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Short communication

Studies on heterosis, combining ability and gene action for earliness, yield and yield components in sponge gourd

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ABSTRACT

The heterosis and combining ability studies of eight parental lines of sponge gourd with half diallel analysis was conducted for earliness and yield contributing characters. The results indicated additive genetic effects for node of 1st female flower appearance. In contrast, sex ratio (M/F), fruits per plant and yield per plant were influenced by non-additive gene effects. While the characters namely vine length, number of primary branches, number of fruiting nodes on main stem, days to first staminate flower appearance, days to first pistillate flower appearance, days to 50% flowering, span of flowering, days to harvestable maturity from anthesis, fruit length, fruit diameter, fruit weight, number of seeds per fruit and seed index were controlled by both additive and non-additive gene effects. Among the parents Patna Local, IC-336759 and IC-284795 showed high significant positive GCA effects as well as *per se* performance for most of the yield and yield related attributes. Promising hybrids with respect to earliness and yield per vine were IC-336759 × Patna Local, IC-284795 × Patna Local and IC-284795 × IC-336759 which can be utilised for heterosis breeding programme for improvement in sponge gourd.

Key words: *Luffa cylindrical*, quantitative traits, staminate flower, pistillate flower, additive gene effects, nonadditive gene effects.

Sponge gourd [*Luffa cylindrica* (Roem.) L.] (2n=2x=26) is one of the minor cucurbitaceous vegetable crop with old world origin in subtropical Asian region particularly India. This crop is being cultivated for centuries in the Middle East, India, China, Japan and Malaysia. In India, it is cultivated on both commercial scale and in kitchen gardens during the spring-summer and rainy season.

The tender and immature fruits are cooked as vegetable, used in the preparation of chutneys and curries and tender fruits are easily digestible and increase appetite when consumed. Sponge gourd is a highly nutritive vegetable and contains moisture of 93.2 g, protein 1.2 g, fat 0.2 g, carbohydrates 2.9 g, vitamins (thiamine 0.02 mg, riboflavin 0.06 mg, niacin 0.4 mg and β carotene 120 mg), minerals (calcium 36 mg, phosphorous 19 mg and iron 1.1 mg) and fibre 0.20 g per 100 g of edible portion (Gopalan *et al.* 2012).

The exploitation of heterosis is much easier in cross pollinated crops like sponge gourd, which provides ample scope for the utilization of hybrid vigour on commercial scale. Heterosis manifestation in sponge gourd is in the form of earliness in maturity, increased productivity and better quality attributes (Islam *et al.* 2012 and Sonavane *et al.* 2013). Diallel (Griffing 1956) is one such analysis which is a useful tool for preliminary evaluation of genetic stock for use in breeding programs with a view to identify good general and specific combiners. Keeping in view the importance of the study and lack of research work done in this minor cucurbit crop in India, this study has been formulated to assess the nature and magnitude of heterosis as well as to determine the nature of gene action for yield, its component characters.

The study was conducted in Alluvial zone of West Bengal at Horticultural Research Station, Mandouri, Bidhan Chandra Krishi Viswavidyala, West Bengal during end of February 2018 to July 2018. Eight genetically diverse parents having contrasting growth habits were selected through D^2 analysis (Mahalanobis 1936). Promising 8 parents were selected based on genetic diversity, variability studies. The seeds were sown in randomized block design (RBD).

Male and female flower buds which open by morning were bagged during evening of previous day with butter paper bags. For crossing the pollen from the bagged male flowers was dusted on to the stigma of bagged female flower of the receptive female parents, pollination was done between 6 AM to 8.30 AM. The pollinated flowers were labelled with paper tags and covered again with the butter paper bag. The paper bags were removed on the next

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day so as to allow normal fruit development. After maturing and drying of the fruits, dry seeds of each cross combination were collected separately and kept in the desiccators for sowing in the next season. The F_1 hybrids of diallel crosses were evaluated along with parents for yield and yield components, the parents and F_1s were planted in a randomized block design with three replications during summer of 2018. The observations were recorded in five randomly selected plants for different morphological traits. Combining ability analysis was carried out according to Griffing (1956) method II model I. In this approach, using a suitable statistical model the component variances due to general and specific combining ability was estimated. Heterosis over mid parent (Average heterosis), better parent (Heterobeltiosis) and commercial check (standard heterosis) were estimated in terms of per cent increase or decrease of the F_1 hybrid over its mid parent, better-parent and commercial check.

Treatment differences were found significant for all the characters studied. The estimate of gca effects, per se performance of the parents, heterosis effects of the crosses have been presented in Tables 2, & 3 respectively. Parents with early flowering type were considered better than those flowering late. The estimates of gca revealed that Patna local was the best general combiner for days to first female flower appearance (-4.93), days to fifty per cent flowering (-4.60) and days to harvestable maturity from anthesis (-1.42) followed by IC-284795 and IC-336759. Sponge gourd, being monoecious crop; ratio of male to female flowers is an important yield attributing trait as lower ratio has been reported to be associated with higher fruit set and subsequently higher fruit yield (Islam *et al*. 2012). In the present study IC-336759 (-4.36) was found to be best general combiner for ratio of male to female flowers followed by Patna local (-2.33) and IC-284795 (-0.54). Total yield per plant is a complex trait and is influenced by various yield attributing traits and environmental effects. High and positive gca effect is the desired criterion to attribute superiority to a genotype over others. In the present study, Patna local (1.03) emerged as the best general combiner for total yield per plant followed by IC-336759 (0.74) and IC-284795 (0.34). Regarding specific combining ability effects the criteria for sorting out the desirable specific combinations remained same as described for gca effects. The best specific combinations for days to first female flowering was IC-544806 × IC-284941 (-6.90) followed by IC-284941 × VRSG-199 (-6.28) and IC-284795 × IC-355633 (-6.00). Cross IC-355633 × VRSG-199 (-4.61) was found to be superior to other crosses for the ratio of male to female flowers, followed by IC-284795 × IC-284840 (-3.18) and IC-355633 × IC-284941 (-3.10). Best combiner for total yield per plant was IC-355633 × Patna Local (1.11), followed by IC-284795 × Patna Local (0.77) and IC-336759 × Patna Local (0.52).

It is apparent from the result that in majority of the hybrids showing the best sca effects, the parental lines involved were either one or both good general combiners having high and desirable gca effects. While selecting the parental lines for obtaining early flowering F1 hybrids, it would be more useful to select those parents which have high negative sca effect in respect of earliness, sex ratio and high positive sca effect for total yield per plant. Therefore, the parents Patna local, IC-284795 and IC-336759 were found promising for selection and recombination breeding. Similar results on combining ability of parents and crosses pertaining to earliness in sponge gourd were reported by Islam *et al.* (2012).

A perusal of the mean performance of parents (Table 2) revealed that among the parents, the genotype Patna local was the earliest in days taken for producing first female flower (40 days), days taken for harvestable maturity from anthesis (7 days) and produced the highest total yield per plant (3.19 kg). It also exhibited lowest sex ratio of male to female flowers (14.50). Among the hybrids IC-336759 × Patna local was the earliest to produce marketable fruit from anthesis (5.35 days) followed closely by IC-284795 × Patna local (6.00 days), similarly the same crosses IC-336759 × Patna local (33.35 days) and followed by IC-284795 × Patna local (33.85 days) were the earlier in producing the first female flower in sponge gourd. The cross combination IC-336759 × Patna local had the lowest sex ratio of male and female flowers (8.32) and produced significantly highest total yield per plant (4.84 kg). In the present study none of the F_1 hybrid was found consistently superior to others for all the characters studied. Heterosis for earliness and increased yield in sponge gourd has been very few. Jiang *et al*. (2002) reported sponge gourd hybrid 'Zhusigua 1' was early maturing as well as high yielder.

The knowledge of genetic nature of quantitative trait is a basic requirement for purposeful management of genetic variability. In the present study, 8 parents were chosen and data from 8 × 8 half diallel were analysed in the F_1 generation for 17 quantitatively inherited traits. This would help to know the general nature of the genetic control of important quantitative traits in sponge gourd. The analysis of variance for combining ability based on Griffing's Model 1 and Method 2 exhibited that components of GCA and SCA mean squares were highly significant for fruit yield per plant along with 16 other quantitative characters in F_1 generation (Table 1). This indicated that the

Table 1. Analysis of variance for combining ability in sponge gourd

Source		Df	VL	PB	FN	DSF	DPF	DFF-length;	SF	SR	NFA	DHM	FL	FD	FW	FPP	NSF	SI	Y
Mean sum of squares	GCA	7	4.34**	5.74**	11.92**	84.13**	126.27**	119.58**	188.34**	65.02**	37.93**	11.38**	126.17**	14.52**	7140.09**	7.16**	1255.49**	54.26**	0.19**
	SCA	28	0.41**	0.75**	1.14**	11.42**	15.91**	22.72**	20.49**	19.97**	1.77**	1.95**	14.09**	2.88**	830.66**	1.51**	207.72**	9.66**	0.07**
	Error	70	0.01	0.02	0.03	0.72	0.22	0.24	0.21	0.05	0.02	0.01	0.05	0.04	1.70	0.00	0.73	0.01	0.00
σ^2gca			0.43	0.57	1.12	8.34	12.60	11.93	18.81	6.50	3.79	1.14	12.61	1.45	713.84	0.72	125.48	5.42	0.02
σ^2sca			0.40	0.74	1.19	10.71	15.69	22.48	20.28	19.93	1.75	1.94	14.05	2.84	828.96	1.51	206.99	9.65	0.07
$\sigma^2gca/\ \sigma^2sca$			1.09	0.78	0.94	0.78	0.80	0.53	0.93	0.33	2.17	0.59	0.90	0.51	0.86	0.48	0.61	0.56	0.28
Predictability ratio $\alpha^2A/(\alpha^2A+\alpha^2sca)$			0.68	0.61	0.65	0.61	0.62	0.51	0.65	0.39	0.81	0.54	0.64	0.51	0.63	0.49	0.55	0.53	0.36

*, ** Significant at 5 and 1% levels; GCA- General combining ability, SCA- Specific combining ability, σ^2gca -Variance due to GCA, σ^2sca-Variance due to SCA, σ^2A- Additive variance

Table 2. Estimates of general combining ability (gi) effects, *per se* performance (in parenthesis) in 8 parents in sponge gourd

Genotype		VL	PB	FN	DSF	DPF	DFF-length;	SF	SR	NFA	DHM	FL	FD	FW	FPP	NSF	SI	Y
									Parents									
1	IC-284795	0.18**	0.58**	0.91**	-1.91**	-3.45**	-3.29**	0.66**	-0.54**	-1.50**	-0.50**	1.04**	0.34**	7.39**	1.40**	8.78**	0.86**	0.34**
		(3.80)	(4.85)	(7.00)	(37.83)	(42.30)	(51.30)	(43.85)	(18.65)	(9.35)	(8.50)	(23.00)	(6.75)	(197.50)	(13.00)	(125.00)	(13.00)	(2.57)
2	IC-336759	0.73**	0.48**	0.55**	-3.02**	-2.92**	-2.00**	4.48**	-2.33**	-1.51**	-0.74**	2.94**	0.82**	27.26**	2.12**	14.60**	1.07**	0.74**
		(4.30)	(5.00)	(6.90)	(35.50)	(41.25)	(53.00)	(46.23)	(17.35)	(8.00)	(7.85)	(25.43)	(7.90)	(212.00)	(13.15)	(120.33)	(13.30)	(2.79)
3	IC-284840	-0.23**	0.15**	0.65**	1.96**	1.58**	0.74**	-0.44**	-0.45**	-1.02**	-0.61**	2.18**	-0.66**	1.07**	-0.18**	0.07	-1.71**	-0.06**
		(3.20)	(4.33)	(6.25)	(39.50)	(45.50)	(54.75)	(40.00)	(20.65)	(10.00)	(9.00)	(21.85)	(5.23)	(189.35)	(10.65)	(115.00)	(9.65)	(2.02)
4	IC-355633	-0.78**	-1.16**	-1.49**	4.19**	5.27**	5.54**	-5.75**	4.71**	2.33**	1.34**	-3.36**	-1.01**	-41.92**	-3.34**	-23.64**	0.01	-1.02**
		(2.25)	(2.50)	(2.85)	(48.00)	(56.35)	(66.25)	(32.65)	(27.00)	(16.00)	(10.50)	(11.50)	(6.75)	(115.50)	(5.36)	(60.00)	(11.00)	(0.62)
5	IC-544806	-0.55**	-0.62**	-1.09**	1.54**	2.00**	1.60**	-1.44**	2.61**	1.62**	-0.12**	-2.76**	-1.03**	-10.69**	-2.01**	-18.58**	-1.06**	-0.59**
		(2.50)	(3.25)	(3.00)	(43.75)	(49.00)	(58.25)	(39.00)	(23.50)	(14.50)	(9.45)	(16.50)	(5.35)	(165.35)	(7.07)	(79.67)	(10.00)	(1.17)
6	IC-284941	-0.59**	-0.69**	-1.12**	1.32**	3.02**	3.45**	-4.06**	-0.18*	2.21**	1.69**	-5.59**	-0.65**	-28.95**	-1.73**	-15.23**	-1.11**	-0.67**
		(2.65)	(3.00)	(3.25)	(45.25)	(54.00)	(65.00)	(37.50)	(21.33)	(15.00)	(10.65)	(12.55)	(6.00)	(130.35)	(7.21)	(75.00)	(9.85)	(0.94)
7	VRSG-199	0.19**	0.16**	0.13**	0.43	-0.55**	-1.42**	-1.08**	0.53	0.63**	0.37**	0.74**	-0.31**	8.09**	0.98**	8.96**	0.20**	0.23**
		(3.50)	(4.00)	(5.00)	(41.35)	(47.00)	(56.00)	(39.65)	(23.00)	(13.35)	(9.35)	(19.65)	(4.75)	(173.33)	(11.40)	(110.00)	(11.50)	(1.98)
8	Patna Local	1.06**	1.10**	1.45**	-4.51**	-4.93**	-4.60**	7.64**	-4.36**	-2.77**	-1.42**	4.81**	2.52**	37.74**	2.75**	25.04**	1.74**	1.03**
		(4.80)	(5.50)	(7.20)	(34.00)	(40.00)	(49.50)	(52.00)	(14.50)	(6.50)	(7.00)	(27.00)	(9.00)	(235.00)	(13.58)	(130.00)	(14.35)	(3.19)
SE(m)		0.03	0.04	0.05	0.25	0.14	0.15	0.14	0.09	0.04	0.02	0.06	0.06	0.39	0.06	0.20	0.05	0.013

*, ** Significant at 5 and 1% levels

Df- Degrees of freedom, (VL)- Vine length (cm); (PB)- No. of primary branches; (FN)- No. of fruiting nodes on main stem; (DSF)- Days to first staminate flower appearance; (DFF)- Days to 50% flowering; (DPF)- Days to first pistillate flower appearance; (SF)- Span of flowering; (SR)- Sex ratio (M/F); (NFA)- Node at which 1st female flower appearance; (DHM)- Days to harvestable maturity from anthesis; (FL)- Fruit length (cm); (FD)- Fruit diameter (cm); (FW)- Fruit weight (g); (FPP)- Fruits per plant; (NSF)- No. of seeds per fruit; (SI)- Seed index (100 seed weight); (Y)- Yield per plant (kg)

Table 3. Estimates of heterosis over better parent (BP) and commercial check (CC) for major characters in sponge gourd

Cross		Days to first pistillate flower appearance		Sex ratio (M/F)		Days to harvestable maturity from anthesis		Yield per plant (kg)	
		BP	CC	BP	CC	BP	CC	BP	CC
1*2	IC-284795 × IC-336759	-15.98**	-18.02**	-32.71**	-29.69**	-33.76**	-7.70**	48.51**	94.83**
1*3	IC-284795 × IC-284840	-17.26**	-13.16**	-34.87**	-24.65**	-30.56**	2.46	28.70**	55.33**
1*4	IC-284795 × IC-355633	-31.06**	-10.38**	-11.11**	34.45**	-29.05**	22.13**	-47.79**	-36.99**
1*5	IC-284795 × IC-544806	-12.96**	-1.61	-9.57**	19.05**	-32.80**	4.10*	-16.88**	0.31
1*6	IC-284795 × IC-284941	-25.00**	-6.57**	-23.36**	-8.40**	-4.69**	66.39**	-15.06**	2.51
1*7	IC-284795 × VRSG-199	-15.64**	-8.54**	-23.26**	-1.12	-26.95**	11.97**	31.17**	58.31**
1*8	IC-284795 × PATNA LOCAL	-21.16**	-23.07**	-43.47**	-40.93**	-29.41**	-1.64	46.97**	120.22**
2*3	IC-336759 × IC-284840	-12.86**	-8.54**	-35.35**	-25.21**	-28.33**	5.74**	31.06**	71.94**
2*4	IC-336759 × IC-355633	-19.88**	4.15**	-22.22**	17.65**	-23.81**	31.15**	-15.77**	10.50**
2*5	IC-336759 × IC-544806	-18.37**	-7.73**	-31.70**	-10.08**	-24.34**	17.21**	6.69**	39.97**
2*6	IC-336759 × IC-284941	-16.85**	3.58*	-36.02**	-23.53**	-22.72**	34.92**	0.96	32.45**
2*7	IC-336759 xVRSG-199	-22.25**	-15.70**	-31.96**	-12.32**	-27.81**	10.66**	41.82**	86.05**
2*8	IC-336759 × PATNA LOCAL	-17.94**	-21.91**	-52.07**	-53.41**	-31.85**	-12.30**	51.99**	127.74**
3*4	IC-284840 × IC-355633	-11.27**	15.34**	-15.43**	27.92**	-33.33**	14.75**	-62.71**	-64.58**
3*5	IC-284840 × IC-544806	4.39**	17.99**	-21.28**	3.64	-31.75**	5.74**	-8.91**	-13.48**
3*6	IC-284840 × IC-284941	-6.94**	15.92**	-26.64**	-12.32**	-30.05**	22.13**	-4.62	-9.40**
3*7	IC-284840 × VRSG-199	-5.23**	2.75	-23.70**	-1.68	-23.53**	17.21**	51.98**	44.36**
3*8	IC-284840 × PATNA LOCAL	-14.58**	-10.34**	-44.55**	-35.85**	-35.56**	-4.92**	15.79**	73.51**
4*5	IC-355633 × IC-544806	-3.38**	25.61**	7.41**	62.46**	-19.46**	38.63**	-28.21**	-60.50**
4*6	IC-355633 × IC-284941	-2.40	26.87**	-29.44**	6.72**	36.62**	138.52**	-45.74**	-76.02**
4*7	IC-355633 xVRSG-199	-20.44**	3.42*	-32.41**	2.24	6.98**	84.15**	1.35	-5.80
4*8	IC-355633 × PATNA LOCAL	-30.79**	-10.03**	-35.00**	-1.68	-40.00**	3.28	15.17**	72.57**
5*6	IC-544806 × IC-284941	-23.80**	-5.07**	-18.09**	7.84**	-22.38**	35.52**	26.78**	-30.25**
5*7	IC-544806 xVRSG-199	-9.74**	2.02	-16.81**	9.52**	-20.63**	22.95**	23.95**	15.20**
5*8	IC-544806 × PATNA LOCAL	-27.24**	-17.76**	-40.35**	-21.48**	-32.80**	4.10*	-7.74**	38.24**
6*7	IC-284941x VRSG-199	-27.36**	-9.51**	-23.26**	-1.12	-0.94	72.95**	21.75**	13.17**
6*8	IC-284941x PATNA LOCAL	-28.80**	-11.30**	-41.41**	-29.97**	-34.27**	14.75**	-4.39*	43.26**
7*8	VRSG-199 × PATNA LOCAL	-17.39**	-10.43**	-49.78**	-35.29**	-40.29**	-8.47**	25.00**	87.30**

*, ** Significant at 5 and 1% levels

inheritance of fruit yield per plant and most of the yield component traits were controlled by both additive and non-additive gene action. Similar results were reported earlier by Sonavane *et al.* (2013a) in sponge gourd. The relative magnitude and importance of additive and non-additive variances in the genetic control of various quantitative characters were further revealed by predictability ratio as suggested by Baker (1978). This reflected the preponderance of additive genetic effects for node of 1st female flower appearance as its value was more than 0.80, this indicated the limited scope of heterosis breeding for this character and population improvement through recurrent selection should be adopted for exploiting the genetic variations (Jha *et al.* 2009). In contrast, predictability ratio of fruits per plant, yield per plant and sex ratio (M/F) were below 0.5, indicating predominant role of non-additive gene action in the expression of these traits in sponge gourd, which can be improved by heterosis breeding. For the other remaining characters both additive and non-additive gene effects were important as the predictability ratios were between 0.5 and 0.80, which can be improved by reciprocal recurrent selection.

CONCLUSION

The results discussed above are quite indicative of the fact that hybrids in sponge gourd have greater potential for maximizing yields with earliness. Based on combining ability analysis and heterosis study, the F_1 hybrids IC-284795 × Patna Local, IC-336759 × Patna Local and IC-284795 × IC-336759 were found to be best performers.

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