Combining Ability and Gene Action in Cucumber (Cucumis Sativus L.)

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Abstract

Combining ability and genetic components of eleven inbred line of cucumber were estimated following line x tester mating design for qualitative and quantitative characters. Three inbred lines were used as tester. Variance within the treatments, parents, parent vs crosses, crosses, testers and line x tester interaction were highly significant for all the characters. Considering the *gca* effects the lines CS08, CS16, CS040, CS07 and CS51 were best for their earliness and other horticulture traits. The hybrids CS07×CS08, CS16×CS44, CS51×CS44, CS40×CS08, CS17×CS39 were superior in terms of yield per plant and its component characters. The magnitude of σ^2SCA was high in all characters compared to σ^2GCA and dominance variance (σ^2D) was higher than the additive genetic variance (σ^2A) indicating that the predominance role of non-additive gene action. The results indicated the importance of heterosis breeding for effective utilization of non-additive genetic variance in cucumber.

Keywords: Cucumber, combining ability, *gca, sca*

1. Introduction

Cucumber *(Cucumis sativus* L.) belongs to the family cucurbitaceae and its centre of origin is India (Renner *et al*., 2007). It is an important and one of the most popular fruit vegetable in Asia. Cucumber is also an ideal vegetable for its edible tender fruits, preferred as salad ingredient, pickles, desert fruit and as a cooked vegetable. The fruit has about 95% water content (Anonymous, 2012) which makes it diuretic, possessing a deep cleansing action due to the presence of some natural chemical constituents such as glycolic, lactic and salicylic acids (Uzodike and Onuoha, 2009). Cucumber is grown widely in different parts of the world. It is year round out door vegetable in the tropics (Eifediyi and Remison, 2010). Since there exist a considerable variability of this crop, it is possible to develop high yielding varieties through breeding approaches like selection or hybridization.

Combining ability is one of the important and powerful tools to identifying the best combiner that may be used in crosses to exploit heterosis. It helps to know the genetic architecture of various characters that enable the breeder to design effective breeding plan for future improvement of the existing materials. The combining ability analysis gives useful information regarding the selection of parents in terms of the performance of their hybrids. Information on the relative importance of general combining ability (GCA) and specific combining ability (SCA) is of value in breeding programs for species which are amenable to the development of F_1 hybrid cultivars such basic information on combining ability in cucumber would aid the breeder in developing improved hybrid cultivars (Tasdighi and Baker, 1981). The line x tester technique was developed by Kempthorne in 1957. It is a good approach for screening the germplasm on the basis of GCA and SCA variances and effects. Line ×tester analysis involving parents give the additional information about the presence or absence of epistasis, average degree of dominance, as well as distribution of dominant and recessive genes in the parents. Application of line × tester technique in a cross-pollinated crop like cucumber for this purpose may be appropriate. The estimates of gene effects and genetic variance help in understanding the genetic potential of the breeding material. Fruit yield being a polygenic character, many genes are involved in its inheritance. Because of the

small effect of individual genes, it is apparently difficult to study their individual effects. The present investigation was undertaken to generate information for identification of good general and specific combiners of cucumber genotypes for the improvement of yield and its attributes.

2. Materials and Methods

The experiment was conducted at the research farm of Horticulture Department, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during March, 2013 to June, 2013. The study consisted of eight inbred lines as female parent and three testers as male parent with diverse genetic base. The parents were selected based on their performance on different horticultural traits, heritability and genetic diversity as evaluated in earlier experiment. The experiment was laid out in randomized complete block design (RCBD) with three replications. Twenty four cross combinations were produced through line x tester mating design in previous year and together with their eleven parents (CS07, CS08, CS16, CS17, CS18, CS39, CS40, CS44, CS50, CS51 and CS52). The characteristics of selected 11 parents are presented in Table 1. The genotypes were randomly allotted in each block. The unit plot size was 1.5×3.75m accommodating 10 plants in each plot having row and plant spacing of 1m $\times 0.75$m, respectively. Adjacent plots were separated by 50 cm and while blocks were separated by 1.0 m.

Chemical fertilizers 69-35-75-5.5-4.3-3.25 kg/ha of N-P-K-S-Zn-B and 10 tons/ha cow-dung were applied (Fertilizer Recommendation Guide, 2012). Half of cow-dung and MoP and the entire amount of TSP, Gypsum, Zinc oxide and Boric acid were applied in the field during final land preparation. The remaining cow-dung, MoP and one third of urea were applied in the pit one week prior to transplanting. Twenty days old seedlings were transplanted. Top dressings were done in the two equal installments at 20 and 40 days after transplanting. Plants were given support by bamboo sticks for climbing on trellis. Trellis were made by bamboo sticks to support the growing plants and allowed them to creep. The seedlings were watered immediately after transplanting. Necessary intercultural operations were done to ensure normal growth and development of the plants. Adult red pumpkin beetles were controlled by applying ripcord @ of 10 ml per 10 liters of water. At fruiting stage to control the attack of fruit fly, pheromone trap were used at a density of 5m^2/trap. Five random competitive plants were selected and tagged from each plot. Observations were recorded on these plants on days to 1st male flower, days to 1st female flower, node at 1st male flower appearance, node at 1st female flower appearance, days to 50% male flower, days to 50% female flower, days to 1st fruit harvest, vine length, number of branches per plant, fruit length, fruit width, flesh thickness, single fruit weight, number of fruits per plant, yield per plant and 1000 seed weight.

2.1 Statistical Analysis

All the quantitative data taken were subjected to ANOVA and differences tested by F-test. The combining ability analysis were done according to Kempthorne (1957) based on the performance of the parents and their relative contribution to the F_1s as determined by the general combining ability effects and specific combining ability effects. For analysis of data MS-EXCEL and R i386 3.0.1 statistical software were used.

Table 1. Characteristics of selected 11 inbred lines of cucumber

Characters	CS07	CS08	CS16	CS17	CS18	CS39	CS40	CS44	CS50	CS51	CS52
Days to 1st male flower	43.4	42.6	42.8	43.1	42.9	43.7	43.5	42.1	41.5	48.5	43.8
Node at 1st male flower appearances	3.9	4.3	4.3	5.1	6.1	5.1	4.6	3.9	4.7	6.4	3.9
Days to 1st female flower	46.5	44.7	45.3	44.9	44.9	46.7	45.8	43.7	45.7	55.6	46.3
Node at 1st female flower appearances	6.2	6.5	6.4	6.1	7.9	7.4	6.9	4.8	7.1	8.9	6.7
Days to 50% plants male flower	45.0	43.7	44.3	44.0	44.7	44.7	45.0	43.7	45.0	51.0	46.0
Days to 50% plants female flower	48.0	46.0	46.7	46.7	46.3	48.3	47.7	44.3	47.7	59.0	48.7
Vine length (cm)	339.1	343.6	351.1	332.0	340.1	175.8	304.4	152.8	357.1	312.5	273.5
No. of branches/plant	9.3	8.2	6.7	7.9	8.8	9.3	9.2	8.9	7.9	7.0	5.1
No. of fruits/plant	8.0	7.0	6.7	7.2	5.9	8.9	8.1	9.8	7.3	5.3	5.0
Days to 1st fruit harvest	59.6	57.7	58.5	57.6	57.9	59.1	58.3	57.0	56.7	68.7	57.9
Fruit length (cm)	16.4	18.5	18.9	20.2	20.3	11.7	20.0	13.3	20.3	22.9	12.6
Fruit width (cm)	4.6	4.2	4.4	4.4	5.1	5.3	5.1	3.5	4.6	6.2	4.1
Flesh thickness (cm)	2.8	2.9	3.0	2.7	3.0	3.5	2.5	2.4	2.8	3.3	2.4
Single fruit weight (gm)	337.8	303.8	424.9	368.9	337.1	171.6	222.1	158.1	287.7	385.4	175.1
Yield per plant (kg)	2.7	2.1	2.9	2.7	2.0	1.5	1.8	1.5	2.1	2.0	0.9
1000 seed weight(gm)	26.8	26.3	27.2	28.9	30.0	23.9	28.8	26.6	23.6	28.2	23.5

3. Results and Discussion

The analysis of variance for combining ability based on mean square of different characters in 11 cucumber inbred lines was presented in Table 2. Variances within the treatments, parents, parent vs crosses, crosses, testers and line ×tester interaction were highly significant for all the characters. Variance due to line was significant for days to 1st male flower and days to 50% male flower. Variance due to tester was significant for most of the characters except node at 1st male flower appearances, node at 1st female flower appearances, flesh thickness and yield per plant which indicates that both additive and no-additive gene actions played significant role for expression of these characters.

Table 2. Analysis of variance based on mean squares and estimates of genetic component in line ×tester study of cucumber

Source of variation	df	Days to 1st male flower	Node at 1st male flower appearances	Days to 1st female flower	Node at 1st female flower appearances	Days to 50% plant male flower	Days to 50% plant female flower	Vine length (cm)	No. of branches per plant
Replication	2	1.23	0.35	0.15	0.63	1.67	3.09	1118.99	0.76*
Treatments	34	41.99**	1.74**	58.17**	8.37**	47.53**	72.92**	12940.99**	12.45**
Parents	10	10.05**	2.21**	30.41**	3.41	12.56**	43.61**	14963.38**	5.13**
Parents vs. Crosses	1	165.95**	4.59**	25.65**	49.47**	83.24**	0.002	6478.74	29.00**
Crosses	23	50.50**	1.41**	71.65**	8.74**	61.19**	88.83**	12342.66**	14.92**
Line	7	63.56*	0.76	65.54	7.99	77.49*	81.46	6406.53	5.97
Tester	2	187.30**	2.62	309.93**	11.90	207.10**	353.84**	79498.45**	76.24**
Line × tester	14	24.42**	1.57**	40.67**	8.66**	32.19**	54.65**	5717.04**	10.63**
Error	68	1.15	0.13	1.88	2.05	1.75	1.22	165.53	0.25

* and ** significant at 5% and 1% level, respectively

Table 2. Cont`d

Source of variation	df	No. of fruits per plant	Days to 1st fruit harvest	Fruit length (cm)	Fruit width (cm)	Flesh thickness (cm)	Single fruit weight (g)	Yield per plant (kg)	1000 seed weight (g)
Replication	2	0.19	2.37	0.67	0.02	0.03	13.69	0.08	1.72
Treatments	34	7.80**	72.03**	34.20**	1.37**	0.33**	15723.23**	0.88**	25.89**
Parents	10	6.54**	33.04**	40.90**	1.57**	0.36**	26226.09**	0.33**	15.26**
Parents vs. crosses	1	78.84**	104.50**	216.00**	2.42**	0.54**	69176.19**	4.42**	0.87
Crosses	23	5.26**	87.58**	23.39**	1.24**	0.30**	8832.72**	0.97**	31.60**
Line	7	2.70	78.73	6.29	0.38	0.13	5144.69	0.57	39.92
Tester	2	29.75**	348.37**	138.31**	5.22*	0.71	39322.18**	5.63	64.78*
Line × tester	14	3.05**	54.75**	15.52**	1.10**	0.33**	6321.10**	0.50**	22.70**
Error	68	0.17	1.01	0.53	0.03	0.01	76.99	0.06	2.53

* and ** significant at 5% and 1% level, respectively.

4. General Combining Ability Effects

The GCA variances of each parent play significant role for the choice of parents. A parent with higher positive significant *gca* effects is considered as a good general combiner. The magnitude and direction of the significant effects for the eleven parents provide meaningful comparisons and would give indications to the future breeding program.

Considering *gca* effects testers CS08 and CS44 were the best for days to 1st male and female flower, node at 1st male and female flower appearances, days to 50% plants male and female flower, vine length, number of branches per plant, number of fruits per plant, days to 1st fruit harvest, fruit length, single fruit weight and yield per plant (Table 3.1). The parental lines CS16 was the best for days to 1st male and female flower, days to 50% male and female flower, number of fruits per plant, days to 1st fruit harvest, fruit length, fruit width, flesh thickness, yield per plant and thousand seed weight, CS17 was the best for days to 1st male and female flower, days to 50% male and female flower, vine length, number of branches per plant, days to 1st fruit harvest, fruit length, single fruit weight and thousand seed weight, CS40 was the best for days to 1st male and female flower, node at 1st male and female flower appearances, days to 50% male and female flower, days to 1st fruit harvest, single fruit weight, CS51 was the best for vine length, fruit length, fruit width , flesh thickness, single fruit weight, yield per plant and thousand seed weight, CS07 was best for number of fruits per plant, single fruit weight and yield per plant; CS50 was the flesh thickness and yield per plant and CS18 was the best for vine length and single fruit weight (Table 3.1, 3.2 and 3.3). These indicated that, CS44, CS08, CS16, CS51, CS40 and CS07 may contribute significant to the performance of their progenies. Krishnaprasad and Singh (1992) reported the two parents were good general combiners for yield and fruit number. Ananthan and Pappiah (1997) reported that general combining ability were significant for days to first male flower, days to first female flower, fruit number per plant, fruit length, fruit girth, and single fruit weight. Similar results were also reported by Verma *et al.* (2000) in days to 50% male and female flowers, fruit length, weight and girth, number of fruits per plant and fruit yield per plant.

Table 3.1. gca effects of flowering behavior of cucumber

Parents	Days to 1st male flower	Days to 1st female flower	Node at 1st male flower appearance	Node at 1st female flower appearance	Days to 50% plant male flower	Days to 50% plant female flower
Lines						
CS07	0.32	0.31	-0.04	0.47	0.18	0.78*
CS16	-1.54**	-1.64**	-0.01	-0.04	-1.71**	-1.67**
CS17	-1.63**	-1.67**	0.21*	-0.59	-1.71**	-2.33**
CS18	1.61**	1.73**	0.12	-0.10	1.74**	1.56**
CS40	-4.94**	-5.22**	-0.68**	-1.75**	-5.37**	-5.67**
CS50	2.46**	2.33**	0.14	1.52**	2.40**	2.67**
CS51	3.32**	2.80**	0.21*	-0.04	4.07**	3.33**
CS52	0.41	1.36**	0.05	0.52	0.40	1.33**
SE gca	0.35	0.45	0.12	0.48	0.44	0.37
SE (gi-gj)	0.51	0.65	0.17	0.67	0.62	0.52
Testers						
CS08	-0.91**	-1.13**	0.04	0.51*	-1.06**	-1.24**
CS39	3.14**	4.02**	0.31**	0.29	3.32**	4.31**
CS44	-2.22**	-2.89**	-0.35**	-0.80**	-2.26**	-3.07**
SE gca	0.22	0.28	0.07	0.29	0.27	0.22
SE (gi-gj)	0.31	0.39	0.11	0.41	0.38	0.32

* and ** significant at 5% and 1% level, respectively

Table 3.2. gca effects for days to 1st fruit harvest, number of branches per plant, vine length, fruit length and fruit width of cucumber

Parents	Days to 1st fruit harvest	No. of branches per plant	Vine length	Fruit length	Fruit width
Lines					
CS07	-0.03	0.29	-2.39	-0.48*	-0.24**
CS16	-1.82**	0.28	2.67	-0.32	0.31**
CS17	-1.77**	0.75**	28.81**	0.75**	-0.12*
CS18	1.29**	0.97**	22.54**	-0.41	-0.14*
CS40	-5.63**	-0.59**	-28.19**	0.69**	0.05
CS50	2.78**	-1.50**	0.24	-0.28	0.01
CS51	3.01**	-0.54**	23.92**	1.31**	0.28**
CS52	2.16**	0.33*	-47.59**	-1.25**	-0.14*
SE gca	0.33	0.17	4.29	0.24	0.06
SE (gi-gj)	0.47	0.23	6.06	0.34	0.08
Testers					
CS08	-1.57**	0.23*	32.62**	2.60**	-0.002
CS39	4.34**	-1.89**	-66.45**	-2.13**	0.47**
CS44	-2.77**	1.65**	33.84**	-0.47**	-0.46**
SE gca	0.20	0.10	2.63	0.15	0.03
SE (gi-gj)	0.29	0.14	3.71	0.21	0.05

* and ** significant at 5% and 1% level, respectively

Table 3.3. gca effects for yield, yield contributing traits and thousand seed weight of cucumber

Parents	No. of fruits per plant	Fruit flesh thickness	Single fruit weight	Yield per plant	Thousand seed weight
Lines					
CS07	0.67**	-0.07**	10.87**	0.35**	-0.87
CS16	0.80**	0.08**	-5.62*	0.18**	2.95**
CS17	-0.47**	-0.08**	13.63**	-0.22**	1.99**
CS18	-0.07	-0.02	15.52**	-0.15*	-2.75**
CS40	0.20	-0.12**	7.34*	0.05	-1.42**
CS50	-0.33*	0.15**	1.36	0.013*	-1.07*
CS51	0.00	0.17**	13.38**	0.21**	2.33**
CS52	-0.80**	-0.13**	-56.48**	-0.42**	-1.17*
SE gca	0.13	0.03	2.92	0.07	0.53
SE (gi-gj)	0.19	0.05	4.14	0.11	0.75
Testers					
CS08	0.15*	-0.10**	18.16**	0.36**	0.61*
CS39	-1.8**	0.20**	-46.38**	-0.55**	-1.86**
CS44	1.03**	-0.10**	28.21**	0.19**	1.25**
SE gca	0.08	0.02	1.79	0.05	0.32
SE (gi-gj)	0.11	0.03	2.53	0.07	0.46

* and ** significant at 5% and 1% level, respectively

5. Specific combining ability (sca) effects

The *sca* effects signify the role of non-additive gene action in the expression of the characters. It indicates the high specific combining ability leading to highest performance of some specific cross combinations. That is why it is related to a particular cross. High *sca* effects may arise not only in crosses involving high × high combination but also in those involving low × high and low × low combination. Thus in practice, some of the low combiners should also be accommodated in hybridization program. Estimates on *sca* effects of the crosses in F_1 generation showed that there were a good number of crosses having significant positive or negative *sca* effect for different important characters of cucumber. None of the hybrids indicated significant positive *sca* effects for all the characters. Sharma *et al.* (2001) and Ram *et al*. (1999) reported similar results in the case of cucumber and bitter gourd, respectively.

Table 4.1. Estimates of sca effects of crosses for flowering behavior of cucumber

Crosses	Days to 1st male flower	Days to 1st female flower	Node at 1st male flower appearance	Node at 1st female flower appearance	Days to 50% plants male lower	Days to 50% plants female flower
CS07×CS08	-3.33**	-3.63**	-1.48**	-3.09**	-4.06**	-4.65**
CS07×CS39	4.75**	6.29**	0.78**	0.67	5.24**	6.14**
CS07×CS44	-1.42*	-2.66**	0.70**	2.43**	-1.18	-1.49*
CS16×CS08	0.80	-0.81	1.03**	0.29	0.50	-1.21
CS16×CS39	0.62	2.31**	0.09	0.84	1.13	2.92**
CS16×CS44	-1.42*	-1.51	-1.12**	-1.13	-1.63*	-1.71**
CS17×CS08	0.29	0.08	0.08	-0.23	0.83	0.46
CS17×CS39	-2.83**	-3.86**	-0.40	-0.33	-3.54**	-4.75**
CS17×CS44	2.53**	3.78**	0.33	0.56	2.71**	4.29**
CS18×CS08	0.65	0.08	-0.17	-0.05	0.39	-0.10
CS18×CS39	1.00	1.53	0.02	0.18	1.01	2.03**
CS18×CS44	-1.64**	-1.62*	0.15	-0.13	-1.40	-1.93**
CS40×CS08	0.07	0.64	-0.04	-0.003	0.50	0.13
CS40×CS39	-2.31**	-2.24**	-0.38	-0.64	-2.21**	-1.75**
CS40×CS44	2.24**	1.61*	0.41*	0.65	1.71*	1.63*
CS50×CS08	-0.60	-0.05	-0.19	3.60**	-0.61	0.79
CS50×CS39	2.22**	1.07	0.20	-1.44	2.35**	1.58
CS50×CS44	-1.62**	-1.02	-0.01	-2.15**	-1.74*	-2.38**
CS51×CS08	-0.93	-0.38	0.01	-0.11	-0.94	-0.88
CS51×CS39	1.35*	1.80*	0.20	0.78	2.01**	2.25**
CS51×CS44	-0.42	-01.42	-0.21	-0.66	-1.07	-1.38*
CS52×CS08	3.05**	4.06**	0.76**	-0.40	3.39**	5.46**
CS52×CS39	-4.80**	-6.89**	-0.51*	-0.04	-5.99**	-8.42**
CS52×CS44	1.76**	2.83**	-0.25	0.45	2.60**	2.96**
SE(sca)	0.61	0.79	0.21	0.82	0.76	0.64
SE (sij- skl)	0.87	1.12	0.29	0.41	1.07	0.90

* and ** significant at 5% and 1% level, respectively

Table 4.2. Estimates of sca effects of crosses for days to 1st fruit harvest, no. of branches per plant, vine length, fruit length and fruit width of cucumber

Crosses	Days to 1st fruit harvest	No. of branches per plant	Vine length	Fruit length	Fruit width
CS07×CS08	-6.94**	1.61**	23.94**	2.08**	0.59**
CS07×CS39	5.71**	-1.50**	-48.99**	-1.05*	-0.41**
CS07×CS44	1.23*	0.11	25.05**	-1.02*	-0.18
CS16×CS08	0.08	-1.21**	25.74**	-2.71**	0.06
CS16×CS39	2.97**	-0.02	-16.66*	0.14	-0.28**
CS16×CS44	-3.05**	1.24**	-9.08	2.57**	0.22*
CS17×CS08	1.17*	2.06**	24.61**	-2.16**	-0.14
CS17×CS39	-5.34**	1.24**	18.21*	3.09**	0.27**
CS17×CS44	4.17**	-3.30**	-42.82**	-0.93*	-0.12
CS18×CS08	0.44	0.17	22.27**	1.86**	0.16
CS18×CS39	1.92**	-1.18**	-51.92**	-0.53	0.08
CS18×CS44	-2.36**	1.01**	29.65**	-1.33**	-0.24*
CS40×CS08	0.26	-0.54*	-12.71	1.94**	0.77**
CS40×CS39	-2.02**	1.11**	30.14**	-0.55	-0.15
CS40×CS44	1.76**	-0.57*	-17.42*	-1.39**	-0.62**
CS50×CS08	0.28	0.57*	-23.54**	-0.04	-0.27**
CS50×CS39	0.90	-0.45	18.91*	-1.42**	-0.48**
CS50×CS44	-1.18*	-0.12	4.62	1.46**	0.75**
CS51×CS08	0.93	0.41	24.70**	0.27	-0.42**
CS51×CS39	2.61**	-1.67**	-15.97*	-2.38**	-0.13
CS51×CS44	-3.54**	1.26**	-8.73	2.11**	0.55**
CS52×CS08	3.77**	-3.06**	-84.99**	-1.22**	-0.76**
CS52×CS39	-6.74**	2.46**	66.28**	2.70**	1.11**
CS52×CS44	2.97**	0.59*	18.72*	-1.48**	-0.35**
SE(sca)	0.58	0.29	7.43	0.42	0.10
SE (sij- skl)	0.82	0.41	10.50	0.59	0.14

* and ** significant at 5% and 1% level, respectively

Table 4.3. sca effects of crosses for fruit flesh thickness, single fruit weight, number of fruits per plant, yield per plant and thousand seed weight of cucumber

Crosses	Flesh thickness	Single fruit weight	No. of fruits per plant	Yield per plant	Thousand seed weight
CS07×CS08	0.49**	35.77**	1.42**	0.60**	-2.03*
CS07×CS39	-0.16**	-44.89**	-0.35	-0.08	-1.51
CS07×CS44	-0.34**	9.12	-1.07**	-0.52**	3.54**
CS16×CS08	-0.22**	30.52**	-1.01**	-0.53**	-0.38
CS16×CS39	-0.15**	-7.13	-0.39	-0.12	0.57
CS16×CS44	0.38**	-23.39**	1.40**	0.65**	-0.19
CS17×CS08	-0.17**	7.35	0.05	-0.03	3.96**
CS17×CS39	0.18**	16.62**	0.78**	0.28*	-3.34**
CS17×CS44	-0.01	-23.97**	-0.83**	-0.25*	-0.61
CS18×CS08	0.02	23.26**	0.65**	-0.10	0.50
CS18×CS39	0.09	-18.73**	-0.02	0.12	1.71
CS18×CS44	-0.11*	-4.52	-0.63**	-0.02	-2.21
CS40×CS08	0.35**	30.24**	0.79**	0.50**	-0.40
CS40×CS39	-0.27**	-27.36**	0.11	-0.08	1.76
CS40×CS44	-0.08	-2.88	-0.90**	-0.42**	-1.36
CS50×CS08	-0.01	-35.45**	-0.38	-0.06	-3.05**
CS50×CS39	-0.23**	2.76	0.25	-0.05	1.56
CS50×CS44	0.24**	32.70**	0.13	0.11	1.48
CS51×CS08	-0.17**	-36.41**	-0.91**	-0.16	1.26
CS51×CS39	-0.04	-18.07**	-0.59*	-0.25*	-3.38**
CS51×CS44	0.21**	54.47**	1.50**	0.41**	2.12*
CS52×CS08	-0.29**	-55.27**	-0.61**	-0.23	0.14
CS52×CS39	0.57**	96.80**	0.21	0.18	2.63**
CS52×CS44	-0.29**	-41.52**	0.40	0.05	-2.78**
SE(sca)	0.06	5.06	0.23	0.13	0.92
SE (sij- skl)	0.08	7.16	0.33	0.19	1.30

* and ** significant at 5% and 1% level, respectively

The *sca* effects of certain crosses were related with *gca* of their parents, as the best cross combinations for most of the characters involved both or at least one parent with high or average *gca* effects for particular trait. Considering the *sca* effects the combinations CS07 × CS08 was best for days to 1st male and female flower, node at 1st male and female flower appearance, days to 50% plants male and female flower, vine length, number of branches and fruits per plant, days to 1st fruit harvest, fruit length, fruit width, flesh thickness, single fruit weight and yield per plant, CS52 ×CS39 was best for days to 1st male and female flowers, node at 1st male flowers appearance, days to 50% plants male and female flowers, vine length, number of branches per plant, days to 1st fruit harvest, fruit length, fruit width, flesh thickness, single fruit weight and thousands seed weight, on the other hand, CS16 ×CS44 was best for days to 1st male flowers, node at 1st male flowers appearance, days to 50% male and female flowers, number of branches and fruits per plant, days to 1st fruit harvest, fruit length, flesh thickness and yield per plant, CS51 ×CS44 was also best for number of branches and fruits per plant, days to 1st fruit harvest, fruit length, fruit width, single fruit weight, thousands seed weight and yield per plant, CS40 ×CS08 was best for number of branches, fruits per plant, fruit length, fruit width, flesh thickness, single fruit weight and yield per plant, CS17 ×CS39

was best for days to first male and female flowers, days to 50% male and female flowers, vine length, fruit length and yield per plant found high *sca* effects which could be exploited for hybrid vigor.

The present findings were in agreement with those reported by Verma *et al.* (2000) and Singh *et al.* (1998) in cucumber. Uddin *et al*. (2009) reported that their crosses showed desirable significant effects in various traits involving high × high, high × low, and low × low combiners indicating the role of additive, dominance and epistatic gene action. Heterosis (high *sca*) in the crosses involving high × high general combiners might be due to additive × additive type interaction which was partially fixable. High *sca* effects in the crosses involving low × low combining parents were possibly due to intra and inter allelic interaction.

6. Genetic Component Analysis

The mean sum of squares due to *gca* and *sca* were used to estimate the variances for *gca* and *sca* respectively, based on these variances the additive and dominance variances and their ratio are also calculated.

The magnitude of σ^2SCA was high in all characters compared to σ^2GCA and dominance variance (σ^2D) was higher than the additive genetic variance (σ^2A) indicating that the predominance of non additive gene action (Table 5.1). Similar result also revealed by Sharma (2010). The estimates of GCA and SCA variances, additive (σ^2A) and non-additive (σ^2D) components of variance for yield per plant and majority of the important traits, shows that non-additive gene action was in preponderance, which proved the possibility of exploitation of hybrid vigor in cucumber. Uddin *et al*. (2009) observed the magnitude of σ^2SCA high in all characters compared to σ^2GCA, and dominance variance (σ^2D) was higher than the additive genetic variance (σ^2A). The ratios of SCA to GCA variance were higher than unity indicating predominated non-additive gene action over additive gene action for all characters. However the prevalence of non-additive gene action and the existence of sizeable amount of additive gene action in the inheritance of yield contributing attributes suggest that transgressive breeding may not be useful for the used parents. Non-additive gene action is prerequisite for launching a heterosis breeding program. Thus heterosis breeding could be the better choice for improvement of cucumber. Prasad *et al.* (2004) and Uddin *et al*. (2009) stated similar results in cucumber.

Table 5.1. Estimation of genetic components of variation and ratios for different characters

Sl. No.	Characters	$\sigma^2 gca$	$\sigma^2 sca$	σ^2additive	σ^2dominance	σ^2D /σ^2A ratio	$\sigma^2 sca$ / σ^2 gca ratio
01.	Days to 1st male flower	0.60	30.20	2.40	15.52	6.47	50.33
02.	Node at 1st first male flower appearance	0.003	0.51	0.01	0.96	96	170
03.	Days to 1st female flower	0.72	44.89	2.87	25.54	8.89	62.35
04.	Node at 1st female flower appearance	0.002	2.49	0.01	4.41	441	1245
05.	Days to 50% plants male flower	0.67	34.62	2.67	20.30	7.60	51.67
06.	Days to 50% plants female flower	0.79	54.03	3.15	35.62	11.30	68.39
07.	Vine length (cm)	152.54	10125.05	610.17	3701.00	6.06	66.37
08.	Number of branches per vine	0.10	10.10	0.41	6.55	15.97	101
09.	Number of fruits per vine	0.08	7.01	0.30	4.27	14.23	87.63
10.	Days to 1st fruit harvest	0.76	50.04	3.05	30.76	10.08	65.84
11.	Fruit length (cm)	0.18	17.62	0.72	9.99	13.87	97.88
12.	Fruit width (cm)	0.003	0.73	0.01	0.72	72	243.33
13.	Flesh thickness (cm)	0.001	0.13	0.003	0.21	70	130
14.	Single fruit weight (g)	57.82	5617.45	231.30	4162.74	17.99	97.15
15.	Yield per plant (kg)	0.01	1.06	0.03	0.88	29.33	106
16.	1000 seed weight (g)	0.20	13.31	0.82	13.44	16.39	66.55

7. Conclusion

Considering the *gca* effects, the tasters CS08 and CS44 were best for earliness and other horticultural traits. However, the parental lines CS16 and CS40 were best for earliness. The inbred lines CS51 and CS07 were best for fruit length, fruit breadth, flesh thickness, single fruit weight, fruits per plant and yield per plant. The hybrids CS07×CS08, CS16×CS44, CS51×CS44, CS40×CS08, CS17×CS39 were superior in terms of yield per plant and its component characters. The magnitude of σ^2SCA was high in all characters compared to σ^2GCA and dominance variance (σ^2D) was higher than the additive genetic variance (σ^2A) indicating that the predominance role of non additive gene action. The results indicated the importance of heterosis breeding for effective utilization of non-additive genetic variance in cucumber.

References

Ananthan, M. and C. M. Pappiah. 1997. Combining ability and correlation studies in cucumber (Cucumis sativus L.). South Indian Hort. 45: 1-2, 57-58.

Anonymous. 2012. Nutritional recommendations for cucumber (Cucumis sativus L.) in open fields, tunnel and greenhouse. Haifa, Pioneering the Future. pp 45.

Eifediyi, E. K. and S. U. Remison. 2010. Growth and yield of cucumber (Cucumis sativus L.) as influenced by farmland manure and inorganic fertilizer. Journal of Plant Breeding and Crop Science. 2(7): 216-220.

Fertilizer Recommendation Guide. 2012. Bangladesh Agricultural Research Council, Farmgate, Dhaka. 1215.

Kempthorne, O. 1957. An introduction to genetic statistics, New York, John Wileys and Sons, Inc., London, pp.1-545.

Krishnaprasad, V. S .R. and D. P. Singh. 1992. Combining ability through line × tester analysis in cucumber (Cucumis sativus L.). Indian J. of Hort. 49(4): 358-362.

Prasad, V.S.R.K., M. Rai, R.S. Pan and A.K. Singh. 2004. Combining ability and standardized potency in crosses between Cucumis sativus L. × C. hardwickii R. Ind. J. of Hort. 61(2): 128-131.

Ram, D., G. Kalloo and M. Singh. 1999. Combining ability of quantitative characters in bitter gourd (Momordica charantica). Indian J. Agric. Sci. 69(2): 122-125.

Renner, S. S., H. Schaefer and A. Kocyan. 2007. Phylogenetics of Cucumis (Cucurbitaceae): cucumber (C. sativus) belongs in an Asian/Australian clade far from melon (C. melo). BMC Evolutionary Biology. 7: 58.

Sharma, A., K. Vidyasagar and N. K. Pathania. 2001. Studies on combining ability for earliness marketable fruit yield in cucumber (Cucumis sativus L.). Himachal J. Agric. Res. 58(7): 578-586.

Sharma, M. 2010. Gene action and heterosis studies involving gynoecious lines in cucumber (Cucumis sativus L.) M.S. Thesis, Department of Vegetable Science and Floriculture, Himachal Pradesh Krishi Vishuavidyalaya, Palampur, India.

Singh, P. K., J. C. Kumar and J. R. Sharma. 1998. Heterosis studied in long fruited bottle gourd. Vegetable Sci, 25(1): 55-57.

Tasdighi, M. and L. R. Baker. 1981. Comparison of single and three way crosses of pickling cucumber hybrids for femaleness and yield once over harvest. J. Amer. Soc. Hort. Sci. 106 (3): 370-373.

Uddin, M. N., M. M. Hossain, M. M. Rahman, S. Ahmad and A.K.M. Quamruzzaman. 2009. Combining Ability and Gene Action In Cucumber (Cucumis Sativus L.). SAARC J. Agri. 7 (1), 64-72.

Uzodike, E. B. and I. N. Onuoha. 2009. The effect of cucumber (Cucumis Sativus L.) extract on acid induced corneal burn in Guinea Pigs. African Journal Online. 15: 3-5.

Verma, T. S., R. V. Singh and S. C. Sharma. 2000. Line $\times$ tester analysis for combining ability in cucumber. Indian J. of Hort. 2: 144-147.