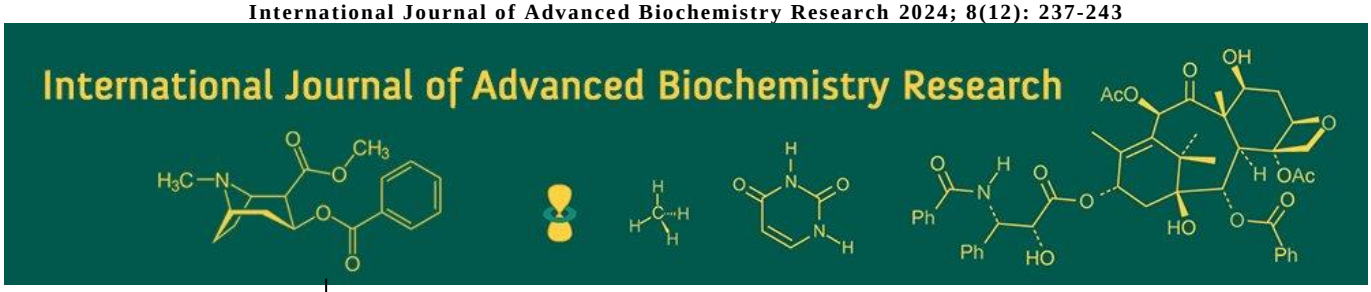

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(12): 237-243
www.biochemjournal.com
Received: 02-08-2024
Accepted: 03-09-2024

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Combining ability studies in cucumber (*Cucumis sativus* L.)

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DOI: https://doi.org/10.33545/26174693.2024.v8.i12d.3102

Abstract
The present investigation entitled "Combining ability studies in cucumber (*Cucumis sativus* L.)" was carried out at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. The study was undertaken on 45 crosses made by 10 x 10 half diallel method and their parents of cucumber along with two commercial hybrids namely Gypsy and Chitra over two growing seasons i.e. *kharif* 2022 and summer 2023. Study explores the combining ability for various important quantitative traits in cucumber *viz*., length of vine (m), Number of nodes per vine, days to 1st female flower, number of fruits/vine, fruit length (cm) fruit diameter (cm), weight of fruit (g), yield/vine (kg), yield/plot (kg) and yield/hectare (t) etc. The F_1 hybrids *viz*. P_1 x P_9 (Cucumber-1 x Cucumber-9), P_2 x P_3 (Cucumber-2 x Cucumber-3), P_4 x P_8 (Cucumber-4 x Cucumber-8), P_4 x P_{10} (Cucumber-4 x Cucumber-10), P_5 x P_7 (Cucumber-5 x Cucumber-7), and P_5 x P_9 (Cucumber-5 x Cucumber-9) showed best *per se* performance and estimates of combining ability (Positive as well as negative) for earliness, yield and yield attributing characters. Persent study displayed direct relationship between *per se* performance and combining ability of hybrids for several traits.

Keywords: Combining ability, cucumber, quantitative traits, half diallel etc.

Introduction
Among the cucurbits, cucumber is distinct with a unique sex mechanism and this feature can easily be manipulated for production of F_1 hybrid seeds. Further, the crop is advantageous in having low inbreeding depression, high heterosis percentage, large number of seeds per fruit and low seed rate requirement per unit area favours commercial exploitation of heterosis in cucumber. The fruits and seeds possess cooling, astringent and antipyretic properties and the fruits are good for people suffering from constipation, jaundice and indigestion (Vashista, 1974) [17]. Considerable heterosis has been manifested in cucumber for various traits such as number of fruits, early and high yield. Heterosis in cucumber has been exploited to maximum advantage in developed countries. The first commercial hybrid in vegetables released for cultivation was in cucumber in 1935 in japan. India, being a Native place of cucumber, possesses great range of genetic variability for qualitative and quantitative characters (Munshi *et al.* 2007) [9]. In spite of this, very little effort has been made for genetic improvement of this crop through exploitation of hybrid vigour. India is the second largest producer of vegetables in the world next only to China, producing 199.88 million tonnes of vegetables annually from an area of 11.06 million hectares (Anon., 2022) [3].
Combining ability is one of the powerful tools in identifying the best combiners that may be used to exploit heterosis or to accumulate fixable genes. The plant breeding programme attempts to improve current kinds and create new types that are superior to commercial cultivars. Variability is required for such crop development programmes. Breeders can easily utilize sufficient variability if it exists. Otherwise, variety is created by the use of several breeding strategies, the most common of which is hybridization, which remains the principal tool for plant breeders. As India is the origin of cucumber a wide range of variability available in this crop. Selection of parents for breeding program is one of the important prerequisite, as general combining ability (GCA) analysis is one of the strategy for selecting desirable parents and cross combinations were selected based on the specific combining

ability (SCA*)* for further exploitation. In this context this experiment was carried out to identify the good general combiner and specific combiner for yield and yield attributing traits.

Cucumber has a broad range of diversity, making it suitable for hybridization. Early maturity, fruit yield and fruit qualities are the decisive elements whether variety will succeed or fail. Knowledge of the nature of gene influence for yield and their contributing qualities is always beneficial in the selection of effective and efficient breeding procedures. Keeping this in mind, the current study is being conducted to investigate the heterosis, combining ability and gene action for quantitative features, as well as to estimate heritability for yield contributing characters and to check the disease and pest tolerance in the F_1 hybrids of cucumber along with the parents.

Although, many researchers have explored the combining ability in cucumber, but the aim of this study was to find out the genotypes which can be further used for the hybridization programmes and develop the new hybrids which are suitable for the Maharashtra state weather condition.

Materials and Methods

The present investigation on ‘‘Combining ability studies in cucumber (*Cucumis sativus* L.)” was carried out at All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif* 2022 and summer 2023. Geographically experimental field has an altitude of 532 m above mean sea level, latitude of 19^0 47’ to 19^0 57’ N and longitude of 74^0 82’ to 74^0 91’ E. Rahuri comes under arid and tropical region and having temperature range 7.30 ºC to 39.30 ºC with 65% relative humidity. The average day length is of 8 hours and 30 minutes. Annual rainfall varies from 307 to 619 mm and average rainfall is 475 mm. Most of this rainfall is received through south-west monsoon. The experiment was conducted on medium black soil with appropriate drainage. The plot was ploughed and harrowed twice to bring the fine tilth of soil.

The inbred lines of ten genotypes were selected for the purpose of crossing programme and sown in crossing block at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Recommended dose of fertilizers and plant protection measures were taken up. The female and male flowers due to opening next morning were aged separately in the evening. Next day, the female flowers were hand pollinated in the morning after anthesis with pollens collected from previously bagged, male flowers and repeating it in the next morning to ensure good fruit set. The parents were also selfed simultaneously to obtain pure seeds of each genotype. The pedicel of each pollinated flower was tied with label bearing the information of female and male parents and date of crossing for identification. Crossing was made in diallel fashion (without reciprocals).

Experiment was laid in randomized block design with two replications having a plant spacing of 1.5 X 0.5 m^2 and plot size of 1.5 X 5 m^2, where the total numbers of treatments are 57 in which 45 F_1 hybrids, 10 parents and 2 standard checks.

Results and Discussion

Mean performance of Parent and hybrids for important quantitative traits

The Mean performance of parents are presented in Table 1 and described below in favorable direction.

Length of vine (m)

In *kharif* season, Cucumber-8 (P_8) (2.93m) and in the summer season Cucumber-7 (P_7) (2.61m) recorded significantly maximum length of vine. In *kharif* season, hybrid combination P_5 x P_9 (3.92m) recorded significantly maximum length of vine. Among the 45 crosses, the cross P_5 x P_9 (3.53m) recorded a significant maximum length of vine in summer. Similar results of parents and hybrids for length of vine were reported by Singh and Tiwari (2006) [15], Tiwari and Singh (2015) [16].

Number of fruits/vine

During *kharif*, the significant maximum number of fruits per vine were produced by parent cucumber 6 (P_6) (13.8) In summer season, the significantly maximum number of fruits per vine were produced by parent cucumber-2 (P_2) (16.2). In *kharif* season, the cross combination P_2 x P_3 (17.1) recorded significantly more number of fruits per vine. Whereas among all the crosses, the cross combination P_2 x P_3 (18.6), P_1 x P_4 (18.6) recorded a significantly maximum number of fruits per vine during summer season. Similar results were found by Sawant *et al*. (2017) [14].

Length of fruit (cm)

During both the season, the significant maximum length of fruit was found in parent cucumber-8 (19.5 cm and 19.7 cm respectively in *kharif* and summer). The result more or less same obtained by Al-Araby *et al.* (2017) [2] and Gharib *et al.* (2020) [6].

Diameter of fruit (cm)

During *kharif*, the significant maximum diameter of fruit was found in parent cucumber-2 (P_2) (4.86cm). In summer season, the significantly maximum diameter of fruit were produced by parent cucumber-3 (P_3) (6.06cm). In *kharif* season, the cross combination P_4 x P_6 (5.16cm) recorded significantly maximum diameter of fruit. Whereas among all the crosses, the cross combination P_4 x P_{10} (5.49cm) recorded a significantly maximum diameter of fruit during summer season. Same results were obtained by Sawant *et al*. (2017) [14] and Abd Rabou (2018) [1].

Weight of fruit (g)

During *kharif*, the significant maximum weight of fruit was found in parent cucumber-2 (P_2) (196.6g). In summer season, the significantly maximum weight of fruit was found in parent cucumber-7 (P_7) (197.8g). In *kharif* season, the cross combination P_4 x P_{10} (209.2g) recorded significantly maximum weight of fruit**.** Whereas among all the crosses, the cross combination P_5 x P_{10} (210.4g) recorded a significantly maximum weight of fruit during summer season.The result coincides in with following studies Sawant *et al*. (2017) [14], Singh and Tiwari (2006) [15], Al-Araby *et al.* (2017) [2], Gharib *et al.* (2020) [6].

Table 1: Mean performance of parents and their crosses in 10x10 half diallel for various characters in cucumber

Sr. No.	Parents/ Hybrids	Length of vine (m)		Number of fruits/vine		Length of Fruit (cm)		Diameter of Fruit (cm)		Average weight of fruit (g)		Weight of fruit/vine (kg)		Weight of fruit/plot (kg)	
		Kharif	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer
Parents															
1.	P_1	2.18	2.36	12.2	11.2	16.6	17.1	4.25	3.96	135.8	144.0	1.66	1.91	16.09	19.31
2.	P_2	2.07	1.91	11.6	16.2	15.4	12.7	4.86	4.55	196.6	175.4	2.43	2.81	22.83	27.84
3.	P_3	1.80	1.87	10.4	9.8	15.2	15.2	3.97	6.06	146.4	169.6	1.46	1.70	13.43	16.53
4.	P_4	2.15	2.18	12.0	9.2	14.2	14.2	3.99	5.83	143.2	140.6	1.43	1.27	13.01	12.65
5.	P_5	2.59	2.07	12.2	11.6	17.6	18.3	4.33	5.19	183.6	178.4	1.96	1.85	18.08	17.30
6.	P_6	2.43	2.12	13.8	15.2	15.8	18.4	3.95	4.47	153.0	175.6	2.08	2.60	19.28	24.60
7.	P_7	2.20	2.61	9.0	10.6	16.4	16.2	3.68	5.95	177.4	197.8	1.59	2.11	14.27	21.08
8.	P_8	2.93	2.09	9.4	11.4	19.5	19.7	3.81	5.13	164.0	149.2	1.47	1.64	13.31	17.01
9.	P_9	2.26	2.28	12.6	14.8	16.6	18.1	4.18	5.16	182.8	151.4	2.22	2.23	21.31	21.37
10.	P_{10}	2.45	2.22	9.2	11.2	18.8	16.2	4.34	5.51	164.6	157.6	1.48	1.73	13.28	17.65
Hybrids															
11.	1 x 2	1.85	1.64	13.2	15.0	18.2	15.8	4.32	3.69	167.0	136.8	2.17	2.05	19.39	18.64
12.	1 x 3	1.65	1.79	14.6	16.0	16.6	15.7	4.22	4.02	176.4	148.4	2.51	2.37	24.40	22.94
13.	1 x 4	2.79	2.53	15.8	18.6	18.6	15.6	3.37	3.65	162.4	142.2	2.43	2.56	23.80	25.48
14.	1 x 5	2.18	1.90	13.0	12.8	14.4	16.9	3.96	4.18	138.8	161.4	1.80	1.94	16.56	18.46
15.	1 x 6	1.63	1.71	14.2	14.8	14.8	15.6	3.83	4.23	132.2	147.2	1.85	2.06	17.05	18.99
16.	1 x 7	1.52	1.61	10.4	8.4	17.6	15.6	3.21	3.42	188.8	183.4	1.88	1.65	18.01	15.77
17.	1 x 8	1.83	2.28	16.6	12.8	17.8	16.7	4.15	3.62	154.0	179.4	2.61	2.26	24.25	21.31
18.	1 x 9	2.45	2.24	14.4	16.4	18.4	16.1	4.12	4.44	188.0	190.2	2.63	3.04	25.92	29.16
19.	1 x 10	2.67	2.32	11.8	13.4	18.2	16.8	4.18	4.66	201.0	202.4	2.37	2.83	25.31	27.61
20.	2 x 3	2.52	2.81	17.1	18.6	16.8	16.8	4.36	4.09	190.2	180.8	2.85	3.15	26.67	29.26
21.	2 x 4	2.73	2.42	11.0	13.4	16.2	14.2	3.89	4.00	145.4	134.2	1.59	1.74	16.03	17.55
22.	2 x 5	2.30	2.95	15.4	13.2	15.2	15.2	4.14	4.22	148.8	181.4	2.52	2.36	24.73	23.44
23.	2 x 6	2.94	2.55	13.0	11.6	15.4	16.1	4.02	4.47	150.0	142.0	1.95	1.73	17.54	16.85
24.	2 x 7	2.64	2.24	12.2	13.6	17.2	14.9	5.08	5.44	170.8	166.2	2.04	2.16	19.89	21.52
25.	2 x 8	2.63	1.97	16.0	13.8	18.8	16.3	4.14	3.41	124.0	145.4	1.61	2.04	16.72	19.68
26.	2 x 9	2.07	1.70	13.2	13.4	14.8	14.6	3.85	4.20	148.4	146.4	1.92	1.90	18.16	17.62
27.	2 x 10	2.50	2.21	12.2	13.8	16.6	15.0	4.23	3.54	172.2	187.4	2.18	2.62	21.51	26.80
28.	3 x 4	2.37	2.26	13.6	12.6	16.0	14.5	4.54	4.10	191.4	178.4	2.48	2.19	23.96	20.61
29.	3 x 5	2.23	2.03	12.4	11.6	17.2	13.5	4.57	4.23	167.2	156.8	2.00	1.72	18.19	16.84
30.	3 x 6	2.19	1.94	15.0	14.0	16.4	16.7	3.94	4.57	163.2	157.8	2.44	2.21	23.45	21.62
31.	3 x 7	2.36	2.07	12.4	12.4	17.6	16.1	3.81	4.07	187.8	188.8	2.25	2.27	21.94	22.84
32.	3 x 8	2.69	2.43	15.2	14.4	18.6	16.5	3.07	3.37	153.2	142.2	2.29	1.99	23.14	20.76
33.	3 x 9	2.60	2.51	13.4	11.6	15.8	15.3	4.13	3.98	1580	157.4	2.05	1.73	19.99	16.53
34.	3 x 10	2.13	1.74	11.0	12.8	16.4	14.7	3.97	4.23	187.7	183.4	2.06	2.20	21.08	22.97
35.	4 x 5	2.54	2.51	13.6	11.8	17.6	14.6	4.23	3.88	164.0	165.2	2.13	1.96	20.19	19.265
36.	4 x 6	3.65	2.91	14.4	16.3	14.8	15.3	5.16	3.89	168.6	148.0	2.36	2.39	22.07	22.885
37.	4 x 7	3.01	2.44	15.6	16.0	16.4	14.8	3.69	4.00	150.6	141.0	2.25	2.26	22.01	22.42
38.	4 x 8	2.51	2.43	13.2	11.6	14.6	15.5	4.35	4.38	195.4	208.8	2.33	2.63	22.28	25.38
39.	4 x 9	2.27	1.79	11.6	11.2	15.6	14.3	3.92	4.15	158.0	156.0	1.73	1.56	18.51	14.82
40.	4 x 10	2.71	2.23	12.6	13.6	19.2	15.3	4.24	5.49	209.2	202.2	2.43	2.73	24.03	26.34
41.	5 x 6	3.37	2.95	13.6	12.8	16.6	20.3	4.19	4.09	176.6	202.2	2.33	2.63	22.11	25.45
42.	5 x 7	3.43	2.90	14.2	12.6	17.4	17.7	4.77	4.80	199.8	194.0	2.79	2.33	26.44	22.40
43.	5 x 8	3.55	2.70	12.4	10.4	16.8	18.6	4.11	4.21	188.8	181.8	2.30	1.96	21.61	18.61
44.	5 x 9	3.92	3.53	13.2	15.4	17.4	17.8	4.70	4.32	196.0	200.4	2.54	3.01	24.39	29.66
45.	5 x 10	3.57	3.17	14.2	10.4	15.2	20.6	4.18	4.66	171.4	210.4	2.39	2.19	22.37	21.21
46.	6 x 7	2.32	2.41	11.8	12.2	17.0	17.9	4.12	4.25	206.0	175.8	2.26	2.11	21.94	21.27
47.	6 x 8	2.61	2.05	14.2	13.6	18.6	17.0	4.47	5.08	186.8	188.4	2.61	2.45	25.05	23.33
48.	6 x 9	2.64	2.17	12.4	11.6	15.6	17.8	4.16	4.81	207.2	207.8	2.51	2.29	23.96	21.69
49.	6 x 10	2.85	2.16	12.6	13.6	20.0	18.3	4.39	4.96	202.4	200.0	2.42	2.60	23.16	25.80
50.	7 x 8	3.55	3.29	10.4	13.6	19.2	20.8	3.95	5.28	181.0	149.8	1.88	1.95	18.06	19.77
51.	7 x 9	2.52	2.85	10.6	12.4	19.8	22.6	4.35	5.14	188.8	207.6	2.03	2.61	18.86	26.10
52.	7 x10	3.35	2.72	9.40	12.2	19.6	21.2	3.89	4.79	206.2	164.0	1.88	1.97	17.82	18.78
53.	8 x 9	2.40	2.37	9.40	15.6	19.8	20.9	4.24	4.99	203.8	168.4	2.09	2.53	18.85	24.80
54.	8 x 10	3.91	2.63	13.0	11.8	20.2	20.2	4.01	5.23	183.8	192.4	2.34	2.23	22.22	21.67
55.	9 x 10	2.81	3.21	8.40	10.4	22.2	19.8	3.97	5.19	201.6	167.8	1.75	1.68	15.93	15.18
Std. Check - 1		2.46	2.34	11.4	12.6	14	15.2	4.08	4.04	153.4	131.6	1.68	1.71	16.47	16.71
Std. Check - 2		2.89	2.51	13.2	15.2	17.8	18.8	4.17	4.38	161.8	168.2	2.1	2.52	20.86	25.57
General mean		2.63	2.34	12.81	13.11	17.77	17.30	4.13	4.51	173.39	171.73	2.13	2.19	20.38	21.36
S.E. ±		0.32	0.27	0.89	0.88	0.72	0.80	0.17	0.18	6.27	6.79	0.13	0.16	1.06	1.36
C.D. 5%		0.92	0.79	2.53	2.49	2.04	2.28	0.50	0.51	17.77	19.26	0.39	0.46	3.02	3.86
C.D. 1%		1.22	1.05	3.37	3.32	2.72	3.03	0.67	0.68	23.65	25.64	0.52	0.61	4.03	5.14

Weight of fruit per vine (kg)

During *kharif*, the significant maximum weight of fruit per vine was found in parent cucumber-2 (P_2) (2.43 kg). In summer season, the significantly maximum weight of fruit per vine were produced by parent cucumber-2 (P_2) (2.81 kg). In *kharif* season, the cross combination P_2 x P_3 (2.85 kg) recorded significantly maximum weight of fruit per vine. Whereas among all the crosses, the cross combination P_2 x P_3 (3.15 kg) recorded a significantly maximum weight

of fruit per vine during summer season. Parallel results were obtained by Sawant *et al*. (2017) [14] and Abd Rabou (2018) [1].

Weight of fruit per plot (kg)

During *kharif*, the significant maximum weight of fruit per plot was found in parent cucumber-2 (P_2) (22.83 kg). In summer season, the significantly maximum weight of fruit per plot were produced by parent cucumber-2 (P_2) (27.84 kg). In *kharif* season, the cross combination P_2 x P_3 (26.67 kg) recorded significantly maximum weight of fruit per plot. Whereas among all the crosses, the cross combination P_2 x P_3 (29.26 kg) recorded a significantly maximum weight of fruit per plot during summer season. Results were same with Sawant *et al*. (2017) [14], Singh and Tiwari (2006) [15].

Combining ability for Important Qunatitative traits

General combining ability (GCA) effects

The general combining ability effects of parents are presented in Table 3 and described below in favorable direction.

Length of vine (m)

Amide of 10 three parent i.e. P_5 (0.50), P_8 (0.21) and P_{10} (0.20) showed significantly positive GCA effect in *kharif* season. While in summer three parents *viz.*, P_5 (0.30) and P8 (0.21) showed significantly positive GCA effect. Highly positive GCA is important for inheritance of length of vine character in cucumber; the result indicated that parents having positive good general combining ability for the same trait. The parental line with high GCA effects may be used in multiple crossing programme for finding desirable hybrids in cucumber. Similar results of significant and positive GCA were also obtained by Kumar *et al.* (2021) [8] and Rajaguru *et al.* (2020) [12].

Number of fruits per vine

For number of fruits per vine four parents *viz.*, P4 (0.82), P6 (0.64), P1 (0.61) and P5 (0.54) showed significantly positive GCA effect in *kharif* season. Parent P_2 (1.24), P_6 (0.58) and P1 (0.56) showed significantly positive GCA effect in summer season. Genotypes under study showed positively significant GCA effect for the same character. It could be suggested that these parental genotypes possess favorable genes to improve hybrids for yield components. Similar results were obtained by Pati *et al.* (2015) [11], Dogra and Kanwar (2019) [5], Jat *et al.* (2016) [7] and Naik *et al.* (2018) [10].

Fruit length (cm)

Parent P_8 (2.00), P7 (1.94), P9 (1.84) and P10 (1.47) showed significantly positive GCA effect in *kharif* season. While in summer two parents *viz.*, P7 (2.66), P9 (1.79), P8 (1.62) and P10 (0.85) showed significantly positive GCA effects. The GCA effects registered that the parents under study were good general combiners for yield contributing trait i.e. fruit length. The results are in proximity with Kumar *et al.* (2021) [8] and Rajaguru *et al.* (2020) [12].

Fruit diameter (cm)

Parent P2 (0.18) and P5 (0.16) showed significantly positive GCA effect in *kharif* season. While in summer three parents *viz.*, P10 (0.37), P7 (0.36) and P9 (0.23) showed significantly positive GCA effects. It is indicated that GCA effects were in positive direction. The result indicated that the parents under evaluation had good GCA score. Similar GCA effects for fruit parameters were found by Bhutia *et al.* (2017) [4], Pati *et al.* (2015) [11], Dogra and Kanwar (2019) [5] and Jat *et al.* (2016) [7].

Average fruit weight (g)

For average fruit weight three parents *viz.*, P_{10} (13.58), P9 (12.56) and P7 (10.07) showed significantly positive GCA effect in *kharif* season. Parent P10 (12.62), P_7 (8.70) and P_5 (8.47) showed significantly positive GCA effect in summer season. The GCA effect is directly proportional to the additive effects and breeding value. The GCA effects indicated that the parents under evaluation were good general combiners. Similar results found by Jat *et al.* (2016) [7], Naik *et al.* (2018) [10] and Sahoo and Singh (2017) [13].

Weight of fruit per vine (kg)

Two parents *viz.*, P_6 (0.11) and P5 (0.10) showed significantly positive GCA effect in *kharif* season, while in summer Parent P_6 (0.12) and P_2 (0.10) showed significantly positive GCA effect. The GCA effect is directly proportional to the additive effects and breeding value. The GCA effects indicated that the parents under evaluation were good general combiners. Similar results found by Bhutia *et al.* (2017) [4], Rajaguru *et al.* (2020) [12], Pati *et al.* (2015) [11] and Sahoo and Singh (2017) [13].

Weight of fruit per plot (kg)

Two parents *viz.*, P_6 (0.83) and P5 (0.65) showed significantly positive GCA effect in *kharif* season, while in summer Parent P_6 (1.00) and P_2 (0.99) showed significantly positive GCA effect. For this character combining ability in positive direction is important. In the present investigation GCA found in both negative as well as positive direction. Similar results found by Dogra and Kanwar (2019) [5], Jat *et al.* (2016) [7], Naik *et al.* (2018) [10], Sahoo and Singh (2017) [13].

Table 2: Analysis of variance for combining ability in 10x10 diallel of cucumber

Source	DF	Length of vine (m)		Number of fruits/vine		Length of Fruit (cm)		Diameter of Fruit (cm)		Average weight of fruit (g)		Weight of fruit/vine (kg)		Weight of fruit/plot (kg)	
		Kharif	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer
GCA	9	1.08**	0.48**	8.79**	5.67**	30.07**	36.83**	0.15**	0.89**	974.30**	788.05**	0.05**	0.08**	3.91**	6.41**
SCA	45	0.24**	0.14*	3.73**	4.39**	5.01**	6.15**	0.14**	0.42**	508.66**	524.57**	0.14**	0.18**	15.14**	17.96**
Error	54	0.10	0.07	0.80	0.78	0.49	0.64	0.03	0.03	40.28	47.06	0.01	0.02	1.17	1.89**

Table 3: Estimation of general combining ability effects for different characters of cucumber in 10 x 10 half diallel

Sr. No.	Parents	Length of vine (m)		Number of fruits/vine		Length of Fruit (cm)		Diameter of Fruit (cm)		Average weight of fruit (g)	
		Kharif	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer
1.	P_1	-0.501**	-0.255**	0.610	0.562*	-0.710**	-0.955**	-0.137**	-0.493**	-11.122**	-3.610
2.	P_2	-0.219*	-0.124	0.410	1.245**	-1.360**	-2.180**	0.187**	-0.299**	-4.472*	-10.527**
3.	P_3	-0.384**	-0.206**	0.227	-0.022	-1.210**	-1.688**	-0.080	-0.080	-3.813*	-5.377**
4.	P_4	-0.005	-0.076	0.827**	-0.030	-1.577**	-2.330**	-0.012	-0.004	-10.688**	-10.877**
5.	P_5	0.502**	0.305**	0.543*	-0.805**	-1.110**	0.112	0.167**	-0.065	-2.922	8.473**
6.	P_6	0.010	-0.226**	0.643*	0.587*	-1.293**	0.112	0.056	-0.038	-1.055	1.890
7.	P_7	0.013	0.163*	-1.340**	-0.772**	1.940**	2.662**	-0.107*	0.362**	10.078**	8.707**
8.	P_8	0.216*	0.211**	0.310	-0.288	2.007**	1.620**	-0.117*	0.007	-2.155	-2.727
9.	P_9	0.163	0.095	-0.773*	0.312	1.840**	1.795**	0.024	0.233**	12.562**	1.423
10.	P_{10}	0.205*	0.113	-1.457**	-0.788**	1.473**	0.853**	0.019	0.377**	13.587**	12.623**
S. E. ± (gi)		0.088	0.077	0.245	0.242	0.193	0.219	0.049	0.049	1.738	1.878
C. D. at 5%		0.177	0.154	0.491	0.486	0.388	0.440	0.099	0.099	3.484	3.766
C. D. at 1%		0.234	0.205	0.654	0.646	0.515	0.584	0.130	0.130	4.640	5.014

*Significant at 5% level **Significant at 1% level

Table 3 continued…

Sr. No.	Parents	Weight of fruit/vine (kg)		Weight of fruit/plot (kg)	
		Kharif	Summer	*Kharif*	Summer
1.	P_1	0.005	0.036	0.166	0.158
2.	P_2	0.014	0.103*	0.118	0.996*
3.	P_3	0.027	-0.075	0.400	-0.638
4.	P_4	-0.078*	-0.131**	-0.499	-1.253**
5.	P_5	0.100*	-0.028	0.655*	-0.429
6.	P_6	0.114**	0.128**	0.833**	1.001*
7.	P_7	-0.091*	-0.051	-0.948**	-0.172
8.	P_8	-0.044	-0.068	-0507	-0.479
9.	P_9	0.014	0.056	0.191	0.269
10.	P_{10}	-0.061	0.030	-0.408	0.548
S. E. ± (gi)		0.037	0.044	0.296	0.377
C. D. at 5%		0.075	0.090	0.595	0.756
C. D. at 1%		0.098	0.117	0.790	1.006

*Significant at 5% level **Significant at 1% level

Specific combining ability

The specific combining ability effects of crosses for different characters in *summer* and *kharif* seasons are presented in Table 4 and described below in suitable direction.

Length of vine (m)

Specific combining ability ranged from (-0.62) to 1.32, during the *kharif* season. On other hand, it was (-0.64) to 0.97 during summer season. The cross combination P_5 x P_9 (1.32) exhibited highest positive significant SCA effect followed by P_4 x P_6 (1.01) in *kharif* season. The cross P_9 x P_{10} (0.97) exhibited highest positive significant SCA effects followed by P_2 x P_3 (0.79) in summer season.

Positively significant SCA effect is good combiner for inheritance of desirable character. The result revealed that the best combinations for the character length of vine generally involved high x low and low x low general combiners, crosses with high SCA. Similar results of significant and positive SCA were also obtained Kumar *et al.* (2021) [8], Rajaguru *et al.* (2020) [12], Pati *et al.* (2015) [11], Jat *et al.* (2016) [7] and Sahoo and Singh (2017) [13].

Number of fruits per vine

The range of SCA for number of fruits per plant was from (-3.06) to 4.83 during the *kharif* season and (-4.46) to 4.99 during summer season. The cross combination P_4 x P_8 (4.83) exhibited highest positive significant SCA effects followed by P_4 x P_7 (3.28) in *kharif* season.

The cross P_1 x P_4 (4.99) exhibited highest positive significant SCA effect followed by P_2 x P_3 (4.29) in summer season.The F_1 crosses exhibiting high SCA effects did not always involve parents with high GCA effects suggesting that the inter-allelic interactions are important for number of fruits per plant trait. These crosses resulted from the parents having high x low GCA effects and thus, reflect additive x additive type of gene action. Results are in proximity with Bhutia *et al.* (2017) [4], Pati *et al.* (2015) [11] Jat *et al.* (2016) [7] and Sahoo and Singh (2017) [13].

Fruit length (cm)

The SCA range for fruit length was from (-3.67) to 6.83 during the *kharif* season and (-3.42) to 8.82 during summer season. The cross combination P_9 x P_{10} (6.83) exhibited highest positive significant SCA effect followed by P_4 x P_5 (4.43) in *kharif* season. The cross P_7 x P_9 (8.82) exhibited highest positive significant SCA effects followed by P_8 x P_{10} (6.41) in summer season. Crosses exhibited positive significant effect for fruit length therefore, these combinations could be exploited in hybrid programme. Results are in accordance with Kumar *et al.* (2021) [8], Rajaguru *et al.* (2020) [12] and Naik *et al.* (2018) [10].

Fruit diameter (cm)

The SCA range for fruit diameter was from (-0.87) to 0.97 during the *kharif* season and (-1.07) to 1.09 during summer season. The cross combination P_4 x P_6 (0.97) exhibited highest positive significant SCA effects followed by P_2 x P_7 (0.86) in *kharif* season. The cross P_4 x P_{10} (1.09) exhibited

highest positive significant SCA effects followed by P_7 x P_9 (1.02) in summer season.

Heterotic hybrids registered positive significant effect for fruit diameter with desirable SCA therefore, these combinations could be considered in further hybrid programmer. Co-accordance SCA effects for fruit parameters were found by Dogra and Kanwar (2019) [5], Jat *et al.* (2016) [7] and Sahoo and Singh (2017) [13].

Average fruit weight (g)

The SCA range for average fruit weight was from (-43.34) to 48.42 during the *kharif* season and (-29.85) to 59.88 during summer season. The cross combination P_8 x P_9 (48.42) and P_3 x P_4 (31.93) exhibited highest positive significant SCA effects in *kharif* season. The cross P_4 x P_8 (59.88) exhibited highest positive significant SCA effects followed by P_1 x P_{10} (35.86) in summer season. Crosses exhibited highest and significant positive SCA effects for fruit weight, the result evident that non- additive type of gene action for inheritance of character. Identical results were found by Bhutia *et al.* (2017) [4], Rajaguru *et al.* (2020) [12], Pati *et al.* (2015) [11].

Yield per vine (kg)

The SCA range for yield per plot was from (-0.49) to 0.67 during the *kharif* season and (-0.69) to 0.93 during summer season. The cross combination P_2 x P_3 (0.67 and 0.93) exhibited highest positive significant SCA effects in *kharif* and summer season respectively. Similar results found by Bhutia *et al.* (2017) [4], Kumar *et al.* (2021) [8], Rajaguru *et al.* (2020) [12], Pati *et al.* (2015) [11], Dogra and Kanwar (2019) [5], Jat *et al.* (2016) [7], Naik *et al.* (2018) [10], Sahoo and Singh (2017) [13].

Yield per plot (kg)

The SCA range for yield per plot was from (-4.70) to 6.28 during the *kharif* season and (-7.00) to 8.44 during summer season. The cross combination P_5 x P_7 and P_5 x P_9 (6.28 and 8.44) exhibited highest positive significant SCA effects in *kharif* and summer season respectively. More or less similar results were obtained by Dogra and Kanwar (2019) [5], Jat *et al.* (2016) [7], Naik *et al.* (2018) [10].

Table 4: Estimation of specific combining ability effects for different characters of cucumber in 10 x 10 half diallel

Sr. No.	Hybrids	Length of vine (m)		Number of fruits/vine		Length of Fruit (cm)		Diameter of fruit (cm)		Average wt. of fruit (g)		Weight of fruit/vine (kg)	
		Kharif	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer
1	1 x 2	-0.06	-0.32	-0.64	0.11	2.42**	1.62*	0.13	-0.04	8.62	-21.58**	0.01	-0.28
2	1 x 3	-0.09	-0.09	0.93	2.38**	0.67	1.02	0.30	0.07	17.36**	-15.13*	0.33*	0.21
3	1 x 4	0.66*	0.51	1.53	4.99**	3.03**	1.57*	-0.61**	-0.37*	10.24	-15.83*	0.36**	0.46**
4	1 x 5	-0.45	-0.49	-0.97	-0.03	-1.62*	0.42	-0.20	0.21	-21.12**	-15.98*	-0.44**	-0.26
5	1 x 6	-0.51	-0.15	0.12	0.57	-1.04	-0.87	-0.22	0.23	-29.59**	-23.60	-0.40**	-0.29
6	1 x 7	-0.62*	-0.64*	-1.69*	-4.46**	-1.47*	-3.42**	-0.68**	-0.97**	15.87**	5.78	-0.17	-0.5**
7	1 x 8	-0.51	-0.02	2.85**	-0.55	-1.34*	-1.28	0.26	-0.41*	-6.69	13.21*	0.51**	0.09
8	1 x 9	0.15	0.05	1.73*	2.44	-0.57	-2.05**	0.09	0.17	12.59*	19.86**	0.47**	0.75**
9	1 x 10	0.33	0.11	-0.17	0.54	-0.41	-0.41	0.16	0.25	24.56**	35.86**	0.29*	0.56**
10	2 x 3	0.49	0.79**	1.93*	4.29**	1.52*	3.35**	0.11	-0.05	24.51**	24.18**	0.67**	0.93**
11	2 x 4	0.32	0.27	-3.06**	-0.89	1.28	1.39	-0.42*	-0.22	-13.40*	-16.91**	-0.48**	-0.42**
12	2 x 5	-0.61*	0.42	2.82**	-0.31	-0.17	-0.04	-0.35	0.06	-17.77**	10.93	0.26*	0.09
13	2 x 6	0.51	0.55*	-0.87	-3.31	0.20	0.85	-0.36	0.28	-18.44**	-21.88**	-0.31*	-0.69**
14	2 x 7	0.21	-0.14	0.30	0.04	-1.22	-2.89	0.86**	0.85**	-8.77	-4.50	-0.02	-0.08
15	2 x 8	0.01	-0.46	2.45**	-0.23	0.30	-0.45	-0.06	-0.82**	-43.34**	-13.86*	-0.49**	-0.19
16	2 x 9	-0.50	-0.61*	0.73	-1.23	-3.52**	-2.33	-0.49**	-0.25	-33.65**	-17.01**	-0.24	-0.45**
17	2 x 10	-0.11	-0.12	0.42	0.26	-1.36*	-0.98	-0.11	-1.06**	-10.88	12.78**	0.09	0.29
18	3 x 4	0.12	0.19	-0.27	-0.42	0.93	1.20	0.49**	-0.33*	31.93**	22.13**	0.39**	0.20
19	3 x 5	-0.52	-0.41	-1.19	-0.65	1.67*	-2.23**	0.34*	-0.14	-0.03	-18.81**	-0.26*	-0.37*
20	3 x 6	-0.06	0.02	1.30	0.35	1.05	0.96	-0.17	0.16	-5.90	-11.23	0.16	-0.03
21	3 x 7	0.09	-0.23	0.68	0.11	-0.97	-2.18**	-0.14	-0.73**	7.56	12.95*	0.17	0.20
22	3 x 8	0.22	0.08	1.83*	1.63	-0.04	-0.74	-0.87**	-1.07**	-14.80*	-22.21**	0.16	-0.06
23	3 x 9	0.18	0.27	1.12	-1.76*	-2.67**	-2.12**	0.04	-0.69**	-24.71**	-11.16	-0.12	-0.44**

Table No. 4 contd…

Sr. No.	Hybrids	Length of vine (m)		Number of fruits/vine		Length of Fruit (cm)		Diameter of fruit (cm)		Average wt. of fruit (g)		Weight of fruit/vine (kg)	
		Kharif	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer
24	3 x 10	-0.32	-0.51	-0.59	0.53	-1.71*	-1.78*	-0.10	-0.58**	3.95	3.63	-0.04	0.05
25	4 x 5	-0.58	-0.06	-0.59	-0.44	4.43**	-0.49	-0.06	-0.57**	3.64	-4.91	-0.03	-0.07
26	4 x 6	1.01	-0.13	0.10	2.66**	-0.17	0.20	0.97**	-0.59**	6.37	-15.53*	0.18	0.20
27	4 x 7	0.37	0.01	3.28**	3.72**	-1.81**	-2.84**	-0.32	-0.88**	-22.75**	-29.35**	0.28*	0.24
28	4 x 8	-0.33	-0.05	4.83**	-1.16	-3.67**	-1.10	0.34*	-0.14	-5.72	59.88**	0.31**	0.63**
29	4 x 9	-0.51	-0.57*	-1.27	-2.16*	-2.51**	-2.48**	-0.23	-0.60**	-17.84**	-7.06	-0.34**	-0.56**
30	4 x 10	-0.12	-0.15	0.40	1.34	-0.54	-0.53	0.095	1.09**	26.33**	27.93**	0.43**	0.63**
31	5 x 6	0.22	-0.47	-0.41	-0.06	1.15	2.76**	-0.17	-0.33*	6.60	19.31**	-0.01	0.33*
32	5 x 7	0.28	0.08	2.17*	1.09	-1.27	-2.38**	0.57**	-0.02	18.67**	4.30	0.64**	0.21
33	5 x 8	0.20	-0.16	-1.27	-1.58	-1.94**	-0.44	-0.07	-0.25	19.90**	3.53	0.10	-0.13
34	5 x 9	1.32**	0.46	0.60	2.81**	-1.17	-1.42	0.37*	-0.37*	12.39*	17.98**	0.28*	0.78**
35	5 x 10	0.23	0.40	2.28**	-1.08	-3.01**	2.32**	-0.14	-0.17	-13.23*	25.78**	0.21	-0.00

36	6 x 7	-0.33	0.12	-0.32	-0.69	-1.49*	-2.18**	0.03	-0.59**	23.00**	-7.31	0.09	-0.16
37	6 x 8	-0.24	-0.28	0.42	0.22	0.03	-2.04**	0.39*	0.58**	16.04**	16.71*	0.40**	0.19
38	6 x 9	-0.16	-0.04	-0.29	-2.37**	-2.79**	-1.42	-0.05	0.09	23.72**	31.96**	0.24	-0.08
39	6 x 10	0.01	-0.07	0.58	0.72	1.97**	0.02	0.17	0.09	15.89**	12.96*	0.22	0.24
40	7 x 8	0.68*	0.57*	-1.39	1.58	2.40**	-0.79	0.03	0.38*	-0.89	-28.70**	-0.12	-0.12
41	7 x 9	-0.28	0.24	-0.11	-0.21	3.17**	8.82**	0.29	1.02**	-7.80	34.95**	-0.03	0.41**
42	7 x 10	0.50	0.09	-0.62	0.68	3.33**	0.77	-0.16	-0.47**	8.56	-29.85**	-0.10	-0.20
43	8 x 9	-0.61*	-0.28	-2.96**	2.49**	3.10**	2.17**	0.19	0.22	48.42**	-2.81	-0.01	0.34*
44	8 x 10	0.85**	-0.03	1.32	-0.20	-1.12	6.41**	-0.03	0.32	-1.60	9.98	0.31*	0.07
45	9 x 10	-0.18	0.97**	-2.19*	-2.20**	6.83**	-0.16	-0.21	0.05	19.48**	-18.76**	-0.34**	-0.60**
S. E. ± Sij		0.30	0.26	0.82	0.82	0.65	0.74	0.17	0.17	5.85	6.32	0.13	0.15
C.D @ 5%		0.60	0.52	1.65	1.64	1.31	1.48	0.34	0.33	11.72	12.67	0.25	0.30
C.D @ 1%		0.79	0.69	2.20	2.18	1.74	1.97	0.45	0.44	15.61	16.87	0.34	0.40

Conclusion

The mean performance of most of the F_1s were superior than the mean (*per se*) performance of the parents for most of the parameters which were studied. *Per se* performance recited that, the parents P_2 (Cucumber- 2), P_4 (Cucumber- 4), P_5 (Cucumber- 5), P_6 (Cucumber- 6), P_8 (Cucumber-8) and P_{10} (Cucumber- 10) were found to be most desirable for more number of characters and most general combiner.

From the investigation of general combining ability, the parents the P_4 (Cucumber- 4), P_5 (Cucumber- 5), P_6 (Cucumber- 6) and P_8 (Cucumber-8) were the good general combiner as they displayed significant GCA effects in desirable direction for most of the characters like earliness, yield attributing characters and qualitative characters.

From the studies on specific combining ability it was observed that cross combination P_1 x P_9, P_2 x P_3, P_4 x P_8, P_4 x P_{10}, P_5 x P_7 and P_5 x P_9 were best specific combinations for most of the traits. These crosses deserve due consideration for their further exploitation as commercial hybrids as they produce higher yield and also showed significant SCA effects.

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