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HETEROSIS AND COMBINING ABILITY FOR YIELD AND YIELD ATTRIBUTES IN CUCUMBER (*Cucumis sativus* L.)

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SUMMARY

Among cucurbits, cucumber is distinct for its unique sex mechanism and this feature can easily be manipulated for the production of F_1 hybrid seeds. Considerable heterosis is manifested in cucumber for various traits. In India, only few studies utilizing Gynoecious lines in heterosis breeding programme have been reported in cucumber. Moreover, the basic information on combining ability in cucumber would aid the breeder in developing improved hybrid cultivars. So keeping this in view the present studies were undertaken to determine the nature and magnitude of genetic variation among parents and F_1's, extent of heterosis in F_1's and to obtain information regarding general and specific combining ability effects of different economic traits. Twenty-eight non-reciprocal F_1 hybrids derived from eight diverse cucumber genotypes including one gynoecious line were evaluated in randomized block design with three replications to study the heterosis and combining ability for yield and yield attributing traits. The analysis of variance indicated significant variability among all the genotypes for all the traits. The mean square due to GCA and SCA were highly significant for all the characters indicating the importance of both additive and non-additive genetic components for the characters under study. The parent 'Summer Kheera' was the best combiner for four characters viz. marketable yield, fruit diameter, fruit length and vine length. On the basis of mean and heterosis over check, the hybrid combination JLG x Summer Kheera and JLG x NCH-1 were best for marketable yield and fruit weight whereas Swarna sheetal x EC-27075 and Pant Kheera-1 x EC-27075 were best for fruit length and diameter. On basis of SCA effects results differ from that of mean and heterosis. On basis of SCA effects Gy-14 x Punjab Naveen and Gy-14 x Pant Kheera-1 were observed best w.r.t yield and yield attributing traits except earliness. The study of inheritance of different characters indicated the predominance of non-additive gene effects for most of the characters. Therefore, the improvement for these characters can be achieved through hybrid development

Key words: Cucumber, diallel analysis, combining ability, heterosis

Key findings: In this investigation, yield and quality attributes of cucumber was governed by both additive and non-additive genes but there is predominance of non-additive gene effects. Therefore, improvement of the characters can be achieved through hybrid development.

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INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable crop of tropical and subtropical regions of the world, grown successfully in

plains as well as hills. Cucumber is used as fresh or processed vegetables (Shetty and Wehner, 2002). The high water content makes cucumbers a diuretic and it also has a cleansing action within the body by removing accumulated pockets of old waste material and chemical toxins. Cucumbers help eliminate uric acid which is beneficial for those who have arthritis, and its fiber-rich skin and high levels of potassium and magnesium helps regulate blood pressure and help promote nutrient functions. The magnesium content in cucumbers also relaxes nerves and muscles and keeps blood circulating smoothly. India being native place of cucumber possesses high genetic variability for vegetative and fruit characters. Low fruiting ability and yield suppression due to its inherent fruiting habits are major limiting factors for cucumber improvement (Lower *et al.*, 1982). Unfortunately, very little attention has been paid for its genetic improvement by using genetically superior parents. A speedy improvement can be brought by assessing the genetic variability and exploitation of heterosis. Heterosis is the stage in which hybrids achieve better than parents in characteristics like yield, reproducibility, resistance, etc. Hayes and Jones (1916) were the first investigators to report heterosis in cucumber. They found 24 to 30 per cent increase in yield over the high yielding parents. Jakimovic (1938) observed that F_1 hybrids were earlier in maturity, higher in yield compared to their respective parents. At national level, F_1 hybrid Pusa Sanyog has been released by IARI, Katrain (Gill *et al.*, 1973) by crossing Gynoecious line (isolated from a Japanese variety Kaga Aomoga Fushinavi) with Green Long of Naples (an Italian variety) which out yielded the recommended variety by 128.78 per cent. More (2002) also demonstrated potentiality in cucumber for development of tropical Gynoecious hybrids. In India, only few studies utilizing Gynoecious lines in heterosis breeding programme have been reported in cucumber (Vijayakumari *et al.*, 1993; More, 2002). Singh *et al.* (2014) observed heterosis and inbreeding depression for yield and its component traits and observed that cross combinations PCUC-15 X PCUC 15-1 followed by CHC-2 X C 99-12, PCUC 15 X CHC 2, PCUC 15-1 X BIHAR and EC 43342 X C 99-12 were top hybrids exhibited high economic heterosis for yield/vine. The exploitation of heterosis is much easier in cross pollinated crops and being cucumber monoecious, provides ample scope for the utilization of hybrid vigor on commercial scale. Combining ability analysis is one of powerful tools available which give the estimates of combining ability effects and aids in selecting desirable parents and crosses for further exploitation. The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize. Badgujar and More (2013) studied fifty six tropical Gynoecious F_1 hybrids resulted by crossing four tropical gynoecious females with 14 monoecious male parents of cucumber for the combining ability studies and observed hybrids H-13, H-210 and H-211 were good specific combiners for several characters. Reddy *et al.* (2014) studied thirty six F_1 hybrids were developed from nine diverse parental cucumber lines, and observed that the parent P1 (Pusa Uday) was the best general combiner for yield per plant whereas highest SCA effect for yield per plant were exhibited by F_1 crosses P2 × P4 (DC-1× Himangi), followed by P1 × P9 (Pusa Uday × Pant Khira). Such studies in cucumber are very few especially by utilizing the gynoecious lines. Therefore, the parent investigation was undertaken to study the nature and magnitude of heterotic effects along with to identify the best combiners involving different plant type of indigenous and exotic origin.

MATERIALS AND METHODS

Experimental material

Eight diverse cucumber parental lines were used to develop 28 F_1s following a half diallel mating design, excluding reciprocals. The parental lines were Gy-14 (Gynoecious), Pant Kheera-1, Swarna Sheetal, Punjab Naveen, Japanese Long Green, EC-27075, Summer Kheera and NCH-1.

Gy-14: It is gynocious line collected from University of Wisconsin, USA. The plant has single vine. Fruits are pickling type, 12-15 cm ling having small spines.

Pant Khira 1: It has been released by GBPUAT, Pantnagar. This is a selection from inbreds of indigenous germplasm at Pantnagar and released in 2001. The fruits are 20 cm long, cylindrical with light, white stripes. Yield is approximately 15000 kg/ha.

Swarna Sheetal: It has been released by HARP, Ranchi. It is tolerant to powdery mildew. Its yield is 20000-30000 kg/ha.

Punjab Naveen: This variety has been released by PAU, Ludhiana in 2008. The plants have dark green leaves, having uniform cylindrical fruit shape and attractive light green colour with smooth surface. The fruits are bitter free, having soft seeds at edible maturity and are very crispy. It is better in quality having high dry matter and vitamin C. It takes 68 days from the transplanting to harvesting. The variety is excellent in taste, appearance, colour, size and texture and its average yield is 17500 kg/ha.

Japanese Long Green: It has been released by IARI, Regional Station, Katrain. This is a temperate variety specifically suited to hills and lower hills. It is extra-early with 45 days maturity. Fruits are 30-40 cm long, with white skin, white spines and light green crisp flesh.

EC-27075: It is the germplasm of PAU, Ludhiana. Fruits are light green, 20-25 cm long and tolerant to downy mildew.

Summer Khira: This is the local gemplasm collected from Ludhiana. Vines are tall and intermeadiate in growth habit. Fruits are 20-25 cm long, dull green in colour. Its average yield is 15000 kg/ha.

NCH-1: It is a germplasm collected from Ludhiana. Vines are tall, intermediate in growth habit. Plant grow rapidly and vigorously. Fruits are light green.

NS-404: It is a hybrid of Namdhari Seeds Pvt Ltd, Bangalore.

Experimental design

The 28 F_1 hybrids along with 8 inbred parents and a standard checks were sown and evaluated for heterosis and combining ability during summer season of 2015. Observations were recorded on five plants, which were replicated thrice in randomized complete block design. The standard package of practices will be followed for raising the crop (Anonymous, 2013). Mean data was subjected for analysis of general combining ability (GCA), specific combining ability (SCA) as per method given by Griffing (1956) (method 2 and model I) using the software BMM.

Data collection

The data on various yield and yield attributing traits will be evaluated in spring-summer season of 2015. Observation were recorded on ten characters, viz. node at which first female flower appears, vine length (cm), fruit length (cm), fruit diameter (cm), marketable yield per plant (kg) and fruit weight (gm).

Data analysis

The combining ability estimates were calculated according to method-2 (Griffing, 1956). Heterosis was calculated as the percentage increase of F_1 performance over the better parent and standard check 'NS-404'.

RESULTS

Analysis of variance and mean of characters

The mean squares for genotypes were highly significant for all the six characters under study (Table 1). This indicated significant genotypic differences for all the characters studied. The analysis of variance for combining ability was appropriate suggesting the presence of significant variation among genotypes (Table 2). Significant value of GCA and SCA indicated presence of both additive and non-additive genes. On basis of mean performance (Table 3), Gy-14 x Punjab Naveen and Gy-14 x Pant

Kheera-1 were observed to bear the female flower at the lowest node whereas JLG x NCH-1 bears female flower at highest node. The mean marketable yield was high for 'JLG x Summer Kheera' and 'EC-27075 x NCH-1'. For fruit length and diameter, mean values were high for crosses Swarna sheetal x EC-27075 and Pant Kheera-1 x EC-27075, respectively.

Table 1. Analysis of variance for the experimental design for different characters.

Characters	Source of variation (d.f.)		
	Replication (2)	Genotype (35)	Error (70)
	Mean squares		
Node at which first female flower appears	0.13**	5.38**	0.18
Vine length	111.58	2417.0**	89.79
Fruit length	0.58**	12.17**	0.35
Fruit diameter	0.03**	0.66**	0.04
Marketable yield per plant	0.18**	0.31**	0.06
Fruit weight	53.0*	1279.30**	23.23

*Significance at 5% level, ** Significance at 1% level

Table 2. Analysis of variance for combining ability for different characters.

Characters	Source of variation (d.f.)		
	GCA (7)	SCA (28)	Error (70)
	Mean squares		
Node at which first female flower appears	4.12**	1.21**	0.06
Vine length	1840.45**	546.96**	29.23
Fruit length	7.37**	3.23**	0.12
Fruit diameter	0.49**	0.15**	0.01
Marketable yield per plant	0.13**	0.10**	0.02
Fruit weight	1102.01**	257.73**	7.74

**Significance at 1% level, *Significance at 5% level

Estimates of general combining ability (GCA) effects

Estimates of general combining ability for various traits have been presented in Table 4. Among eight parental lines 'Summer Kheera' was the best combiner for four characters viz. marketable yield (0.14), vine length (15.55), fruit diameter (0.34) and fruit length (0.70). Pant Kheera-1 was best combiner for node number of first female flower appears (-0.98) whereas, NCH-1 was the best combiner for fruit weight (13.2).

Estimates of specific combining ability (SCA) effects

The SCA represents dominance and epistatic effects and can be related with heterosis. The cross combination Gy-14 × Pant Kheera-1 had highest SCA (Table 5) for three characters viz. vine length (42.83), fruit length (0.96) and fruit diameter (3.45). Cross combination JLG × EC-27075 exhibited maximum SCA for node number of first female flower appears (-1.85) whereas, Gy-14 × Punjab Naveen had highest SCA for marketable yield per plant (0.57). Cross combination EC-27075 × NCH-1 had highest SCA for fruit weight (39.2).

Table 3. Mean effects of crosses for different characters.

Parents	Node at which first female flower appears	Vine Length (cm)	Fruit length (cm)	Fruit diameter (cm)	Marketable yield per plant (kg)	Fruit weight (g)
GY-14 × Pant Kheera-1	3.33	118.2	15.20	4.18	2.74	171.00
GY-14 × Swarna Sheetal	4.00	106.12	9.96	4.20	3.04	121.00
GY-14 × Punjab Naveen	3.17	98.66	11.45	4.68	2.81	208.33
GY-14 × JLG	4.00	109.77	10.38	4.13	2.17	197.00
GY-14 × EC-27075	3.68	105.34	11.58	4.35	2.78	202.67
GY-14 × Summer Kheera	3.67	130.23	11.33	4.55	2.80	181.32
GY-14 × NCH-1	3.81	118.15	11.80	4.50	2.88	236.83
Pant Kheera-1 × Swarna Sheetal	3.72	165.55	16.62	4.53	2.84	197.08
Pant Kheera-1 × Punjab Naveen	3.05	136.2	15.39	4.23	2.88	191.83
Pant Kheera-1 × JLG	4.03	152.03	17.33	5.43	2.21	221.27
Pant Kheera-1 × EC-27075	4.40	129.63	17.33	5.59	2.88	210.33
Pant Kheera-1 × Summer Kheera	5.03	142.63	15.73	5.44	3.00	215.89
Pant Kheera-1 × NCH-1	3.43	147.73	16.61	4.32	2.31	198.03
Swarna Sheetal × Punjab Naveen	4.73	183.2	17.41	4.01	2.30	168.19
Swarna Sheetal × JLG	5.27	180.23	15.92	4.31	2.13	186.68
Swarna Sheetal × EC-27075	5.53	168.37	17.50	4.83	2.17	245.33
Swarna Sheetal × Summer Kheera	6.43	165.13	15.62	5.28	2.20	197.10
Swarna Sheetal × NCH-1	3.64	147.3	16.73	4.64	2.30	245.83
Punjab Naveen × JLG	4.40	106.53	16.40	4.58	2.55	206.00
Punjab Naveen × EC-27075	3.53	149.36	16.37	4.72	2.55	214.17
Punjab Naveen × Summer Kheera	6.67	141.90	16.45	4.98	2.65	226.37
Punjab Naveen × NCH-1	6.50	153.62	15.28	4.82	2.57	210.27
JLG × EC-27075	4.73	201.67	17.21	5.20	2.72	183.27
JLG × Summer Kheera	7.07	183.47	16.21	4.65	3.31	187.78
JLG × NCH-1	7.93	182.6	15.40	4.37	2.43	251.00
EC-27075 × Summer Kheera	4.83	181.77	17.19	5.24	2.46	185.35
EC-27075 × NCH-1	6.33	171.33	15.52	4.88	3.13	230.71
Summer Kheera × NCH-1	6.00	185.06	17.38	4.40	2.56	214.53

Table 4. General combining ability (GCA) effects of parents for different characters.

Parents	Node at which first female flower appears	Vine length	Fruit length	Fruit diameter	Marketable yield per plant	Fruit weight
Gy-14	0.34**	11.37**	0.54**	-0.37**	-0.16**	8.22**
Pant Kheera-1	-0.98**	-27.36**	-1.90**	-0.15**	0.11*	-21.64**
Swarna Sheetal	-0.84**	-3.37*	-0.52**	0.16**	0.09*	2.31**
Punjab Naveen	-0.30	1.58	0.57**	-0.10*	-0.12**	-5.61**
Japenese Long Green	0.08	-9.36**	0.23*	0.03	-0.10*	4.81**
EC-27075	0.39**	5.88**	0.06	0.16**	0.06	-1.04
Summer Kheera	0.63**	15.55**	0.70**	0.34**	0.14**	-0.26
NCH-1	0.68**	5.70**	0.33**	-0.06	-0.02	13.2**
CD 5%	0.15	3.23	0.20	0.07	0.08	1.64
CD 1%	0.19	4.29	0.27	0.10	0.11	2.18

Table 5. Specific combining ability (SCA) effects of crosses for different characters.

Parents	Node no. at which first female flower appears	Vine Length	Fruit length (cm)	Fruit diameter (cm)	Marketable yield per plant (kg)	Fruit weight (g)
Gy-14 × Pant Kheera-1	1.19**	42.83**	3.45**	0.96**	-0.16	22.11**
Gy-14 × Swarna Sheetal	0.11	17.98**	1.47**	0.20*	-0.45**	8.19**
Gy-14 × Punjab Naveen	-0.23	-34.63**	-0.44	0.19*	0.57**	3.08
Gy-14 × JLG	0.90**	29.25**	1.27**	-0.25*	0.52**	-15.23**
Gy-14 × EC-27075	0.89**	19.41**	1.25**	-0.38**	-0.19	-35.02**
Gy-14 × Summer Kheera	-0.16	35.46**	1.45**	-0.07	0.01	7.00**
Gy-14 × NCH-1	1.49**	-3.18	-0.94**	0.06	-0.10	22.7**
Pant Kheera-1 × Swarna Sheetal	0.90**	-13.79**	-1.38**	-0.39**	0.27*	-10.31**
Pant Kheera-1 × Punjab Naveen	-0.47*	-26.2**	-1.97**	0.34**	0.25*	7.95**
Pant Kheera-1 × JLG	-0.01	-4.15	-1.70**	-0.34**	-0.42**	-6.14**
Pant Kheera-1 × EC-27075	-0.65**	-23.83**	-1.33**	-0.26**	-0.03	-2.95
Pant Kheera-1 × Summer Kheera	-0.90**	-8.59	-1.23**	-0.24**	-0.02	3.59
Pant Kheera-1 × NCH-1	-0.81**	-10.84**	-1.38**	0.14	0.20	-10.87**
Swarna Sheetal × Punjab Naveen	-0.73**	-12.65**	0.58*	0.41**	0.34**	-4.51*
Swarna Sheetal × JLG	-0.13	14.12**	0.38	0.66**	-0.36**	14.5**
Swarna Sheetal × EC-27075	-0.70	-23.52**	-0.42	0.69**	0.15	9.42**
Swarna Sheetal × Summer Kheera	0.32	-20.19**	0.23	0.35**	0.20	14.2**
Swarna Sheetal × NCH-1	-1.34**	-5.25	-1.15**	-0.35**	-0.34**	-17.12**
Punjab Naveen × JLG	0.57*	17.67**	0.36	-0.21*	-0.22*	-12.16**
Punjab Naveen × EC-27075	0.53*	10.26**	0.71*	0.18	-0.35**	17.7**
Punjab Naveen × Summer Kheera	1.18**	-2.63	-0.41	0.44**	-0.38**	-4.63*
Punjab Naveen × NCH-1	-1.66**	-10.63*	0.43	0.23*	-0.14	0.74
JLG × EC-27075	-1.85**	2.19	1.32**	-0.05	0.01	10.76**
JLG × Summer Kheera	1.04**	-14.93**	0.37	0.02	0.02	22.18**
JLG × NCH-1	0.82**	6.62	-0.43	0.28**	0.11	-7.38**
EC-27075 × Summer Kheera	1.12**	11.4*	0.70*	-0.45**	0.53**	-10.55**
EC-27075 × NCH-1	1.94**	10.84*	0.27	0.31**	-0.19	39.2**
Summer Kheera × NCH-1	0.10	-0.57	-0.27	0.03	0.43**	-4.25
CD 5%	0.39	8.60	0.54	0.19	0.21	4.38
CD 1%	0.52	11.43	0.71	0.25	0.28	5.81

JLG – Japanese Long Green

Estimates of heterosis

The estimates of better parent heterosis for yield traits under evaluation and heterosis over standard check 'NS-404' is given in table 6**.** Negative heterosis is desirable for node at which first female flower appears. The cross combination Pant Kheera-1 × NCH-1 exhibited maximum heterosis over better parent (-37.29) (Table 6), whereas cross combination Pant Kheera-1 × Punjab Naveen over the standard check, NS-404 (-27.38). Pant Kheera-1 × Summer Kheera exhibited maximum heterosis over better parent for vine length (29.75), whereas JLG × EC-27075 exhibited maximum heterosis over the standard check, NS-404 (35.80).

For fruit length cross Pant Kheera-1 × NCH-1 exhibited maximum heterosis over better parent (7.37), whereas Swarna Sheetal × EC-27075 exhibited maximum heterosis over the standard check, NS-404 (9.38). The cross combination Swarna Sheetal × Summer Kheera exhibited maximum heterosis over fruit diameter over better parent (15.46) and Pant Kheera-1 × EC-27075 cross maximum heterosis over fruit diameter over standard checks 'NS-404' (16.53). Cross Swarna Sheetal × EC-27075 exhibited maximum heterosis for fruit weight over better parent (12.35), whereas JLG × NCH-1 exhibited

Table 6. Estimation of heterosis (%) over better parent (BP) and commercial check (NS-404) for different characters of cucumber.

Hybrids	Node no of first female flower		Vine length		Fruit length (cm)		Fruit diameter (cm)		Marketable yield per plant (kg)		Fruit weight (gm)	
	BP	NS-404	BP	NS-404	BP	NS-404	BP	NS-404	BP	NS-404	BP	NS-404
GY-14 × Pant Kheera-1	-4.76**	-20.63**	-33.4**	-20.40**	-1.75**	-5.00**	-16.90**	-12.92**	15.61**	9.60**	-18.44**	-22.27**
GY-14 × Swarna Sheetal	14.29**	-4.76**	-39.92**	-28.54**	-38.73**	-37.77**	-8.02**	-12.43**	40.90**	21.73**	-44.59**	-45.00**
GY-14 × Punjab Naveen	-9.52**	-24.60**	-23.49**	-33.56**	-25.72**	-28.42**	8.66**	-2.43**	-1.97**	12.53**	-17.92**	-5.30
GY-14 × JLG	14.29**	-4.76**	-39.65**	-26.08**	-38.19**	-35.10**	3.25**	-13.96**	-23.44**	-13.33**	-6.04*	-10.45**
GY-14 × EC-27075	5.05**	-12.46**	-43.75**	-29.07**	-29.71**	-27.60**	-13.07**	-9.44**	21.40**	11.20**	-3.34	-7.88**
GY-14 × Summer Kheera	4.76**	-12.70**	-38.87**	-12.30**	-32.72**	-29.19**	1.11**	-5.21**	9.24**	11.87**	-15.51**	-17.58**
GY-14 × NCH-1	8.95**	-9.21**	-28.19**	-20.44**	-19.64**	-26.27**	7.14**	-6.25**	25.07**	15.07**	-2.85	7.65**
Pant Kheera-1 × Swarna Sheetal	-17.88**	-11.43**	-6.72	11.48*	2.30**	3.90**	-9.87**	-5.56**	19.83**	13.60**	-9.75**	-10.42**
Pant Kheera-1 × Punjab Naveen	-35.52**	-27.38**	-23.26**	-8.28	-0.54	-3.83**	-15.90**	-11.88**	0.46**	15.33**	-24.42**	-12.80**
Pant Kheera-1 × JLG	-26.26**	-3.97**	-16.42**	2.38	3.17**	8.33**	8.02**	13.19**	-21.91**	-11.60**	6.21*	0.58
Pant Kheera-1 × EC-27075	-19.56**	4.76**	-30.79**	-12.70**	5.18**	8.33**	11.20**	16.53**	21.66**	15.33**	0.96	-4.39
Pant Kheera-1 × Summer Kheera	-7.98**	19.84**	29.75**	-3.95	-6.57**	-1.67**	8.15**	13.33**	17.19**	20.00**	0.60	-1.87
Pant Kheera-1 × NCH-1	-37.29**	-18.33**	-16.76**	-0.52	7.37**	3.81**	-14.12**	-10.00**	-2.39**	-7.47**	-18.76**	-9.98**
Swarna Sheetal × Punjab Naveen	4.34**	12.54**	3.72	23.37**	7.16**	8.83**	-12.33**	-16.53**	-19.74**	-7.87**	-33.74**	-23.55**
Swarna Sheetal × JLG	16.26**	25.40**	-0.09	21.37**	-5.24**	-0.50	-5.76**	-10.28**	-24.62**	-14.67**	-14.51**	-15.15**
Swarna Sheetal × EC-27075	22.15**	31.75**	-10.11**	13.38**	6.19**	9.38**	-3.33**	0.69**	-5.39**	-13.33**	12.35**	11.52**
Swarna Sheetal × Summer Kheera	42.02**	53.17**	-22.48**	11.20*	-7.26**	-2.40**	15.46**	9.93**	-14.06**	-12.00**	-9.74**	-10.41**
Swarna Sheetal × NCH-1	-19.57**	-13.25**	-16.6**	-0.81	2.95**	4.56**	1.46**	-3.40**	00	-8.00**	0.85	11.74**
Punjab Naveen × JLG	-6.98**	4.76**	16.6**	-28.26**	-2.38**	2.50**	6.34**	-4.51**	-11.15**	2.00**	-18.84**	-6.36**
Punjab Naveen × EC-27075	-25.30**	-15.87**	-20.25**	0.58	-0.69*	2.29**	-5.53**	-1.60**	-11.15**	2.00**	-15.62**	-2.65
Punjab Naveen × Summer Kheera	40.94**	58.73**	-33.34**	-4.44	-2.30**	2.83**	10.59**	3.68**	-7.78**	5.87**	-10.82**	2.89
Punjab Naveen × NCH-1	37.42**	54.76**	-10.92*	3.45	-0.93**	-4.52**	11.91**	0.49**	-10.34**	2.93**	-17.16**	-4.42
JLG × EC-27075	-24.08**	12.62**	7.67	35.80**	4.37**	7.56**	4.07**	8.40**	-4.00**	8.67**	-7.17**	-16.70**
JLG × Summer Kheera	23.33**	68.25**	-13.87**	23.55**	-3.74**	1.31**	3.33**	-3.13**	16.84**	32.27**	-12.50**	-14.65**
JLG × NCH-1	27.34**	88.89**	10.97*	22.96**	-8.31**	-3.73**	4.05**	-8.96**	-14.02**	-2.67**	2.97	14.09**
EC-27075 × Summer Kheera	-15.65**	15.08**	-14.67**	22.40**	2.08**	7.44**	4.73**	9.10**	-4.04**	-1.73**	-13.63**	-15.75**
EC-27075 × NCH-1	-3.01**	50.79**	-8.39	15.38**	-5.85**	-3.02**	-2.33**	1.74**	35.94**	25.07**	-5.36*	4.87*
Summer Kheera × NCH-1	4.71**	42.86**	-13.12**	24.62**	3.21**	8.62**	-2.22**	-8.33**	0.13	2.53**	-11.99**	-2.48
CD 5%	0.71		9.04		0.58		0.34		0.41		4.65	
CD 1%	0.97		12.22		0.74		0.42		0.51		6.29	

JLG – Japanese Long Green, BP= Better Parent [Delete vertical line, explain BP and NS-404]

Table 7. Genetic components of variance and ratio of component of genetic variances.

Characters	Additive (D)	Dominance (H_1)	Non-additive (H_2)	F	E	$(H_1/D)^{1/2}$	$H_2/4H_1$	$(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F$	h^2/H_2
Node at which first female flower appears	0.71	5.32**	4.01**	-0.10	0.06	7.53	0.19	0.99	0.26
Vine length (cm)	1126.26**	2943.83**	1721.89**	1373.75*	29.23	2.61	0.15	1.00	0.01
Fruit length (cm)	3.00	17.42**	9.22**	6.66*	0.12	5.81	0.13	1.07	0.09
Fruit diameter (cm)	0.33**	0.61**	0.54**	0.22	0.015	1.86	0.22	1.78	0.12
Marketable yield per plant (kg)	0.03*	0.36**	0.33**	0.01	0.02	10.45	0.23	1.28	-0.01
Fruit weight (gm)	303.30**	2656.70**	2279.28**	150.59	7.74	8.76	0.21	1.00	0.36

maximum heterosis for over standard check, NS-404 (14.09). For marketable yield per plant the cross combination Gy-14 × Swarna Sheetal exhibited maximum heterosis over better parent (40.90) and cross combination JLG × Summer Kheera exhibited maximum heterosis over standard check, NS-404 (32.27).

This study showed the significance of D1, H1 and H2 expressed the presence of both additive and non-additive variances but the values of dominance variance (H_1) were higher than the additive genetic variance for all characters except vine length (Table 7). This showed the presence of non-additive gene action (dominance) involved in the inheritance of these characters. The estimates of mean degree of dominance $(H_1/D)^{1/2}$ were much higher than unity for all the traits showing over-dominance. The positive values of F for vine length, fruit length, fruit diameter, marketable yield per plant and fruit weight indicated more frequency of dominant alleles than recessive alleles in the parents irrespective whether or not the dominance alleles have increasing or decreasing effect. The proportion of genes with positive and negative effects ($H_2/4H_1$) in the parents was observed less than 0.25 for all the characters considering genes are to be asymmetrically distribution of favorable and unfavorable genes in the parent. The proportion of dominant and recessive genes $[(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F]$ in the parents were higher than unity in case of fruit length, fruit diameter and marketable yield of fruits per plant which also suggested the excess of dominance genes than recessive ones for control of the characters and values lower than unity in case of node number of first female flower appears. The values were equal to unity in case of vine length and fruit weight indicating full dominance for trait. Number of blocks of dominant genes (h^2/H_2) indicated that one group of genes showed dominance for all the traits under study.

DISCUSSION

Genetic variability among genotypes for desirable traits plays crucial role for proficient selection. The mean squares for genotypes were highly significant for all the characters under study. The mean squares due to general combining ability (GCA) as well as specific combining ability (SCA) effects were highly significant for all the characters. Existence of both additive and non-additive type of gene action was observed due to significant mean squares for general combining ability and specific combining ability. Kumar *et al*. (2011) reported that both additive and non-additive gene action play predominance role for traits like node number of first female flower, total yield per plant, fruit weight, fruit length and fruit diameter. However, Bairagi *et al*. (2013) also reported same findings.

The mean performance of parents and their hybrids is believed to be one of the essential events for their appraisal. The parents with high mean value may or may not converse their high performance to their hybrids. This parental aptitude is expected in terms of general combining ability effects. The general combining ability effects in the desired direction provide a support in selection system. The parents having greater general combining ability effects in most wanted direction for traits of attention can be selected for further hybridization and assessment programs. In the present investigation Summer Kheera was best combiner for four traits marketable yield per plant, vine length, fruit length and fruit diameter. These results are in conformity with findings of Kumar *et al.* (2011) and Bairagi *et al.* (2013).

In this investigation cross Gy-14 × Pant Kheera-1 had highest SCA for three characters viz., vine length, fruit length and fruit diameter. JLG × EC-27075 exhibited maximum SCA for node number of first female flower whereas; Gy-14 × Punjab Naveen had highest SCA for marketable yield per plant. Kushwaha *et al.* (2011) also reported significant SCA for traits like fruit length, fruit weight, fruit diameter and yield per vine.

The magnitude of two types of heterosis i.e., heterosis over better parent (heterobeltiosis) and heterosis over standard check 'NS-404' (standard heterosis) as shown by different crosses for the traits under estimation indicated sufficient departure from parental material for these parameters. In the present investigation crosses shown negative heterobeltiosis for node at which first female flower appear which is a

most desirable character for getting early yield. Therefore, negative heterosis is desirable for node at which first female flower appears. Similar results were reported by Dogra and Kanwar (2011). The observations like number of primary branches per plant and vine length have a positive correlation with total number fruits and thus yield in cucurbits (Srivastava and Srivastava, 1976). Pant Kheera-1 × Summer Kheera exhibited maximum heterosis over better parent for vine length (29.75), whereas JLG × EC-27075 exhibited maximum heterosis over the standard checks NS-404 (35.80). These results are in agreement with the finding of Bairagi *et al.* (2005) and Singh *et al.* (1999).

The positive and significant heterosis value for fruit yield per plant is desirable for exploitation of hybrid vigor. The cross combination Gy-14 × Swarna Sheetal exhibited maximum heterosis for marketable yield per plant over better parent and cross combination JLG × Summer Kheera exhibited maximum heterosis standard check, 'NS-404'. Yield of cucumber is positively correlated with the fruit length, fruit diameter and fruit weight, whereas fruit weight is time function. In the present investigation crosses shown positive and significant heterosis for marketable yield, fruit diameter, fruit length and fruit weight. These results are in agreement with the finding of Singh *et al.* (2014), Singh *et al.* (2010), Singh *et al.* (2012) and Cramer and Wehner (1999).

At the same time of presence of predominantly large amount of non-additive gene action for yield and its related traits as observed in the present study, necessitates the maintenance of the heterozygosity in the population. In the present investigation, considerable amount of heterosis was observed in desired direction of fruit yield and yield related characters.

REFERENCES

Anonymous (2013). *Package of Practices for Vegetable Crops.* pp. 20-21. Punjab Agricultural University, Ludhiana.

Badgujar CD, More TA (2013). Combining ability studies in tropical gynoecious cucumber hybrids. *Adv. in Plant Sci.* 26: 635-640.

Bairagi SK, Ram HH, Singh DK, Maurya SK (2005). Exploitation of hybrid vigour for yield and attributing traits in cucumber. *Indian J. Hort.* 62: 41-45.

Bairagi SK, Ram HH, Singh DK (2013). Analysis of combining ability in cucumber (*Cucumis sativus* L.) through half diallel mating system. *Ann. Hort.* 6: 308-314.

Dogra BS, Kanwar MS (2011). Exploiting for yield and horticultural traits in cucumber (*Cucumis sativus* L.). *Indian J. Plant Genet. Res.* 24: 332-339.

Gill HS, Singh JP, Pachauri DC (1973) Pusa Sanyog outyields other cucumbers. *Indian Hort.* 18: 11-30.

Griffing B (1956). Concept of general and specific combining ability in diallel cross system. *Aust. J. Biol. Sci.* 9: 463-493.

Hayes HK, Jones DR (1916). First generation crosses in cucumbers. *Conn. Storrs Agric. Stat. Res.* 40: 319-22.

Jakimovic AD (1938). Heterosis in cucumber. *Fruit Veg. Grower* 12: 17-19.

Kumar J, Munshi AD, Kumar R, Sureja AK (2011). Studies on heterosis in slicing cucumber. *Indian J. Hort.* 67:197-201.

Kushwaha ML, Yadav LB, Maurya RP (2011). Heterobeltiosis and combining ability in cucumber (*Cucumis sativus*) under mid hilly area of Uttrakhand. *Prog. Agric.* 11: 103-107.

Lower RL, Nienhius J, Miller CH (1982). Gene action and heterosis for yield and vegetative characteristics in a cross between a gynoecious pickling cucumber inbred and a *Cucumis sativus* var *hardwickii* R line. *J. Am. Soc. Hort. Sci*. 107: 75-78.

More TA (2002). Development and exploitation of tropical gynoecious lines in F_1 hybrid of cucumber. *Acta Hort.* 588: 261-267.

Reddy ANK, Munshi AD, Behera TK, Sureja AK, Sharma RK (2014). Studies on combining ability in cucumber. *Indian J. Hort.* 71: 349-353.

Shetty NV, Wehner TC (2002). Estimation of fruit grade weights based on fruit number and total fruit weight in cucumber. *Hort. Sci*. 37: 1117-1121.

Singh AK, Gautam NC, Singh RD (1999). Heterosis in cucumber (*Cucumis sativus L*). *Veg. Sci.* 26: 126-128.

Singh R, Singh AK, Kumar S, Singh BK, Singh S P (2012). Heterosis and inbreeding depression for fruit characters in cucumber. *Indian J. Hort.* 69: 200-204.

Singh SK, Kishor GR, Srivastava JP (2010). Commercial exploitation of hybrid vigour in cucumber. *Prog. Agric.* 10: 266-269.

Singh SK., Singh SV, Srivastava JP (2014). Heterosis and inbreeding depression for yield and its component traits in cucumber. *Agriways* 2: 47-51.

Sprague GF, Tatum LA (1942). General vs. specific combining ability in single crosses of corn. *J. Am. Soc. Agron.* 34: 923-932.

Srivastava VK, Srivastava LS (1976). Genetic parameters, correlation coefficient and path coefficient analysis in bittergourd. *Indian J. Hort.* 33:66-70.

Vijayakumari P, More TA, Shesadri VS (1993). Heterosis in tropical and temperate gynoecious hybrids in cucumber. *Veg. Sci.* 20: 152-57.

Wehner TC, Miller CH (1985). Effect of gynoecious expression on yield and earliness of a fresh market cucumber hybrid. *J. Am. Soc. Hort. Sci.* 110: 464-466.