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Combining ability analysis in *Lagenaria siceraria* for growth and yield attributes

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Abstract
The experiment was conducted to access the magnitude of variance for GCA and SCA and identify promising parents and crosses for further improvement in bottle gourd under semi-arid conditions. Eight parents were crossed in diallel fashion (excluding reciprocals) in Zaid-2015. In kharif-2016, these parents and F_1s were evaluated in RBD with three replications under four environments. Results showed environment wise combining ability analysis revealed significant differences for GCA and SCA variances indicating necessity of both additive and non-additive gene effects in the genetic control of characters studied. The GCA/SCA showed preponderance of non-additive gene action for most of the characters. As regards GCA effects, parents PSPL, NR and PN for days to opening of first female flower, days to first fruit set, number of nodes at first female flower appearance, number of primary branches, number of marketable fruits per vine, number of pickings and total fruit yield; PSPL and PN for fruit length and PK for fruit girth emerged as good general combiner. The crosses *viz*. PSPL × NR, PN × PSPL, PN × PS for days to opening of first female flower, days to first fruit set, number of primary branches, fruit girth, number of pickings, PSPL × NR, PK × AB, PN × PSPL for number of nodes at first female flower appearance, number of marketable fruits per vine, PSPL × NR, PK × AB, PN × PS for fruit length and PN × PS, PK × AB, PN × PSPL for fruit yield (q/ha) had maximum SCA effects in desirable direction emerged as good specific combiners. All these crosses offer good promise for improvement of respective component characters in specific environment and ultimately fruit yield.

Keywords: Bottle gourd, combining ability, growth, yield

Introduction

Bottle gourd is one of the most important vegetable among cucurbits mainly due to its prolific bearing habit, low cost of cultivation and utility as a cooked vegetable. It's tender edible fruits are also used for preparation of sweets, pickles, rayata etc. (Thamburaj and Singh, 2005) [20]. Pulp is used for overcoming constipation, cough, night blindness, and as an antidote against certain poisons. Fruit pulp is good source of fibre-free carbohydrate and fruit pericarp for crude fibre. Fruits contain 2.5% carbohydrates, 0.2% protein, 0.1% fat, minerals 0.5% and 0.6% fibre (Deore *et al.*, 2008) [5]. The juice of bottle gourd is very helpful in urinary disorder, excessive thrust and insomnia (Singh, 2013) [17]. It occupies an area of 181 thousand hectares with the production of 2977 thousand MT in India (Anon., 2020) [3]. Bottle gourd is monoecious, annual vine with soft pubescence and also a vigorous, running or climbing vine with large leaves and a lush appearance. Tender fruits are variable in size, shape and have wide genetic diversity. Although, It fruit has huge demand in the market due to nutritional and easily digestible property. Therefore hybrids variety are gaining more popularity due to their high productivity, improved quality, built in resistance, environmental adaptation and earliness, which results into better monetary returns to vegetable growers. Plant breeding revolves around selection which can be effectively practiced only in the presence of variability of desired traits. Therefore, the combining ability analysis is to selection of elite genotypes elucidates the nature and magnitude of different types of gene action involved in the expression of quantitative characters. This information is having probable use in formulating and executing an efficient breeding programme for obtain maximum genetic gain with minimum time and resource. Diallel design has been found suitable to select the parents from germplasm which will be employed in the present study to determine the GCA and SCA of the parents and crosses for qualitative and quantitative characters, respectively. However, a very little systemic attention has been paid by plant breeder to study per se performance for earliness, yield and It's related traits.

Hence, the present investigation was undertaken to determine the mechanism of gene action involved in inheritance of yield components in bottle gourd further, select elite parental line can be utilized for future hybridization programmes.

Materials and Methods

The present investigation was undertaken to estimate the combining ability for growth and yield attributes in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] under different environments. Eight genetically diverse parents namely, Pusa Naveen (PN), Punjab Komal (PK), Pusa Summer Prolific Long (PSPL), Narendra Rashmi (NR), Pusa Samaridhi (PS), Pant Lauki -3 (PL-3), Arka Bahar (AB) and Udaipur Local (UL) were crossed in diallel fashion excluding reciprocals in *Zaid*, 2015. Eight parents and their 28 F_1s were evaluated in Randomized Block Design (RBD) with three replications under four different environments with different date of sowing *viz*., 10 July (E_1), 20 July (E_2), 30 July (E_3) and 10 August (E_4) at Horticulture farm, SKN College of Agriculture, Jobner-Jaipur (Rajasthan). The parents and F_1's were grown in a plot with a spacing 2.50 m × 0.75 m in *kharif* -2016. All the recommended package of practices was followed for growing the bottle gourd. The observation were recorded on five randomly selected plants each replication different growth and yield attributes like days to opening of first female flower, days to first fruit set, number of node at first female flower appearance, number of primary branches per vine, fruit length (cm), fruit girth (cm), number of marketable fruits per vine, number of pickings and total fruit yield (q/ha). The combining ability analysis of data pooled over the environments was carried using the method suggested by (Singh 1973) [16], which is an extension of (Griffing's method II, Model-I 1956) to estimate the significance and interactions of GCA and SCA effects with environments.

Results and Discussion

The combining ability analysis revealed that the GCA and SCA variances were significant for the characters in each environment, indicating the importance of both additive and non-additive genetic control of all the characters under study. However, the GCA/SCA ratio being less than unity showed that the additive gene action was more important for days to opening of first female flower, days to first fruit set, number of nodes at which first female flower appearance, number of primary branches per vine, days to first fruit harvest, fruit length, fruit girth, average weight of first three harvested fruits, number of pickings, number of marketable fruits per vine and total fruit yield (Muthaiah *et al.* 2017; Acharya *et al.* 2019) [11, 1] [Table 1-2].

Early opening of female flower, days to first fruit set and appearance of female flower at lower nodes is desirable in bottle gourd, which is reflected by the negative combining ability effects. GCA effects in all the environments ranged from -2.36 (NR) to 2.43 (UL) for days to opening of female flower, from -2.28 (NR) to 2.93 (UL) for days to first fruit set and from -1.04 (PN) to 1.29 (UL) for appearance of female flower at lower node [Table 3, 4]. The parental lines NR, PN and PSPL were good general combiners possessed negative significant GCA effects in all the environments for these traits. More number of primary branches per vine, fruit length, fruit girth, number of marketable fruits per vine and number of pickings is desirable for obtaining higher yield. The GCA effects in all the environments ranged from -0.79 (AB) to 0.78 (PSPL) for number of primary branches; from -7.05 (PK) to 5.13 (PSPL) for fruit length (cm); from -2.33 (UL) to 4.01 (PK) parents for fruit girth; from -1.62 (UL) to 1.10 (PSPL) for number of marketable fruits per vine; from –1.57 (UL) to 1.11 (PSPL) for number of pickings and from -6.94 to 5.46 for fruit yield (q/ha). The significant positive GCA effects were recorded from parents PSPL, NR and PN for number of primary branches, number of marketable fruits per vine, number of pickings and total fruit yield (Figure 1); PSPL and PN for fruit length (cm) and PK for fruit girth in all the environments and they are good general combiners [Table 5].

Thus, it is suggested that breeding for these characters would be effective only when material is tested over a wide range of environments. However, some parents having consistent desirable GCA estimates for some characters in all the environments were NR and PSPL for days to opening of first female flower, days to first fruit set, number of nodes at first female flower appearance, number of primary branches per vine, number of marketable fruits per vine, fruit yield (q/ha), number of pickings. PN except number of nodes at first male flower appearance, fruit girth (cm) and parent PK for fruit girth (cm). The results obtained in the present study are corroborative with the findings of (Rehana and Sharma 2007; Adarsh *et al.* 2015; Singh *et al.* 2015; Janaranjani *et al.* 2016) [14, 2, 19, 7] in bottle gourd.

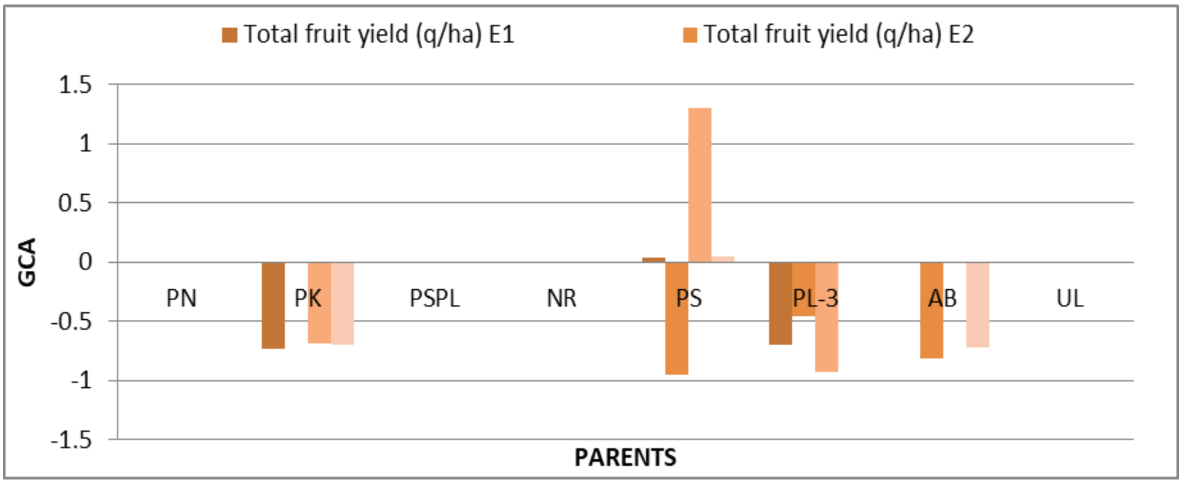

Fig 1: General combining ability effects of bottle gourd parents for total fruit yield (q/ha) in different environments

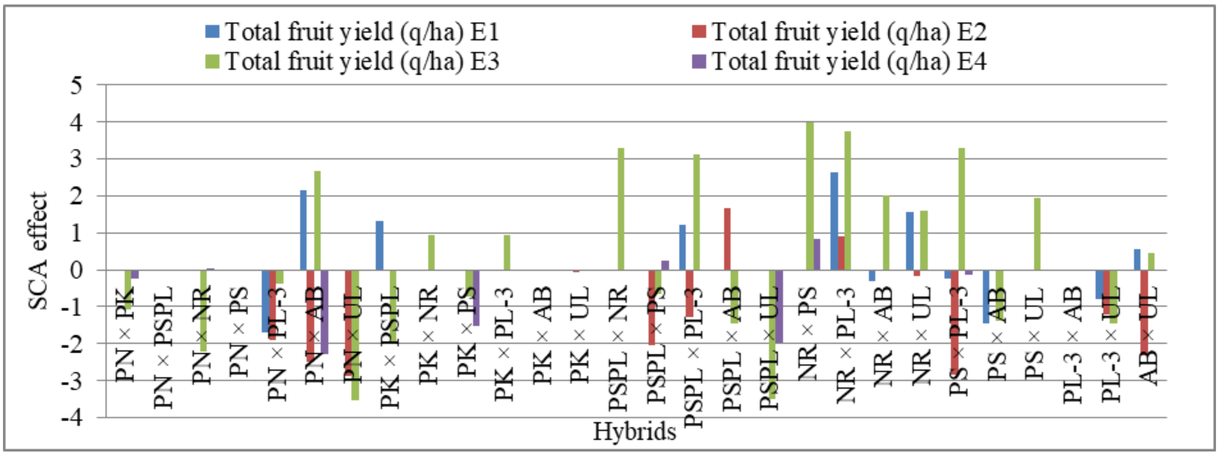

Fig 2: Specific combining ability effects of bottle gourd parents for total fruit yield (q/ha) in different environments

Table 1: Analysis of variance for growth and its contributing characters of bottle gourd pooled over environments

Source of variation	d.f.	Mean sum of square							
		DOF	DFS	NNFF	NPV	AWTH	NMF	TFY (q/ha)	NP
Environments (E)	3	117.65**	49.60**	47.13**	8.30**	0.50**	20.75**	307.86**	44.99**
Replication within E	8	0.46	0.88	1.42**	0.04	0.03	0.16	7.34	0.04
Genotypes	35	111.11**	134.39**	18.47**	10.00**	2.24**	26.12**	491.07**	24.43**
Parents	7	45.82**	83.42**	9.54**	5.46**	0.55**	10.12**	259.87**	12.62**
F_1's (Hybrids)	27	129.95**	143.39**	21.22**	11.52**	2.54**	30.15**	537.55**	27.48**
Parents v/s F_1's	1	59.34**	248.15**	6.48**	0.55**	5.98**	29.45**	854.29**	24.61**
Genotypes x E	105	2.87**	3.22**	1.50**	0.89**	0.16**	1.43**	34.60**	0.85**
Parents x E	21	3.66**	2.98**	1.21**	0.47**	0.07*	0.67**	18.86**	0.31**
F_1's x E	81	2.34**	2.13**	1.53**	0.92**	0.18**	1.63**	37.67**	1.01**
Parents v/s F_1's x E	3	11.67**	34.53**	2.49**	3.17**	0.22**	1.26**	61.91**	0.32**
Error	280	1.24	1.43	0.41	0.07	0.04	0.24	9.55	0.08

*, ** Indicate significance at 5 and 1 per cent level, respectively.

DOF = Days to opening of first female flower
DFS = Days to first fruit set
NPV = Number of primary branches/vine
NNFF = Number of nodes at first female flower appearance
TFY = Total fruit yield
FL = Fruit length (cm) at marketable stage
NMF = Number of marketable fruits per vine
FG = Fruit girth (cm)
NP = Number of pickings

Table 2: Analysis of variance for combining ability for growth and yield contributing characters of bottle gourd in different environments

Source of variation	D.F.	ENV.	DOF	DFS	NNFF	NPV	FL	FG	NMF	TFY (q/ha)	NP
GCA	7	E1	23.89**	22.33**	4.46**	2.52**	117.03**	36.70**	4.93**	161.51**	6.44**
		E2	27.00**	24.66**	2.69**	1.15**	127.39**	23.08**	7.20**	188.47**	7.74**
		E3	21.80**	24.65**	4.07**	1.88**	125.62**	29.69**	6.74**	121.26**	4.36**
		E4	18.57**	23.97**	5.01**	2.49**	152.97**	13.62**	4.90**	55.95**	5.29**
SCA	28	E1	7.04**	7.88**	1.37**	0.69**	35.11**	7.02**	1.32**	23.54**	1.58**
		E2	5.72**	8.56**	0.97**	1.15**	38.99**	7.72**	3.25**	43.56**	1.77**
		E3	6.46**	8.88**	1.19**	0.96**	40.12**	6.12**	1.51**	21.80**	0.97**
		E4	7.85**	10.79**	1.98**	0.47**	32.57**	9.26**	0.65**	27.15**	0.96**
Error	70	E1	0.75	0.52	0.14	0.01	0.26	0.19	0.08	2.39	0.03
		E2	0.52	0.13	0.13	0.02	0.88	0.65	0.11	2.59	0.02
		E3	0.11	0.63	0.05	0.03	0.27	0.34	0.07	5.73	0.03
		E4	0.22	0.57	0.21	0.03	0.79	0.54	0.05	1.68	0.03
GCA: SCA Ratio		E1	0.37	0.30	0.35	0.37	0.34	0.53	0.39	0.75	0.41
		E2	0.51	0.29	0.30	0.10	0.33	0.32	0.23	0.45	0.44
		E3	0.34	0.29	0.35	0.20	0.31	0.51	0.46	0.72	0.46
		E4	0.24	0.23	0.27	0.56	0.48	0.15	0.81	0.21	0.57

*, ** Indicate significance at 5 and 1 per cent level, respectively.

Table 3: Estimates of general and specific combining ability effects for days to opening of first female flower, days to first fruit set and number of nodes at first female flower appearance

Genotypes	Days to opening of first female flower				Days to first fruit set				Number of node at first female flower appearance			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
GCA effects												
PN	-0.85**	-0.81**	-0.93**	-0.88**	-0.94**	-0.95**	-0.78**	-0.93**	-0.52**	-0.31**	-0.83**	-1.04**
PK	0.43	0.42*	0.19	0.23	0.42*	0.21	0.26	0.77**	0.19	0.18	0.11	0.27
PSPL	-1.64**	-1.90**	-1.47**	-1.04**	-1.61**	-1.59**	-1.43**	-1.18**	-0.55**	-0.47**	-0.53**	-0.55**
NR	-2.22**	-2.36**	-1.98**	-2.14**	-2.06**	-2.06**	-2.28**	-2.26**	-0.81**	-0.80**	-0.61**	-0.78**
PS	-0.19	0.23	-0.03	0.25	0.39	0.17	0.17	0.05	0.00	0.19	0.10	0.25

PL-3	0.51	0.30	0.16	0.04	0.18	0.14	0.13	0.20	-0.02	0.19	0.58**	0.23
AB	1.89**	1.70**	1.94**	1.54**	1.12**	1.25**	1.08**	0.42	0.42**	0.14	0.12	0.81**
UL	2.08**	2.43**	2.12**	2.01**	2.50**	2.82**	2.85**	2.93**	1.29**	0.89**	1.07**	0.82**
S.E. (g_i)	0.26	0.21	0.1	0.14	0.21	0.11	0.23	0.22	0.11	0.11	0.07	0.14
S.E. (g_i- g_j)	0.39	0.32	0.15	0.21	0.32	0.16	0.35	0.34	0.17	0.16	0.10	0.20
SCA effects												
PN × PK	0.19	-0.03	0.02	-0.10	5.26**	5.68**	5.07**	4.91**	-0.20	0.87*	1.09**	-0.72
PN × PSPL	-5.18**	-3.97**	-4.57**	-5.40**	-5.31**	-6.23**	-4.77**	-3.46**	-1.95**	-1.67**	-1.86**	-1.84**
PN × NR	3.58**	2.03**	2.93**	3.55**	3.46**	3.68**	2.97**	1.17	0.83*	0.56	0.56**	1.19**
PN × PS	-4.16**	-4.90**	-4.31**	-5.08**	-4.81**	-4.54**	-4.76**	-5.11**	-1.40**	-0.92**	-1.51**	-1.72**
PN × PL-3	0.74	1.46*	0.52	1.34**	-1.76**	-2.02**	-1.69*	-1.38*	0.02	-0.68*	-0.26	0.37
PN × AB	2.33**	3.64**	2.40**	2.23**	1.81**	1.70**	1.36	1.87**	0.64	1.13**	-0.06	1.21**
PN × UL	2.22**	2.45**	2.20**	2.53**	0.32	0.75*	-0.13	-0.16	1.53**	0.37	1.13**	-0.37
PK × PSPL	0.81	1.93**	1.15**	1.07*	-1.46*	-1.67**	-1.13	-2.23**	1.46**	0.67*	1.09**	1.07*
PK × NR	1.39	1.39*	1.26**	1.67**	1.85**	1.54**	2.04**	1.70*	1.26**	-0.22	2.16**	1.07*
PK × PS	3.04**	0.88	3.16**	2.69**	2.32**	0.76*	-0.78	-1.00	1.59**	0.83*	0.35	1.50**
PK × PL-3	-1.17	-0.26	-1.12**	-1.47**	0.22	1.01**	0.52	-0.36	-0.54	-0.07	-0.88**	-0.36
PK × AB	-4.20**	-3.30**	-3.67**	-2.41**	-4.26**	-4.21**	-4.57**	-4.25**	-2.36**	-1.65**	-1.67**	-2.71**
PK × UL	0.56	0.79	0.08	-0.34	-1.13	-0.83*	-1.82*	-2.50**	0.52	0.16	-1.30**	-0.98*
PSPL × NR	-4.95**	-4.03**	-5.19**	-4.71**	-4.54**	-4.93**	-5.34**	-5.66**	-2.11**	-1.87**	-2.18**	-2.48**
PSPL × PS	2.28**	1.61*	2.69**	4.66**	2.43**	3.06**	1.61*	1.23	0.22	-0.17	0.12	2.35**
PSPL × PL-3	-0.47	-0.28	-0.13	-0.68	1.49*	1.71**	1.48*	1.36*	0.35	0.50	-0.13	1.01*
PSPL × AB	2.51**	0.36	2.28**	2.33**	2.08**	1.73**	1.21	1.33	1.19**	0.59	1.17**	0.89*
PSPL × UL	0.72	-1.03	0.26	0.22	2.42**	2.22**	1.38	0.98	0.22	0.78*	0.45*	-1.01*
NR × PS	-3.12**	-1.25	-2.73**	-3.07**	-3.68**	-3.27**	-3.75**	-4.20**	-1.43**	-1.36**	-1.05**	-1.15**
NR × PL-3	-0.75	0.43	-0.36	0.13	-0.84	-1.38**	-0.91	-0.55	0.38	0.67*	0.06	1.62**
NR × AB	-1.55	-1.59*	-1.05**	-3.74**	-1.15	-1.21**	-3.23**	-2.37**	-0.77*	-1.09**	-0.94**	-1.79**
NR × UL	-0.53	-2.17**	-1.05**	-0.82	0.01	-0.24	-0.27	-0.47	-0.04	0.66*	-0.41*	0.36
PS × PL-3	-0.66	-0.91	-0.42	-1.10*	0.05	0.55	1.22	0.92	-0.27	0.80*	-0.34	-1.03*
PS × AB	-0.37	0.04	-0.94**	-0.60	-0.69	-0.71*	-1.77*	-3.07**	1.26**	0.33	0.56**	0.84*
PS × UL	-0.46	-1.32*	-0.52	-0.40	-1.41*	-1.85**	-0.83	-3.45**	0.96**	-1.48**	0.39	-0.62
PL-3 × AB	2.84**	-0.53	2.07**	2.40**	3.05**	2.86**	0.99	0.23	-0.22	-0.57	-0.26	-1.62**
PL-3 × UL	-1.16	-2.70**	-1.89**	-2.13**	-1.08	-1.00**	-2.07**	1.35	0.35	-0.39	0.12	1.09*
AB × UL	3.25**	-1.58*	3.59**	3.46**	2.02**	2.10**	-0.21	4.04**	-0.05	-0.60	0.99**	1.46**
SE sij	0.79	0.65	0.30	0.43	0.65	0.33	0.72	0.68	0.34	0.33	0.20	0.42
SE (Sij-Sik)	1.16	0.97	0.44	0.63	0.97	0.48	1.06	1.01	0.50	0.48	0.30	0.61
SE (Sij-Ski)	1.20	0.83	0.18	0.35	0.83	0.21	1.01	0.91	0.22	0.21	0.08	0.34

*, ** Indicate significance at 5 and 1 per cent level, respectively.

Table 4: Estimates of general and specific combining ability effects for number of primary branches per vine, fruit length and fruit girth (cm)

Genotypes	Number of primary branches per vine				Fruit length (cm)				Fruit girth (cm)			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
GCA effects												
PN	0.24**	0.44**	0.47**	0.44**	0.83**	2.07**	2.68**	2.86**	0.74**	-0.44	0.33	-0.08
PK	-0.05	-0.04	0.01	-0.09	-6.27**	-7.05**	-6.82**	-6.87**	4.01**	3.36**	3.35**	2.11**
PSPL	0.78**	0.42**	0.45**	0.57**	5.13**	4.39**	3.78**	4.17**	0.23	0.43	1.01**	0.95**
NR	0.43**	0.16**	0.33**	0.53**	0.28	0.51	3.11**	1.03**	-0.21	0.20	-0.28	0.33
PS	-0.02	-0.03	0.07	-0.01	2.68**	2.75**	0.27	4.20**	-1.49**	-0.93**	-0.96**	-0.62**
PL-3	-0.05	-0.06	-0.09	-0.56**	0.28	0.03	0.24	0.16	0.22	-0.08	0.25	-0.42
AB	-0.57**	-0.40**	-0.73**	-0.79**	-0.07	0.15	-0.09	-3.05**	-1.23**	-0.85**	-1.38**	-0.43
UL	-0.76**	-0.49**	-0.50**	-0.09	-2.87**	-2.84**	-3.18**	-2.50**	-2.28**	-1.68**	-2.33**	-1.83**
S.E. (g_i)	0.03	0.04	0.05	0.05	0.15	0.28	0.15	0.26	0.13	0.24	0.17	0.22
S.E. (g_i- g_j)	0.04	0.06	0.08	0.08	0.23	0.42	0.23	0.40	0.19	0.36	0.26	0.33
SCA effects												
PN × PK	0.83**	0.22	0.20	0.05	-5.19**	-7.26**	-7.51**	-3.43**	2.97**	-4.98**	-1.03	-4.40**
PN × PSPL	1.01**	1.23**	1.48**	1.31**	7.57**	7.03**	8.60**	8.30**	2.91**	3.73**	3.62**	4.61**
PN × NR	-2.39**	-2.76**	-2.80**	-1.66**	-9.32**	-6.73**	-8.04**	-6.43**	-3.38**	-0.90	-3.30**	-1.94**
PN × PS	1.39**	1.22**	1.10**	0.91**	9.04**	9.97**	8.19**	7.70**	1.84**	4.21**	4.98**	3.18**
PN × PL-3	-0.26**	-0.60**	0.70**	0.00	-8.21**	0.56	-0.57	-1.06	3.01**	-0.07	-0.37	0.71
PN × AB	-0.54**	0.13	0.14	0.28	-0.89	-0.97	1.39**	0.85	-4.04**	-2.74**	-3.36**	-3.31**
PN × UL	-0.95**	0.17	0.30	-0.31	1.60**	-0.07	1.35**	4.00**	0.74	1.98**	1.25*	1.78**
PK × PSPL	-0.46**	-0.29*	-0.46**	-0.14	-0.59	-2.78**	-2.31**	-1.54	-2.28**	-2.24**	1.35*	-1.30
PK × NR	-0.41**	0.19	0.12	-0.62**	-3.07**	-2.60**	-4.44**	-1.60	0.10	1.69*	2.43**	3.84**
PK × PS	-1.06**	-1.13**	-0.10	0.07	-5.04**	-5.54**	-1.39**	-5.16**	-0.83*	4.01**	3.37**	6.33**
PK × PL-3	-0.26**	-0.40**	0.42*	0.03	4.36**	2.88**	3.93**	4.18**	3.82**	0.45	1.58**	-7.01**
PK × AB	0.12	1.45**	1.14**	0.18	7.91**	16.23**	11.09**	8.12**	3.61**	5.03**	-2.32**	0.60
PK × UL	-0.38**	-0.83**	-0.8**	-0.13	-0.59	-1.45	0.05	2.83**	-0.95*	1.19	0.73	1.42*
PSPL × NR	1.23**	1.60**	1.57**	1.08**	10.35**	14.26**	10.82**	10.79**	2.34**	2.53**	2.11**	2.14**

PSPL × PS	-0.44**	-0.12	-0.27	-0.25	3.46**	2.54**	-3.06**	3.91**	0.47	0.41	-0.81	-0.15
PSPL × PL-3	-0.61**	-0.40**	-0.24	0.12	-3.04**	-0.76	-0.07	-2.97**	-2.55**	-1.61*	-2.00**	-1.40*
PSPL × AB	0.14	-2.23**	-1.21**	-1.53**	-6.39**	-7.38**	-1.14*	-2.76**	1.28**	0.23	0.21	-0.04
PSPL × UL	0.17	0.01	0.04	0.19	-3.40**	-7.89**	-6.85**	-6.61**	-2.96**	-2.77**	-2.93**	-2.43**
NR × PS	1.07**	-1.05**	0.91**	0.88**	1.46**	5.30**	7.51**	4.60**	-1.15**	-3.56**	-3.29**	-2.37**
NR × PL-3	0.02	0.81**	0.89**	0.46**	6.21**	0.95	6.82**	6.87**	1.39**	1.65*	2.27**	2.49**
NR × AB	0.76**	0.92**	0.79**	0.65**	7.19**	0.39	2.43**	2.62**	2.01**	2.01**	2.41**	1.32
NR × UL	-0.45**	-0.88**	-0.95**	-0.17	-4.55**	-5.82**	-6.38**	-1.67*	3.34**	1.35	1.56**	1.39*
PS × PL-3	-0.19*	0.27*	-1.63**	-0.37*	-0.19	-3.82**	-8.16**	-1.09	-1.17**	0.27	-2.69**	-2.43**
PS × AB	0.14	-0.40**	0.30	0.23	-12.84**	-7.24**	-12.83**	-9.08**	2.97**	1.49*	1.54**	0.64
PS × UL	0.42**	0.65**	0.35*	0.50**	4.46**	2.45**	2.50**	6.17**	1.27**	1.52*	1.55**	1.16
PL-3 × AB	-0.10	0.17	-0.01	-0.32*	0.60	-2.69**	-6.01**	-3.34**	-4.15**	1.53*	0.40	0.66
PL-3 × UL	0.25**	-0.24	-0.03	0.20	2.46**	3.87**	4.29**	3.71**	1.42**	-2.13**	0.63	1.72*
AB × UL	-0.42**	-1.48**	-0.92**	0.30	3.41**	3.35**	5.62**	3.25**	-2.8**	-3.36**	-1.89**	-3.17**
SE sij	0.09	0.13	0.16	0.16	0.46	0.85	0.47	0.81	0.4	0.73	0.53	0.67
SE (Sij-Sik)	0.13	0.19	0.23	0.23	0.68	1.26	0.70	1.19	0.58	1.08	0.78	0.99
SE (Sij-Ski)	0.02	0.03	0.05	0.05	0.42	1.41	0.43	1.26	0.3	1.04	0.54	0.86

*, ** Indicate significance at 5 and 1 per cent level, respectively.

Table 5: Estimates of general and specific combining ability effects for number of marketable fruits per vine, number of pickings and fruit yield (q/ha)

Genotypes	Number of marketable fruits per vine				Number of pickings				Total fruit yield (q/ha)			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
GCA effects												
PN	0.45**	0.67**	0.59**	0.24**	0.52**	0.81**	0.50**	0.37**	3.28**	3.02**	3.18**	1.14**
PK	-0.01	-0.17	0.06	0.04	-0.08	-0.07	-0.08	0.06	-0.73	-4.28**	-0.69	-0.70
PSPL	0.81**	1.10**	0.93**	0.83**	1.00**	1.11**	0.76**	0.94**	4.74**	5.46**	3.09**	3.47**
NR	0.51**	0.82**	0.79**	0.70**	0.72**	0.64**	0.47**	0.85**	4.09**	4.97**	3.58**	2.69**
PS	0.05	-0.18	-0.15	-0.11	0.05	-0.05	-0.08	0.07	0.04	-0.95	1.30	0.05
PL-3	-0.15	-0.48**	-0.15	-0.13	-0.59**	-0.81**	-0.08	-0.63**	-0.70	-0.46	-0.93	-2.73**
AB	-0.15	-0.22*	-0.45**	-0.10	-0.09	-0.06	-0.08	-0.53**	-3.88**	-0.81	-3.36**	-0.72
UL	-1.51**	-1.54**	-1.62**	-1.47**	-1.53**	-1.57**	-1.41**	-1.13**	-6.86**	-6.94**	-6.17**	-3.18**
S.E. (g_i)	0.08	0.10	0.08	0.07	0.05	0.04	0.05	0.05	0.46	0.48	0.71	0.38
S.E. $(g_i - g_j)$	0.13	0.15	0.12	0.10	0.08	0.06	0.08	0.08	0.69	0.72	1.07	0.58
SCA effects												
PN × PK	-1.78**	-1.58**	-0.02	-0.29	0.26	1.48**	1.21**	0.04	-4.81**	-7.91**	-1.09	-0.24
PN × PSPL	2.00**	3.59**	1.98**	1.58**	2.52**	3.25**	1.78**	1.35**	9.35**	11.97**	9.41**	7.81**
PN × NR	-1.56**	-2.39**	-1.76**	-0.07	-1.88**	-1.30**	-1.49**	-1.20**	-4.68**	-4.96**	-2.22	0.02
PN × PS	2.35**	2.85**	1.06**	0.55**	2.49**	2.21**	1.42**	2.13**	8.99**	12.89**	5.65*	9.24**
PN × PL-3	-0.23	0.04	-1.26**	-0.30	-0.36*	-0.68**	-0.81**	-0.48**	-1.70	-1.89	-0.38	-6.39**
PN × AB	-0.27	-0.82**	0.41	0.01	-1.27**	-1.20**	-0.07	-0.72**	2.14	-2.50	2.66	-2.28
PN × UL	0.85**	0.53	1.21**	-0.43*	-0.41*	-0.92**	-0.84**	-0.11	-3.54*	-2.86	-3.55	-8.40**
PK × PSPL	-0.23	-0.66*	-0.18	-0.27	-1.08**	-1.07**	-0.94**	-0.77**	1.31	-5.17**	-1.94	-2.74*
PK × NR	0.00	-1.01**	-0.58*	-0.27	0.02	-0.80**	-0.70**	-0.73**	-3.36*	-4.29**	0.94	-3.21**
PK × PS	-0.03	-0.59	-0.19	-0.74**	-0.72**	-0.53**	-0.63**	-0.11	-5.53**	-4.81**	-0.72	-1.54
PK × PL-3	0.88**	0.81**	-0.30	0.64**	0.40*	-0.05	-0.01	-0.26	4.31**	4.48**	0.93	5.52**
PK × AB	1.86**	3.54**	1.75**	0.97**	1.45**	1.28**	1.28**	1.68**	8.28**	12.24**	9.74**	6.72**
PK × UL	-0.94**	-0.76*	-0.25	0.35	-0.77**	-0.65**	-0.98**	0.56**	-3.34*	-0.08	7.00**	5.00**
PSPL × NR	2.37**	3.78**	2.69**	1.77**	3.24**	3.37**	2.61**	2.07**	9.70**	13.68**	3.28	7.43**
PSPL × PS	-0.12	-0.45	0.29	0.35	-2.33**	-0.50**	-0.63**	0.13	-3.85**	-2.04	-0.65	0.26
PSPL × PL-3	-0.10	0.40	0.59*	0.36	-0.04	-0.05	0.11	-0.14	1.20	-1.27	3.14	4.00**
PSPL × AB	-0.97**	-1.73**	-2.26**	-0.67**	0.31	-1.33**	-0.94**	-1.26**	-4.39**	1.66	-1.44	-5.42**
PSPL × UL	-0.76**	-1.35**	-0.38	-0.08	-0.05	-0.15	0.05	0.25	-3.43*	-6.93**	-3.51	-1.99
NR × PS	0.74**	2.17**	0.82**	1.11**	0.60**	0.76**	0.46**	1.24**	4.33**	6.41**	4.00	0.83
NR × PL-3	0.43	0.36	0.66**	0.59**	-0.39*	-0.46**	0.46**	-0.04	2.65	0.91	3.76	-2.40*
NR × AB	0.92**	1.35**	1.08**	-0.74**	0.63**	0.75**	0.43**	0.72**	-0.32	4.67**	2.03	4.87**
NR × UL	-0.74**	-1.24**	-0.59*	0.15	0.21	0.06	0.03	0.09	1.56	-0.17	1.61	3.15**
PS × PL-3	-0.09	0.37	1.17**	-0.03	0.48**	-0.47**	0.30	0.70**	-0.24	-2.83	3.30	-0.13
PS × AB	-0.78**	-0.04	-1.33**	-0.57**	-0.34*	0.31*	0.06	-0.38*	-1.44	-4.61**	-1.40	-3.48**
PS × UL	-0.14	-0.44	-0.84**	0.38	-0.04	0.03	0.51**	-0.97**	3.20*	4.25**	1.93	4.80**
PL-3 × AB	-0.82**	-1.67**	-0.23	0.28	-0.17	0.42**	-0.11	-0.32*	-5.05**	3.09*	-4.41*	4.55**
PL-3 × UL	0.93**	0.18	-0.78**	0.21	0.36*	0.66**	0.46**	0.36*	-0.78	-1.22	-1.46	-7.04**
AB × UL	-0.11	-0.6*	-0.96**	0.72**	-0.47**	0.22	0.35*	-0.18	0.56	-2.32	0.47	-3.34**
SE sij	0.26	0.30	0.24	0.20	0.16	0.13	0.16	0.16	1.40	1.46	2.17	1.18
SE (Sij-Sik)	0.38	0.44	0.35	0.30	0.23	0.19	0.23	0.23	2.07	2.16	3.21	1.74
SE (Sij-Ski)	0.13	0.18	0.11	0.08	0.05	0.03	0.05	0.05	3.82	4.14	9.17	2.69

*, ** Indicate significance at 5 and 1 per cent level, respectively.

In general, it was examined that top parents on the basis of high *per se* performance also had high GCA effects *e.g.* NR, PN and PSPL. Since GCA effects are attributed to additive and additive × additive gene effects, these parents for GCA effects have good potential for included characters and can be used in a diverse crossing programme to synthesize a dynamic population with most of the favorable genes accumulated (Griffing,1956) [6].

Overall good general combiners for fruit girth were PK in all the environments as well as pooled data analysis with significant positive GCA effect. The present findings are in close conformity with results of (Parmar and Pathak 2018; Jayanth *et al.* 2019) [12, 8] in bottle gourd.

Among various flowering attributes, five crosses in E_1, 9 in E_2 and E_4, and 10 in E_3 for days to opening of first female flower; eight crosses in E_1, 13 in E_2, 10 in E_3 and 11 crosses in E_4 for days to first fruit set; and six crosses in E_1, eight crosses in E_2, nine crosses in E_3 and ten crosses for number of nodes at first female flower appearance were desirable specific combiner having significant SCA effect in desirable direction. The best specific combiners above the mentioned characters on the basis of SCA effect were PN × PSPL, PSPL × NR, PK × AB and PN × PS, resulted from good × good, good × poor and poor × poor GCA effects of parents [Table 3]. Parent having poor × poor and good × poor GCA effect reflect dominance × dominance and additive × dominance type of gene action, respectively. Similar findings were also reported by (Shinde *et al.* 2016; Quamruzzaman *et al.* 2020) [15, 13] in bottle gourd.

A total of five crosses in E_1, nine in E_2 and E_4, and ten in E_3 showed negative significant SCA effect from which crosses PN × PSPL, PN × PS, PK × AB, PSPL × NR for days to opening of female flower; eight crosses in E_1, thirteen in E_2, ten in E_3 and eleven crosses in E_4 showed significant negative SCA effect in which the crosses *viz.*, PN × PSPL, PN × PS, PN × PL-3, PK × AB, PSPL × NR and NR × PS for days to first fruit set and six crosses in E_1, eight crosses in E_2, nine crosses in E_3 and ten crosses in E_4 environments showed negative SCA effects from which crosses PN × PSPL, PN × PS, PK × AB, PSPL × NR, NR × PS and NR × AB in all the environments revealed negative significant SCA effects for number of nodes at first female flower appearance. They may be regard as best crosses for further improvement in bottle gourd crop [Table 3].

In bottle gourd, SCA effects are generally of great importance for commercial exploitation of heterosis by (Kumar *et al.* 2011) [10] in bottle gourd. It is expected that, if a cross combination has high SCA effect with at least one good general combiner parent for particular trait, may offer desirable transgressive segregants in the later generation (Jinks and Jones, 1958) [9]. In the present investigation, in general, there was no consistency over environments for the ranks of the crosses with high SCA effects. Furthermore, a number of crosses exhibited change in magnitude and direction of SCA effects in different environments, which might be the consequence of high SCA × environment interaction. The findings are accordance with results of earlier workers (Bairwa *et al.* 2015) [4].

The top cross combinations which were significant and good in E_1, E_2, E_3 and E_4 environments were PN × PSPL, PN × PS, PK × AB and PSPL × NR for days to opening of first female flower, days to first fruit set, number of node at first female flower appearance, number of primary branches per vine, fruit length, fruit girth, number of marketable fruits per vine, total fruit yield (kg/vine and q/ha) and number of pickings [Table 1-3]. The findings are accordance with results of earlier workers (Kumar *et al.* 2011) [10] in bottle gourd.

In the present study, out of 28 crosses, eight crosses in E_1 and E_2, ten in E_3 and seven crosses in E_4 showed significant positive SCA effect from which PN × PSPL, PN × PS, PSPL × NR, NR × AB and PS × UL for primary branches per vine; 13 crosses in E_1 and E_3, 10 in E_2, and 14 crosses in E_4 showed significant positive SCA effect from which PN × PSPL, PN × PS, PK × PL-3, PK × AB, PSPL × NR, NR × PS, PS × UL, PL-3 × UL and AB × UL for fruit length; 14 crosses in E_1, 12 in E_2, 13 in E_3 and 10 in E_4 showed significant positive SCA effect from which crosses *viz.* PN × PSPL, PN × PS, PSPL × NR, NR × PL-3 for fruit girth [Table 4]; nine crosses in E_1, seven in E_2, ten in E_3 and eight crosses in E_4 showed significant positive SCA effect from which crosses PN × PSPL, PN × PS, PK × AB, PSPL × NR and NR × PS; for number of marketable fruits per plant; nine crosses in E_1, ten in E_2, eleven in E_3 and nine in E_4 each environments showed positive significant SCA effects from which crosses PN × PSPL, PN × PS, PK × AB, PSPL × NR, NR × PS, NR × AB and PL-3 × UL for number of pickings and seven crosses in E_1, nine crosses in E_2, four crosses in E_3 and eleven crosses in E_4 in all the environments showed significant positive SCA effect from which crosses PN × PSPL, PN × PS and PK × AB in all the environments exhibited significant positive SCA effect, which is desirable and good combiners for higher fruits yield [Table 3 and figure 2].The crosses combiners *i.e.* PN × PSPL, PN × PS, PSPL × NR in all the environments showed maximum SCA effect. These crosses resulted from the parents having good × good, poor × poor, poor × good and good × poor GCA effects and thus, reflect dominance × dominance, dominance × additive and additive × dominance type of gene actions, respectively. These results were in close conformity with those of (Shinde *et al.* 2016; Jayanth *et al.* 2019) [15, 8] in bottle gourd.

The top crosses with high positive SCA percentage and desirable for E_1 were PSPL × NR for fruit length (cm) at marketable stage (10.35), total fruit yield q/ha (9.70), number of pickings (3.24) and number of marketable fruits per vine (2.37) and PK × PL-3 for fruit girth (3.82) [Table 4, 5], whereas, the crosses with high negative SCA were PN × PSPL for days to first fruit set (-5.31) and days to opening of first female flower (-5.18) [Table 3]. The results are accordance with of Singh *et al.* 2013 [17]; Janaranjani *et al.* 2016 [7] in bottle gourd. The crosses of high positive SCA effect for E_2 were PK × AB for fruit length (cm) at marketable stage (16.23), fruit girth (5.03), PSPL × NR for total fruit yield q per ha (13.68), number of marketable fruits per vine (3.78) and number of pickings (3.34), whereas, the crosses with high negative SCA were PN × PSPL for days to first fruit set (-6.23) and days to opening of first female flower (-4.90). The findings are close confirmatory with the results of (Kumar *et al.* 2011 [10]; Adarsh *et al.* 2015 [2]; Shinde *et al.* 2016 [15]; Parmar and Pathak, 2018 [12]) in bottle gourd. The crosses of high positive SCA for E_3 were number of marketable fruits per vine (2.69) and number of pickings (2.61), PK × AB for fruit length (cm) at marketable stage (11.09), total fruit yield q per ha (9.74) and PN × PS for fruit girth (4.98), whereas, the crosses with high negative SCA were PSPL × NR for days to first fruit set (-5.34), days to opening of first female flower (-5.19) and number of node at first female flower appearance (-2.18). The results obtained in the present study are corroborative with the findings of Singh and Singh (2009) [18] in bottle gourd. The crosses of high positive SCA for E_4 were PSPL × NR for fruit length (cm) at marketable stage (10.79), PN × PS for total fruit yield q per ha (9.24) and PK × PS for fruit girth (6.33), whereas, the crosses with high negative SCA were PSPL × NR for days to first fruit set (-5.66) and days to opening of first female flower (-5.40). The present study is accordance with reports of (Vaniya *et al.* 2008 [21]; Singh *et al.* 2015 [19]; Quamruzzaman *et al.* 2020 [13]) in bottle gourd.

Overall crosses based on high SCA were PN × PSPL, PN × PS, in E_1; PSPL × NR, PN × PSPL in E_2 and E_3; PSPL × NR, PK × AB in E_4 for total yield per vine. As the environment effect on the expression of the character was very high, different crosses emerged in different environments for fruit yield. Thus, these crosses can be included in the breeding programme for improvement in the favour of yield in specific environment. Similar results have also been obtained by (Janaranjani *et al.* 2016 [7]; Parmar and Pathak 2018 [12]) in bottle gourd.

According to the present investigation, it can be suggested that selection of desirable parents and development of hybrid seed will be a beneficial approach for resulting progenies to develop and execute effective breeding programme to evolve earliness and high yielding varieties.

References

1. Acharya SK, Kaushik RA, Ameta KD, Dubey RB, Upadhyay B. Heterosis and combining ability in bitter gourd (*Momordica charantia* L.). International Journal of Bioassays 2019;8.1:5692-5711.
2. Adarsh A, Kumar R, Kumar A, Chaurasiya J, Singh HK, Roy C. Combining ability analysis in bottle gourd (*Lagenaria siceraria* Mol. Standl) for earliness and fruit yield. Green Farming 2015;6(5):988-990.
3. Anonymous. India Horticulture Database, NHB, Gurgoan 2020. www.nhb.gov.in.
4. Bairwa SK, Soni AK, Singh B, Yadav PK. Combining ability studies in ridge gourd [*Luffa acutangula* (Roxb.) L.]. The Bioscan 2015;10(4):1969-1974.
5. Deore PM, Kotecha PM, Pawar VD. Studies on processing of bottle gourd into juice and powder. Ind. Fd. Pach. 2008;62(6):116-120.
6. Griffing JB. Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Sciences 1956;9:463-493.
7. Janaranjani KG, Kanthaswami V, Kumar SR. Heterosis, combining ability and character association in bottle gourd for yield attributes. International Journal of Vegetable Science 2016;22(5):490-515.
8. Jayanth S, Lal M, Duhan DS, Vidya R. Estimation of heterosis and combining ability for earliness and vegetative traits in bottle gourd [*Lagenaria siceraria* (Molina.) Standl]. International Journal of Chemical Studies 2019;7(1):20-25.
9. Jinks JL, Jones RM. Estimation of the components of heterosis. Genetics 1958;43:223-234.
10. Kumar A, Singh B, Kumar M. Exploitation of hybrid vigour for yield in bottle gourd [*Lagenaria siceraria* (Molina) Standl] using line x tester analysis. Vegetos 2011;24(2):45-48.
11. Muthaiah K, Gasti VD, Sanganamoni M, Arindam D, Vittal M. Combining ability studies for early and yield traits in ridge gourd [*Luffa acutangula* L. Roxb.]. International Journal of Agriculture Sciences 2017;9(26):4319-4321.
12. Parmar SS, Pathak M. Combining ability and heterosis for yield and its contributing traits in bottle gourd (*Lagenaria siceraria*). SKUAST Journal of Research 2018;20(1):37-42.
13. Quamruzzaman AKM, Salim MMR, Akhter L, Rahman MM, Chowdhury MAZ. Heterosis, combining ability and gene action for yield in bottle gourd. American Journal of Plant Sciences 2020;11(3):642-652.
14. Rehana N, Sharma SP. Combining ability studies in bottle gourd (*Lagenaria siceraria* (Mol.) Standl). Crop Research 2007;33(1-3):148-151.
15. Shinde S, Supe VS, Bhalekar MN, Gaikwad SS. Combining ability studies in bottle gourd (*Lagenaria siceraria* Mol. Standl.) in summer season. Asian Journal of Sciences and Technology 2016;7(5):2842-2845.
16. Singh D. Diallel analysis for combining ability over several environments. Indian Journal of Horticulture 1973;33:469-81.
17. Singh D. Vegetable Science. New Vishal Publications, New Delhi 2013,241-242.
18. Singh PP, Singh SP. Combining ability analysis in relation to heterosis for yield and its components in bottle gourd. Vegetable Sciences 2009;36(1):98-99.
19. Singh SP, Singh B, Pooranchand KV, Singh V. Studies on combining ability in bottle gourd, Annals of Horticulture 2015;8(1):116-117.
20. Thamburaj S, Singh N. Vegetables, Tuber crops and Spices, Directorate of Information and publications of Agriculture, ICAR, New Delhi 2005,271-272.
21. Vaniya BD, Dhaduk LK, Vachhani JH. Heterosis studies in bottle gourd in relation to diallel crossing system. International Journal of Biology 2008;6(1):131-134.