFF with no significant difference between them in both seasons.

The GCA effects of NFFN trait of P_4had the highest positive value followed by P_5 in both seasons (Table 6).The highest positive value of GCA effects for FW was recorded with P_3 while the highest negative value was recorded with P_1 in both seasons. P_1 showed the highest negative GCA value while P_5 showed the highest positive GCA value for FL in both seasons. P_4 recorded the highest negative GCA effects followed by P_5 for FD during the two seasons. Regarding fruit color (L, -a and b), both P_4 and P_5 showed desirable negative GCA effects in both seasons. The GCA effects of FNP and YP traits were positive values with highly significant probability level in both seasons. P_2 and P_4 parents exhibited desirable negative GCA effects for WL trait in both seasons (Table 7).

Table 6. Estimates of general combining ability (GCA) effects of five inbred lines in a half diallel design for main stem length (MSL), internode length (INL), branches number (BN), days until the first female flowering (DUF), node of the first female flower (NFFF) and number of female flowers per node (NFFN) of cucumber during 2022/2023 and 2023/2024 seasons.

The Inbred lines	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022/2023 season					
P_1	-0.154**	-0.027ns	-1.600**	-0.09ns	4.95**	-0.18**
P_2	0.115**	0.159**	0.019ns	0.82**	5.10**	-0.04ns
P_3	0.101**	0.397**	-0.410**	1.72**	4.81**	-0.23**
P_4	0.001ns	-0.293**	1.114**	-0.99**	-7.43**	0.30**
P_5	-0.063**	-0.236**	0.876**	-1.47**	-7.43**	0.15*
	2023/2024 season					
P_1	-0.149**	-0.057ns	-1.571**	-0.219*	4.93**	-0.12ns
P_2	0.128**	0.252**	0.048ns	0.590**	5.08**	-0.22*
P_3	0.085**	0.300**	-0.381**	1.257**	4.89**	-0.12ns
P_4	0.004ns	-0.152*	1.095**	-0.600**	-7.45**	0.30**
P_5	-0.068**	-0.343**	0.810**	-1.029**	-7.45**	0.16*

***, ** significance at 0.05 and 0.01probability levels, respectively, ns = non-significant. MSL = Main stem length, INL = Internode length, BN = Branches number, DUF = days until the first female flowering, NFFF = Node of the first female flower and NFFN = Number of female flowers per node.**

Table 7. Estimates of general combining ability (GCA) effects of five inbred lines in a half diallel design for fruit weight (FW), fruit length (FL), fruit diameter (FD), fruit color (L, -a and +b), fruit number per plant (FNP), yield per plant (YP) and weight loss (WL) of cucumber during 2022/2023 and 2023/2024 seasons.

The Inbred lines	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season								
P_1	-6.74**	-1.62**	-0.08*	-0.48**	0.02ns	-0.15ns	-1.73**	-0.50**	1.01**
P_2	4.09**	0.47**	0.12**	1.71**	0.16**	0.99**	-4.88**	-0.26**	-0.76**
P_3	5.85**	0.21*	0.16**	1.93**	0.39**	2.15**	-5.69**	-0.25**	-0.06ns
P_4	-1.85**	0.19*	-0.12**	-1.55**	-0.29**	-1.60**	6.55**	0.51**	-0.55**
P_5	-1.36**	0.76**	-0.08*	-1.61**	-0.29**	-1.40**	5.74**	0.49**	0.35**
	2023/2024 season								
P_1	-6.36**	-1.53**	-0.07**	-0.29**	0.07ns	-0.03ns	-2.23**	-0.51**	1.32**
P_2	5.22**	0.47**	0.14**	1.78**	0.14**	1.11**	-4.28**	-0.21**	-0.88**
P_3	5.42**	0.20*	0.15**	1.32**	0.34**	2.02**	-5.28**	-0.31**	0.06ns
P_4	-1.95**	0.18*	-0.11**	-1.25**	-0.27**	-1.65**	6.15**	0.46**	-0.80**
P_5	-2.34**	0.68**	-0.10**	-1.57**	-0.27**	-1.45**	5.63**	0.57**	0.31**

***, ** significance at 0.05 and 0.01probabilty levels, respectively, ns = non-significant. FW = Fruit weight, FD = Fruit diameter, FL = Fruit length, L = lightness, -a = indicates blue, +b = indicates yellow, FNP= Fruit number per plant, YP = Yield per plant and WL = weight loss.**

Specific combining ability effects

Results in Tables (8 and 9) showed specific combining ability for some traits of cucumber during 2022/2023 and 2023/2024 season. The results indicated that P_2 x P_4 and P_4 x P_5 hybrids had high significance level for all traits under study compared with other hybrids in both seasons.

Table 8. Estimates of specific combining ability (GCA) effects of five inbred lines in half diallel crosses for main stem length (MSL), internode length (INL), branches number (BN), days until the first female flowering (DUF), node of the first female flower (NFFF) and number of female flowers per node (NFFN) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022/2023 season					
$P_1 \times P_2$	-0.03ns	0.048ns	-0.84*	-0.56ns	4.29**	-0.27ns
$P_1 \times P_3$	0.25**	0.176ns	-0.41ns	-2.46**	4.57**	-0.08ns
$P_1 \times P_4$	0.15**	0.467**	-0.94*	-0.75*	-6.19**	0.40*
$P_1 \times P_5$	0.16**	0.576**	-0.03ns	-0.27ns	-6.19**	0.21ns
$P_2 \times P_3$	-0.19**	0.257ns	-0.70ns	2.63**	3.43**	0.11ns
$P_2 \times P_4$	0.21**	-0.352*	2.11**	-1.32**	-6.33**	0.59**
$P_2 \times P_5$	0.08ns	-0.343*	1.02*	-3.17**	-6.33**	0.40*
$P_3 \times P_4$	0.03ns	-0.124ns	1.21**	-1.56**	-6.05**	0.11ns
$P_3 \times P_5$	0.16**	-0.348*	1.78**	-0.08ns	-6.05**	-0.08ns
$P_4 \times P_5$	0.36**	-0.457**	0.92*	-0.70*	6.19**	0.40*
2023/2024 season						
$P_1 \times P_2$	-0.02ns	0.63**	-0.70*	0.540*	3.97**	-0.41*
$P_1 \times P_3$	0.22**	0.25ns	-0.27ns	-1.127**	4.16**	-0.17ns
$P_1 \times P_4$	0.17**	0.20ns	-0.75*	-0.937**	-6.17**	0.40*
$P_1 \times P_5$	0.18**	0.06ns	-0.13ns	-0.508*	-6.17**	-0.13ns
$P_2 \times P_3$	-0.19**	0.27ns	-0.56*	0.063ns	3.68**	-0.08ns
$P_2 \times P_4$	0.20**	-0.44*	1.97**	-1.413**	-6.32**	0.49*
$P_2 \times P_5$	0.13**	-0.09ns	1.25**	-1.984**	-6.32**	-0.03ns
$P_3 \times P_4$	0.04ns	-0.66**	1.40**	-0.413ns	-6.13**	0.06ns
$P_3 \times P_5$	0.14**	-0.30ns	1.68**	0.016ns	-6.13**	0.54*
$P_4 \times P_5$	0.36**	-0.35*	0.87**	-0.794**	6.21**	0.44*

***, ** significance at 0.05 and 0.01 probability levels, respectively, ns = non-significant. MSL = Main stem length, INL= Internode length, BN = Branch numbers, DUF = days until the first female flowering, NFFF = Node of the first female flower and NFFN = Number of female flowers per node.**

Table 9. Estimates of specific combining ability (SCA) effects of five inbred lines in half diallel crosses for fruit weight (FW)), fruit length (FL), fruit diameter (FD), fruit color (L, -a and +b), fruit number per plant (FNP), yield per plant (YP) and weight loss (WL) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season								
$P_1\times P_2$	-2.44**	1.34**	-0.07ns	-2.94**	0.46**	-0.95**	-0.75ns	-0.08ns	-0.99**
$P_1\times P_3$	3.59**	1.10**	-0.20*	0.30ns	-0.73**	2.05**	-2.60**	0.33*	-1.14**
$P_1\times P_4$	8.57**	-0.04ns	0.01ns	0.24ns	-0.32*	-0.57ns	1.83**	0.30*	-0.70**
$P_1\times P_5$	13.03**	-0.28ns	0.07ns	-0.39ns	-0.79**	-0.77*	1.97**	0.75**	2.79**
$P_2\times P_3$	-9.71**	0.67**	0.50**	0.28ns	-0.67**	0.25ns	-3.79**	0.77**	-1.31**
$P_2\times P_4$	-2.78**	0.87**	-0.06ns	-2.94**	-1.23**	-2.07**	11.30**	0.98**	-0.43*
$P_2\times P_5$	2.88**	-0.04ns	-0.13ns	-1.68**	-1.05**	-1.73**	2.44**	0.06ns	0.24ns
$P_3\times P_4$	3.96**	0.13ns	-0.16*	-0.30ns	0.18ns	-2.47**	3.44**	0.38**	1.23**
$P_3\times P_5$	-3.91**	-0.11ns	0.07ns	-0.07ns	0.61**	-1.73**	4.92**	0.33*	0.29ns
$P_4\times P_5$	2.96**	0.75**	0.11ns	-0.76*	-0.88**	-0.99**	1.68**	0.39**	-1.47**
2023/2024 season									
$P_1\times P_2$	1.89*	1.33**	-0.09ns	-2.09**	0.58**	-0.87**	-1.21*	-0.02ns	-0.95**
$P_1\times P_3$	0.46ns	1.03**	-0.20**	1.07**	-0.09ns	2.35**	-2.87**	0.24**	-0.80**
$P_1\times P_4$	12.32**	-0.11ns	0.03ns	-0.85**	-0.27*	-0.58*	1.70**	0.27**	-1.20**
$P_1\times P_5$	10.04**	-0.11ns	0.09ns	-1.04**	-0.57**	-0.58*	2.89**	0.70**	3.33**
$P_2\times P_3$	-10.62**	0.20ns	0.53**	0.07ns	-0.62**	0.48ns	-3.49**	0.70**	-1.75**
$P_2\times P_4$	-3.59**	0.89**	-0.08ns	-3.69**	-1.07**	-2.09**	11.75**	1.02**	-0.40*
$P_2\times P_5$	1.17ns	0.06ns	-0.09ns	-1.91**	-0.80**	-1.65**	2.60**	0.04ns	0.64**
$P_3\times P_4$	-1.16ns	0.33ns	-0.19**	-0.10ns	-0.11ns	-2.84**	4.08**	0.13ns	1.71**
$P_3\times P_5$	0.29ns	-0.17ns	-0.03ns	-2.02**	-0.01ns	-2.30**	5.27**	0.35**	0.24ns
$P_4\times P_5$	3.79**	0.85**	0.13*	-0.71**	-0.63**	-0.83**	1.17*	0.29**	-1.75**

*** and ** significance at 0.05 and 0.01 probability levels, respectively, ns = non-significant. FW = Fruit weight, FD = Fruit diameter, FL = Fruit length, L = lightness, -a = indicates blue, +b = indicates yellow, FNP = Fruit number per plant, YP = Yield per plant and WL = weight loss.**

Heterosis

Data in Tables (10 and 11) show the heterosis percentage based on mid-parent for some traits of cucumber during 2022/2023 and 2023/2024 seasons.

Table 10. Heterosis percentage relative to mid-parent (H M.P%) for main stem length (MSL), internode length (INL), branches number (BN), days until the first female flowering (DUF), node of the first female flower (NFFF) and number of female flowers per node (NFFN) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022/2023 season					
$P_1\times P_2$	3.35*	4.49ns	-11.54ns	-5.14**	9.92**	0.00ns
$P_1\times P_3$	12.90**	7.95*	-6.12ns	-8.95**	12.50**	0.00ns
$P_1\times P_4$	14.58**	12.12**	-7.14ns	-6.94**	-91.04**	45.45**
$P_1\times P_5$	15.43**	13.43**	3.70ns	-5.79**	-91.04**	27.27ns
$P_2\times P_3$	-2.84*	2.24ns	1.89ns	3.85*	5.34*	20.00ns
$P_2\times P_4$	11.63**	-9.29**	33.33**	-7.26**	-91.43**	63.64**
$P_2\times P_5$	8.06**	-9.43**	24.14**	-11.84**	-91.43**	45.45**
$P_3\times P_4$	7.80**	-4.00ns	26.32**	-7.14**	-91.04**	27.27ns
$P_3\times P_5$	11.81**	-7.89*	34.55**	-3.61**	-91.04**	9.09ns
$P_4\times P_5$	22.68**	-12.46**	25.81**	-7.17**	0.00ns	50.00**
	2023/2024 season					
$P_1\times P_2$	4.31**	17.65**	-7.69ns	-1.63*	7.58**	-27.27ns
$P_1\times P_3$	12.20**	7.04ns	-2.04ns	-4.84**	9.23**	-9.09ns
$P_1\times P_4$	15.63**	2.94ns	-3.57ns	-5.83**	-91.18**	33.33*
$P_1\times P_5$	16.58**	3.12ns	3.70ns	-4.64**	-91.18**	0.00ns
$P_2\times P_3$	-2.63*	3.90ns	5.66ns	-2.36**	6.06**	0.00ns
$P_2\times P_4$	11.63**	-10.81*	33.33**	-7.32**	-91.43**	45.45**
$P_2\times P_5$	10.48**	-2.86ns	27.59**	-8.64**	-91.43**	9.09ns
$P_3\times P_4$	8.06**	-16.88**	29.82**	-4.03**	-91.18**	27.27ns
$P_3\times P_5$	11.65**	-9.59*	34.55**	-2.86**	-91.18**	45.45**
$P_4\times P_5$	23.32**	-14.29**	25.81**	-6.33**	0.00ns	50.00**

***, ** significance at 0.05 and 0.01 probability levels, respectively, ns = non-significant. MSL=Main stem length, INL = Internode length, BN = Branch numbers, DUF = days until the first female flowering, NFFF = Node of the first female flower and NFFN = Number of female flowers per node.**

Table 11. Heterosis percentage relative to mid-parent (H M.P%) for fruit weight (FW), fruit length (FL), fruit diameter (FD), fruit color (L, -a and +b), fruit number per plant (FNP), yield per plant (YP) and weight loss (WL) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season								
$P_1 \times P_2$	0.24ns	19.50**	-1.48ns	-14.91**	6.55**	-11.57**	3.88*	16.25ns	-16.33**
$P_1 \times P_3$	7.45**	15.72**	-5.83ns	-0.97ns	15.16**	8.00**	-4.55*	26.84*	-13.49**
$P_1 \times P_4$	18.98**	6.92**	-2.06ns	-4.28**	14.68**	-13.23**	12.46**	23.46**	-10.67**
$P_1 \times P_5$	24.47**	2.35ns	1.55ns	-5.62**	19.76**	-13.14**	9.09**	29.29**	32.43**
$P_2 \times P_3$	-11.49**	12.09**	17.54**	-3.88**	18.79**	-6.38**	-2.59ns	38.87ns	-23.77**
$P_2 \times P_4$	-2.34**	13.19**	-0.50ns	-15.94**	30.27**	-25.56**	38.79**	38.73**	-15.92**
$P_2 \times P_5$	3.25**	4.66*	-1.01ns	-11.88**	27.48**	-22.60**	15.68**	17.29**	0.94ns
$P_3 \times P_4$	5.04**	6.59**	-3.96ns	-3.47*	6.48**	-23.55**	17.77**	27.17**	7.21**
$P_3 \times P_5$	-1.51ns	2.59ns	4.48ns	-2.17ns	0.81ns	-18.56**	16.72**	23.07**	5.66*
$P_4 \times P_5$	9.96**	7.77**	3.70ns	-7.71**	23.05**	-23.49**	15.79**	22.27**	-15.48**
2023/2024 season									
$P_1 \times P_2$	5.03**	18.31**	-1.94ns	-12.68**	-0.20ns	-9.72**	3.10ns	16.81**	-14.54**
$P_1 \times P_3$	3.69**	14.11**	-6.22*	0.29ns	4.65*	9.66**	-4.58*	20.90**	-8.02**
$P_1 \times P_4$	23.11**	6.83**	-1.52ns	-8.68**	10.33**	-12.64**	12.70**	19.94**	-15.16**
$P_1 \times P_5$	22.04**	4.09ns	2.06ns	-9.55**	13.62**	-11.16**	11.46**	26.18**	40.16**
$P_2 \times P_3$	-12.85**	7.53**	17.21**	-5.44**	16.67**	-5.30**	-0.85ns	33.87**	-27.68**
$P_2 \times P_4$	-3.13**	13.04**	-1.48ns	-18.82**	25.51**	-25.09**	40.21**	36.72**	-16.88**
$P_2 \times P_5$	1.98**	5.15*	0.00ns	-14.30**	21.97**	-21.50**	16.67**	15.57**	7.40*
$P_3 \times P_4$	-0.95ns	7.61**	-5.83*	-4.85*	10.20**	-26.04**	20.00**	17.91**	12.73**
$P_3 \times P_5$	1.22ns	2.06ns	0.49ns	-10.68**	8.76**	-22.02**	18.49**	19.91**	7.71*
$P_4 \times P_5$	10.59**	9.38**	3.66ns	-10.51**	19.45**	-22.75**	15.73**	17.67**	-18.31**

***, ** significance at 0.05 and 0.01, respectively, ns = non-significant. FW = Fruit weight, FD = Fruit diameter, FL = Fruit length, L = lightness, -a = indicates blue, +b = indicates yellow, FNP = Fruit number per plant, YP = Yield per plant and WL = weight loss.**

The highest positive value of heterosis for MSL and negative value for INL were recorded with P_4x P_5. The hybrids of P_2 x P_4, P_2 x P_5, P_3 x P_4, P_3 x P_5 andP_4 x P_5 gave high positive value of heterosis for BN in both seasons. P_2 x P_4, P_2 x P_5, P_4 x P_5 exhibited high positive value of heterosis with highly significant level in both seasons. The highest negative value of heterosis for NFFF was observed in P_2 x P_4, P_2 x P_5. The cross P_2 x P_4gave the highest positive value followed by P_4 x P_5 for NFFN in the first season. Desirable values were observed for FW, FL, color (L, -a and +b), FN, YP and WL with P_2 x P_4 andP_4 x P_5 hybrids compared with other hybrids in both seasons. P_2 x P_3 exhibited the highest negative value with highly significant level for FD in both seasons. Concerning the heterosis based on better parent, the results in Table (12 and 13) showed that P_2 x P_4 exhibited high significant levels for all traits of cucumber under study in both seasons.

Table 12. Heterosis percentage relative to better parent (H B.P %) for main stem length (MSL), internode length (INL), branches number (BN), days until the first female flowering (DUF), node of the first female flower (NFFF) and number of female flowers per node (NFFN) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	MSL (m)	INL (cm)	BN	DUF	NFFF	NFFN
	2022/2023 season					
$P_1\times P_2$	-6.90**	-5.10ns	-17.86*	-6.25**	7.46**	0.00ns
$P_1\times P_3$	3.11ns	-3.90ns	-8.00ns	-11.36**	12.50**	0.00ns
$P_1\times P_4$	11.11**	8.82*	-18.75**	-8.80**	-95.31**	33.33*
$P_1\times P_5$	14.21**	8.57*	-6.67ns	-8.80**	-95.31**	16.67ns
$P_2\times P_3$	-4.31**	0.00ns	-3.57ns	2.27*	2.99ns	20.00ns
$P_2\times P_4$	3.45*	-15.31**	25.00**	-10.16**	-95.52**	50.00**
$P_2\times P_5$	-1.72ns	-14.29**	20.00**	-15.63**	-95.52**	33.33*
$P_3\times P_4$	1.33ns	-12.20**	12.50*	-11.36**	-95.31**	16.67ns
$P_3\times P_5$	3.11ns	-14.63**	23.33**	-9.09**	-95.31**	0.00ns
$P_4\times P_5$	20.20**	-13.71**	21.88**	-8.33**	0.00ns	50.00**
2023/2024 season						
$P_1\times P_2$	-6.03**	8.11ns	-14.29**	-3.97**	5.97**	-33.33*
$P_1\times P_3$	2.68ns	-5.00ns	-4.00ns	-7.81**	9.23**	-16.67ns
$P_1\times P_4$	12.12**	-5.41ns	-15.63**	-5.83**	-95.38**	33.33*
$P_1\times P_5$	15.96**	0.00ns	-6.67ns	-5.83**	-95.38**	0.00ns
$P_2\times P_3$	-4.31**	0.00ns	0.00ns	-3.12*	4.48*	0.00ns
$P_2\times P_4$	3.45*	-10.81*	25.00**	-9.52**	-95.52**	33.33*
$P_2\times P_5$	0.00ns	-8.11ns	23.33**	-11.90**	-95.52**	0.00ns
$P_3\times P_4$	1.79ns	-20.00**	15.63**	-7.03**	-95.38**	16.67ns
$P_3\times P_5$	2.68ns	-17.50**	23.33**	-7.03**	-95.38**	33.33*
$P_4\times P_5$	20.20**	-18.92**	21.88**	-7.50**	0.00 ns	50.00**

***, ** significance at 0.05 and 0.01, respectively, ns = non-significant. MSL = Main stem length, INL = Internode length, BN = Branches number, DUF = days until the first female flowering, NFFF = Node of the first female flower and NFFN = Number of female flowers per node.**

Table 13. Heterosis percentage relative to better parent (H B.P%) for fruit weight (FW), fruit length (FL), fruit diameter (FD), fruit color (L, -a and +b), fruit number per plant (FNP), yield per plant (YP) and weight loss (WL) of cucumber during 2022/2023 and 2023/2024 seasons.

Hybrid	FW (g)	FL (cm)	FD (cm)	L	-a	+b	FNP	YP (kg)	WL (%)
	2022/2023 season								
$P_1 \times P_2$	-15.61**	4.40ns	-3.85ns	-21.97**	12.50**	-21.00**	-7.59**	12.87**	-25.09**
$P_1 \times P_3$	-9.69**	1.10ns	-9.35ns	-5.46**	17.57**	-5.54*	-13.10**	23.31**	-20.12*
$P_1 \times P_4$	10.11**	-6.59*	-4.04*	-6.65**	16.06**	-13.32**	4.76**	5.64**	-20.54**
$P_1 \times P_5$	15.27**	-14.71**	-1.01**	-8.75**	21.69**	-13.14**	0.00ns	8.93ns	18.93**
$P_2 \times P_3$	-11.68**	12.09**	15.89**	-7.85**	22.77**	-8.62**	-5.04*	38.68ns	-26.30**
$P_2 \times P_4$	-11.93**	13.19**	-4.81**	-24.64**	39.29**	-33.44**	16.07**	21.76**	-16.53**
$P_2 \times P_5$	-6.96**	-0.98ns	-5.77ns	-21.64**	36.88**	-30.86**	-4.60**	1.31ns	0.57ns
$P_3 \times P_4$	-5.46**	6.59*	-9.35*	-10.02**	10.04**	-33.08**	0.60ns	11.48*	2.91ns
$P_3 \times P_5$	-11.41**	-2.94ns	-1.87ns	-9.56**	4.60ns	-28.77**	-1.72ns	6.18ns	2.51ns
$P_4 \times P_5$	9.88**	1.96ns	3.16ns	-8.54**	23.53**	-23.57**	13.79**	20.02**	-16.40**
2023/2024 season									
$P_1 \times P_2$	-12.14**	3.68ns	-4.72ns	-19.70**	5.60*	-19.43**	-6.34**	12.52**	-25.50**
$P_1 \times P_3$	-13.35**	0.00ns	-10.09**	-2.85*	9.75**	-3.96*	-11.97**	16.88**	-16.01**
$P_1 \times P_4$	13.58**	-5.49*	-3.00ns	-9.63**	11.42**	-12.90**	4.85**	2.43ns	-26.94**
$P_1 \times P_5$	14.04**	-11.88**	-1.00ns	-11.10**	14.51**	-11.16**	1.74ns	5.08*	21.76**
$P_2 \times P_3$	-12.96**	7.53**	15.60**	-10.39**	17.67**	-7.32**	-2.50ns	33.38**	-31.30**
$P_2 \times P_4$	-13.00**	11.83**	-5.66*	-26.05**	31.47**	-32.96**	19.39**	20.59**	-18.07**
$P_2 \times P_5$	-9.52**	0.99ns	-5.66*	-22.42**	28.02**	-29.94**	-2.33ns	-0.71ns	6.96ns
$P_3 \times P_4$	-11.14**	6.45*	-11.01**	-8.75**	14.41**	-35.06**	3.64*	3.67ns	5.64ns
$P_3 \times P_5$	-10.29**	-1.98ns	-6.42*	-14.92**	13.14**	-31.71**	0.58ns	2.70ns	1.92ns
$P_4 \times P_5$	9.08**	3.96ns	2.06ns	-11.13**	19.69**	-22.98**	13.37**	14.14**	-19.15**

***, ** significance at 0.05 and 0.01 probability levels, respectively, ns = no significant. FW = Fruit weight, FD = Fruit diameter, FL = Fruit length, L = lightness, -a = indicates blue, +b = indicates yellow, FNP = Fruit number per plant, YP = Yield per plant and WL = weight loss.**

DISCUSSION

Traditional breeding has made revolution in cultivation of cucumber by exploiting gynoecious along with parthenocarpic traits. Also, traditional breeding is exploited for major changes in important qualitative traits such as fruit size, fruit yield and early maturity (Jat *et al* 2021). In cucumber, strategies of conventional breeding contribute immensely in development of improved cultivars with high productivity, superior quality and different biotic and abiotic stresses resistance. The current study as traditional breeding produced inbred lines and F_1 hybrids with high yield, quality and storability during postharvest shelf life. The results revealed that the mean performance of the crossesP_2 x P_4 (monoecious x gynoecious) and P_4 x P_5 (gynoecious x gynoecious) exhibited the best value for all traits under study. These results indicated that the parents P_2, P_4 and P_5 might be recommended as good combiners in the new breeding program. These results are in agreement with those reported by Kumar *et al* (2018).

Analysis of variance for combining ability of all traits of inbred lines and F_1 hybrids of greenhouse cucumber under study showed high significance for both GCA and SCA during two seasons. The high significant level of GCA and SCA mean squares suggests that additive and non-additive components play an important role in heritable variance which are responsible for variation observed in traits. These observations are in line with the results of Dogra and Kanwar (2011), Mule *et al* (2011) and Sarkar and Sirohi (2011) in cucumber. Also, Ene *et al* (2019) stated that GCA variance had a significant role in fruit length and diameter, indicating that additive genes had greater effects on genetic control in these traits. Furthermore, both additive and non-additive components are involved in the heritable variance for fruit length, diameter, fruit yield and total yield (Lopez-Sese and Staub 2002;Olfati*et al* 2012).GCA/SCA ratio is more than one in all traits except -a trait which showed the preponderance of additive gene effects.P_4 and P_5 had high significant variance for internode length, branch numbers, days until the first female flowering, node of the first female flower, number of female flowers per node, fruit weight, fruit diameter, fruit length, fruit color (L= lightness, -a = indicates blue, +b = indicates yellow), fruit number per plant, yield per plant and weight loss during postharvest shelf life of greenhouse cucumbers under study in both seasons. This suggests that the parthenocarpic gynoecious inbred lines P_4 and P_5 are good combiners for these traits. Traits with significant variance for GCA has been suggested as the best strategy of improvement which indicate the predominance of additive gene effects while SCA has been suggested through hybridization, hence, the predominance of non-additive gene effects (Ene *et al* 2019).Also, the potentiality of any line to be used as a parent in hybridization depends on the F_1 hybrid performance derived from it and its GCA effects (Bhutia *et al* 2017).

The specific combining ability signifies the predominance of non-additive gene action for the expression of traits. The crosses with high SCA effects are useful to achieve high performance of hybrids. In the current study, the specific combinations $P_2 \times P_4$ and $P_4 \times P_5$were identified as best hybrids and provided the high significant values for all the traits of greenhouse cucumber under study. These could be due to they involved parents with high × high, low × high or low × low general combining ability effects, especially for main stem length, fruit weight, fruit number per plant and yield per plant which indicate the presence of additive and non-additive genes effects in controlling the traits. In some traits, the superiority of combinations involving high × low or low × low general combiners as parents may be due to the genetic diversity among parents in the form of heterozygous loci number of parent which involved in the crosses (Bhutia *et al* 2017 and Kumar *et al* 2018).In some investigated traits, parent with low GCA effects gave hybrids with high SCA effects, this may be due to complementary gene effect, while parents with high GCA effects produced hybrids with low SCA effects, which may be attributed to lack of complementation of the parental genes (Hussien and Hamed 2015). According to Ene *et al* (2019) and Singh *et al* (2013), high × high GCA combinations can be used for developing superior variants through pedigree method, while high × low GCA combinations are suitable for heterosis breeding. The current study suggested that P_2, P_4 and $P_5$are good general combiners and can be utilized in a hybridization program.

Hybrid vigour or heterosis is a biological phenomenon which describes superiority of the F_1hybrid offspring resulting from crossing of genetically dissimilar homozygous parents over the average of both its parents (Baranwal *et al* 2012). Heterosis is useful for exploiting dominance and over dominance in producing hybrids. Heterosis plays a vital role in enhancing cucumber yield. Also, it refers to the phenomenon in which the F_1 hybrid produced from crossing of two genetically dissimilar genotypes or inbred lines, displays decreased or increased vigor over the mid or better parent value (Poehlman 1979).In cucurbits, heterosis was first distinguished by Hays and Jones (1961). In commercial production, F_1 hybrid seeds are heterozygous gynoecious with gynoecious character and called predominantly female (Wien 1997).Simi *et al* (2017) reported that high heterosis in F_1 hybrids of cucumber indicated genetic diversity between parents, and may be used for development of hybrid varieties in cucumbers. Additionally, several studies suggested that gynoecious is considered an important economic trait to determine the earliness and yield of cucumber, therefore, using a gynoecious line in breeding program can enhance cucumber yield (Jat *et al* 2021; Swamy 2023). The current study revealed that crosses of P_2 x P_4 (monoecious x gynoecious) and P_4 x P_5 (gynoecious x gynoecious) were the best hybrid combinations for vegetative growth, flowering, yield and storability during postharvest shelf life. These results are in agreement with Jat *et al* (2015) and Jat *et al* (2016), who found that gynoecious × gynoecious and gynoecious × monoecious hybrids exhibited maximum heterosis followed by monoecious × monoecious for earliness and yield. In this context, sex expression of gynoecious in gynoecious × monoecious F_1 hybrid is governed by partial dominance (More and Munger1987). Also, El-Remaly *et al* (2021) stated that the non-additive gene action appeared by heterosis values in cucumber. So, this study shows that the F_1 hybridsP_2 x P_4 and P_4 x P_5can be exploited for genetic improvement, yield and storability traits of greenhouse cucumbers.

CONCLUSION

From the present study, it is concluded that P_2, P_4, P_5 are promising inbred lines due to their good vegetative growth, flowering, high productivity, good fruits quality and storability during postharvest shelf life at room temperature. Therefore, the parents P_2, P_4, P_5 could be used as promising progenies for commercial traits of greenhouse cucumber. While, the crosses P_2 x P_4 and P_4 x P_5exhibited the best value for SCA effects and heterosis for all traits under study.

REFERENCES

Akhtar, P, I. Ahmad, A. Jameela, M Ashfaque and Z. Begum (2020). Energizing effectiveness of cucumber (Khayarain) for health. A Review Article. Journal of Emerging Technologies and Innovative Research 7(11):906-917.

Baranwal, V. K., V. Mikkilineni, U. B. Zehr, A. K. Tyagi and S. Kapoor (2012). Heterosis: emerging ideas about hybrid vigour. Journal of experimental botany 63(18): 6309-6314.

Beyer, E.J. (1976). Silver ion, a potent antiethylene agent in cucumber and tomato. HortScience., 11, 195-196.

Bhutia, T.L., A.D. Munshi, T.K. Behera, A.K. Sureja and S.K. Lal (2017). Combining ability for yield and yield related traits and its relationship with gene action in cucumber. Indian J. Hort. 74(1): 51-55. https://doi.org/10.5958/0974-0112.2017.00013.5

Chaudhary, B.S., R.S. Paroda and V.P. Singh (1978). Stability and genetic architecture of harvest index in wheat. J. Plant Breed. 81, 312-318.

Dogra, B.S., and M.S. Kanwar (2011). Selecting parents for developing superior hybrids in cucumber (*Cucumis sativus* L.). Adv. Hort. Sci. 25(4):239–244.

El-Remaly, E.B., H.I. Abd El-Hakim, S.S. Smuda and T.G. Abedelmaksoud (2021). Breeding new pickling cucumber hybrids: A. Morphological characterization and genetic studies. Egypt. J. Agric. Res., 99 (4): 464-474. doi. 10.21608/ejar.2021.96322.1151

Ene C. O., P.E. Ogbonna, C. U. Agbo and U. P. Chukwudi (2019). Heterosis and combining ability in cucumber (*Cucumis sativus* L.). Information Processing in Agriculture 6: 150-157.

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

Hays, H. K. and D. F. Jones (1961). First generation crosses in cucumber. Conn Agric Expt Sta Ann Rpt: 319-322.

Huang, S, R. Li, and Z. Zhang (2011). Genomic data for the domestic cucumber (*Cucumis sativus* var. sativus L.). GigaScience Database. https://doi.org/10.5524/100025

Hussien, A.H. and A.A. Hamed (2015). Diallel analysis for studying heterosis and combining ability of some economical yield traits in pumpkin. J. Plant Prod. 6(3):261–270.

Jat, G.S., A.D. Munshi, T.K. Behera, H. Choudhary and B. Dev (2015). Exploitation of heterosis in cucumber for earliness, yield and yield components utilizing gynoecious lines. Indian Journal of Horticulture 72 (4): 494-499.

Jat, G.S., A.D. Munshi, T.K. Behera and B.S. Tomar (2016). Combining ability estimation of gynoecious and monoecious hybrids for yield and earliness in cucumber (*Cucumis sativus* L.) Indian Journal of Agricultural Sciences 86 (3): 399-403.

Jat, G.S., T.K. Behera, S. Lata, and S. Kumar (2021). Classical Genetics and Traditional Breeding in Cucumber (*Cucumis sativus* L.). In: (Edr. Haiping Wang) Cucumber Economic Values and Its Cultivation and Breeding. https://doi.org/10.5772/intechopen.97593

Kumar, S., R. Kumar and R.K. Dogra (2018). Heterotic potential, potence ratio, combining ability and genetic control of seed vigour traits for yield improvement in cucumber (*Cucumis sativus*). Indian Journal of Agricultural Sciences 88 (5): 771–778. https://doi.org/10.56093/ijas.v88i5.80088

Lopez-Sese, A.I., and J. Staub (2002). Combining ability analysis of yield components in cucumber. J. Americ. Socie. Hort. Sci. 127:931–937.

Mather, K. and J.L. Jinks (1982). Biometrical genetics. 3rd Ed. Champan and Hall, London.

More, T.A. and H.A. Munger (1987). Effect of temperature and photoperiod on gynoecious sex expression and stability in cucumber. Vegetable Science, 14: 42-50.

Mule, P.N., V. Khandelwal, A.B. Patil and B.R. Chaudhary (2011). Combining ability studies in cucumber (*Cucumis sativus* L.). Veg. Sci. 38(2):203–205.

Nasef, I.N. (2018). Short hot water as safe treatment induces chilling tolerance and antioxidant enzymes, prevents decay and maintains quality of cold-stored cucumbers. *Postharvest Biol. Technol.*, 138, 1-10.

Olfati, J.A., H. Samizadeh, B. Rabieiand G. Peyvast (2012). Griffing's methods of comparison for general and specific combining ability in cucumber. Sci. World J. 2012: 1–4.

Poehlman, J. M. (1979). Breeding Field Crops. 2nd edition Westport, Connection: The AVI Publishing Company, Inc.

Sarkar, M. and P.S. Sirohi (2011). Diallel analysis of quantitative characters in cucumber (*Cucumis sativus* L.). Veg. Sci. 38:73–75.

Simi, F., N.A. Ivy, H.B. Saif, S. Akter and M.F.A. Anik (2017). Heterosis in cucumber (*Cucumis sativus* L.). Bangladesh J. Agril. Res. 42(4): 731-747.

Singh, A.K., R.S. Pan and P. Bhavana (2013). Heterosis and combining ability analysis in bitter gourd (*Momordica charantia* L.). Bioscan 8(4):1533–1536.

Swamy, K.R.M. (2023). Origin, distribution, taxonomy, botanical description, genetics, genetic diversity and breeding of Cucumber (*Cucumis sativus* L.). International Journal of Development Research, 13(02): 61542-61559.

Wien, H. C. (1997). The physiology of vegetable crops. CAB international Wallingford, Oxon OXlOSDE, UK.

التربية التقليدية لخيار الصوب لإنتاج سلالات وهجن ذات إنتاجية وجودة عالية وفترة بقاء بعدالحصاد طويلة

إبراهيم ناصف ناصف

قسم البساتين كلية الزراعة جامعة قناة السويس - الإسماعيلية - مصر.

أجريت هذه الدراسة على خيار الصوب؛ لإنتاج سلالات مرباه داخلياً بالتلقيح الذاتي لمدة ستة أجيال متتالية بين عامى ٢٠١٦ و٢٠٢١م فى مزرعة خاصة بجمعية العاشر من رمضان، الإسماعيلية، مصر. أنتجت عشرة هجن خلال عام ٢٠٢٢/٢٠٢١م بالتهجين نصف التبادلى بين السلالات الخمس المرباه داخلياً.قيمت السلالات الخمس والهجن المنتجة منها بالمقارنة مع الصنف التجاري (كساب) خلال الموسمين الشتويين ٢٠٢٣/٢٠٢٢ و٢٠٢٤/٢٠٢٣م. وتم تسجيل قياسات طول الساق الرئيسي، وطول السلامية، وعدد الأفرع، والأيام حتى تزهير أول زهرة مؤنثة، ورقم العقدة لأول زهرة مؤنثة، وعدد الأزهار المؤنثة على العقدة، ووزن الثمرة، وقطر الثمرة، وطول الثمرة، ولون الثمرة، وعدد الثمار على النبات، والمحصول الكلى للنبات، وفقد الوزن خلال فترة البقاء بعد الحصاد. أظهرت النتائج اختلافات معنوية عالية بين التراكيب الوراثية فى كل الصفات تحت الدراسة.كما لوحظت معنوية عالية لكل من القدرة العامة والخاصة على التآلف لكل الصفات فى الموسمين، والتى تقترح أهمية الفعل الجينى للجينات المضيفة، وغير المضيفة فى كل الصفات. علاوة على ذلك، أظهرت التهجينات $P_4 \times P_2$ و$P_5 \times P_4$ قيم مرغوبة لكل من القدرة الخاصة على التآلف وقوة الهجين. فى الغالب، يمكن استخدام الأباء P_2 وP_4 وP_5 فى برامج التربية لإنتاج الهجن المؤنثة البكرية العقد لخيار الصوب.

المجلة المصرية لتربية النبات ٢٨ (٣): ٣١٧ - ٣٤١ (٢٠٢٤)