International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM October 2022, 13(10):1047-1056 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3117

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3117

Genetic Variability, Diversity, Heterosis and Combining Ability in Sponge Gourd [*Luffa cylindrica* (Roem.) L.]

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ABSTRACT

This experiment was conducted at Mandouri farm, Horticultural Research Station, Bidhan Chandra Krishi Viswavidyala (BCKV), West Bengal, India during March, 2014 to July, 2018. The objectives of the research were to determine genetic variability, phenotypic performance and diversity for yield and 17 yield attributing traits of the 45 sponge gourd germplasm. To study the heterosis and combining ability of parental lines with half diallel analysis for earliness and yield contributing characters. PCV (phenotypic coefficient of variation) was higher than GCV (genotypic coefficient of variation) for all the traits studied. Higher PCV and GCV were recorded for traits namely number of primary branches plant^{-1}, number of fruiting nodes on main stem, sex ratio (male/female), fruits plant^{-1} and fruit yield plant^{-1}. Based on Mahalanobis' D^2 statistic, the genotypes of sponge gourd were grouped into 7 different clusters. Fruit yield plant^{-1}, weight of fruit and number of fruiting nodes on main stem had maximum contribution towards genetic divergence. Among the parents, Patna Local, IC-336759 and IC-284795 showed high significant positive GCA effects as well as *per se* performance for yield and yield related attributes. Additive as well as non-additive gene action regulating the different traits. The traits under non additive gene action. The magnitude of standard heterosis was found in desirable direction for early and yield traits *viz*., days to first pistillate flower appearance in the cross IC284795×Patna Loca (-23.07%), for 50% flowering in the cross IC-284795×Patna Local (-18.89%), sex ratio in the cross IC-336759×Patna Local (-53.41%), for number of fruit vine^{-1} in the cross IC-284795×Patna Local (34.56%) and average fruit weight in the cross IC336759×Patna Local (110.09%). Promising germplasm Patna Local may be subjected for regional yield trail along with released variety with a view to develop new variety of sponge gourd. The superior hybrids can be exploited for hybridization programme.

KEYWORDS: Combining ability, earliness, genetic variability, heterosis, yield

Citation* (VANCOUVER)*: Kumar and Pandit, Genetic Variability, Diversity, Heterosis and Combining Ability in Sponge Gourd [*Luffa cylindrica* (Roem.) L.]. *International Journal of Bio-resource and Stress Management*, 2022; 13(10), 1047-1056. HTTPS://DOI.ORG/10.23910/1.2022.3198.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Funding: The manuscript made from my Ph.D research project conducted at Bidhan Chandra Krishi Viswavidhyalaya (BCKV), West Bengal with the kind and supports from BCKV and ICAR PhD Senior Research Fellowship..

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 03rd June 2022 RECEIVED in revised form on 10th September ACCEPTED in final form on 02nd October 2022 PUBLISHED on 18th October 2022

1. INTRODUCTION

Sponge gourd originated from subtropical Asian region particularly India (Swarup, 2006). Sponge gourd is a highly nutritive vegetable and contains protein, fat, carbohydrates, vitamins, minerals and fibre (Gopalan et al., 2012). Sponge gourd fruits contain more protein and carotene than ridge gourd (More and Shinde, 2001). Dried fruits having large volume of fibrous portion are used for body scrubbing, clearing utensils, making shoe-soles, filters, etc (Shah et al., 1980, Bal et al., 2004, Altinsik et al., 2010). It has medicinal properties; Juice from the leaves are use to cure conjunctivitis. The leaves and fruits are good remedies for Jaundice (Manikandaselvi et al., 2016). Roots have laxative effects and the oil from the seeds is used for cutaneous complaints (Chauhan, 1972). Being a minor crop and its cultivation is not yet flourished at commercial scale and area of cultivation is not known.

Information on genetic divergence among the plant material is vital to a plant breeder for efficient choice of parents for hybridization (Arunachalam, 1981). This is a monoecious annual climber, but there are various sex forms like staminate, pistillate and hermaphrodite are found (Takahashi, 1980). There are different fruit shapes, colours and lengths' ranging from few centimetres to a meter indicates the presence of wide genetic variability (Singh et al., 2020). High GCV, PCV indicates wider diversity. It is an established fact that genetically diverse parents are likely to contribute desirable segregants and/or to produce high heterotic crosses (Ram et al., 2006, Golani et al., 2007). More diverse the parents greater are the chances of obtaining high heterotic F1 and broad spectrum of heritability in segregating generations (Murty and Arunachalam, 1966). Precise information on the extent of genetic diversity among population is crucial in any crop improvement program, as selection of plants based on genetic diversity has become successful in several crops (Ananda and Rawat, 1984). The parent's identified on the basis of divergence analysis would be more promising. The quantification of genetic diversity through biometrical procedures will be made it possible to choose the genetically diverse parents for a successful hybridization program (Jain et al., 1975). Cluster analysis and PCA (principal component analysis) are the important genetic diversity measuring tools employed for exhibiting relative genetic differences among the genotype collection of various crop species (Jagadev and Samal, 1991). Genetic divergence is measured by D^2 statistic (Mahalanobis, 1936).

Exploitation of heterosis is easier in cross pollinated crops like sponge gourd, which provides ample scope for the utilization of hybrid vigour on commercial scale. Heterosis manifestation is in the form of earliness in increased productivity, maturity and better-quality attributes (Islam et al., 2012, Chaudhary, 2017, Costa et al., 2019). Diallel analysis provides an efficient means of rapidly obtaining an overall picture of the genetic control of a character in a set of parents in the early generations (Jinks and Hayman, 1953, Hayman, 1954).The analysis of combining ability helps in selecting suitable genotypes as parents for hybridization and crosses for characterizing the nature and magnitude of gene action involved in quantitative traits (Acquaah, 2007, Simranpreet et al., 2022). The use of contrasted lines in breeding programmes could contribute to create high yield varieties (Akbar et al., 2008). On the other hand, plant selection for high yield can be effective only if the variables under selection have high heritability (Anonymous, 1995). Due to the importance of the study and lack of research works done in this crop, this study has been formulated to gather information on genetic variability, diversity, and to assess the nature and magnitude of heterosis for yield, its component traits.

2. MATERIALS AND METHODS

The study was conducted at Mandouri farm, Horticultural Research Station, Bidhan Chandra Krishi Viswavidyala (BCKV), West Bengal, India located at latitude of 22.9452° N and longitude of 88.5336°E, 7 m above mean sea level. The experimental location is in Alluvial zone of West Bengal. The experiment was conducted during March, 2014 to July, 2018.

A total of 45 genotypes were collected from different sources namely, ICAR- IIVR, Varanasi; ICAR-NBPGR, New Delhi; Andhra Pradesh and Bihar, parts of West Bengal. They were evaluated for 2 years by planting in March, 2014 and July, 2015. The seeds were sown with spacing of 1.0 m×0.75 min randomized block design (RBD). The crop was grown under irrigated conditions as per package of practices recommended by Singh and Singh(2009). To control the pests and diseases need based plant protection measures were taken up.Five random plants were selected for collection of various observations of17 traits studied.

Promising 8 parents were selected based on genetic diversity and variability studies. The seeds were sown in pits with 1 m row spacing and 0.75 m spaced between plants in a row during June, 2015 to March, 2016. All cultural practices followed as per recommended package of practices (POP) as in previous seasons.

Sponge gourd is monoecious crop;on the same plant it produces male and female flowers separately. For crossing male and female flower buds which open by next day morning were bagged during evening of previous day with butter paper bags. Pollen from the bagged male flowers was collected for crossing and dusted on to the stigma of bagged female flower of the receptive female parent; pollination was done in the morning @ 6 AM to 8.30 AM. The pollinated flowers were labelled with tags and covered again with the butter paper cover. The paper bags were removed on the next day so as to allow normal fruit development. After maturing and drying of the fruits, dry seeds for each cross combination were collected separately. 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 RBD with 3 replications during March-July, 2018.

The data recorded were subjected to GCV, PCV, broad sense heritability (H^2), genetic advance as % of mean (GAM) were computed by the methods suggested by Panse and Sukhatme (1985). Analysis of genetic divergence was done according to Mahalanobis' D^2 (1936) statistic. Combining ability analysis was carried out according to Jinks and Hayman (1953). Heterosis over mid parent (Average heterosis), better parent (Heterobeltiosis) and commercial check (standard heterosis) were estimated in terms of % increase or decrease of the F_1 hybrid over its mid parent, better-parent and commercial check (Hayes and Foster, 1976).

3. RESULTS AND DISCUSSION

There were significant differences for all the traits studied in 45 genotypes of sponge gourd. The extent of variability present in genotypes measured in terms of mean, range, phenotypic coefficient of variation, genotypic coefficient of variation,heritability and genetic advance (Table 1). There was a wide variation among the genotypes studied. Highrange of variation was recorded for average weight of fruit (74.96–184.29 g) followed by average length of the fruit (11.37–25.54 cm). The narrowrange of variation was recorded in 100 seed weight (10.73–13.01). Phenotypic coefficients of variations were higher than their genotypic coefficient of variations indicating the environmental influences. Higher magnitude of PCV and GCV (>20.01%) were observedfor number of primary branches, fruiting nodes number on main stem, male to female flower ratio, number of fruits plant^{-1} and fruit yield plant^{-1}. Itindicates that maximum variability existed in the genotypes studied for 17 traitsand there is good scope for improvement of these traits. Results of similar kind were reported by Signh et al. (2002)in ridge gourd and Sharma et al. (2017) in sponge gourd. For most of the traits the difference between GCV and PCV is less, indicates less influence of environment on them and hence simple phenotypic selection is effective in improvement of these traits.

Higher heritability (>60%, Robinson, 1966) and genetic

Table 1: Estimation of variability for 17 traits in 45 selected genotypes of sponge gourd

Sl. No.	Character	Range		Mean	GCV %	PCV %	h^2 (Broad sense)	Genetic advance as % of mean
		Maximum	Minimum					
1.	Vine length (m) (at 90 DAS)	4.85	01.98	03.29	12.55	14.30	89.55	22.70
2.	Number of primary branches	4.80	01.80	03.09	24.56	24.94	96.99	49.83
3.	Number of fruiting nodes on main stem	7.20	02.20	04.20	34.46	34.67	98.79	70.55
4.	Days to first male flower appearance	49.85	30.88	42.26	10.71	12.45	73.91	18.96
5.	Days to first female flower appearance	55.50	35.23	46.54	11.13	11.89	87.58	21.45
6.	Days to 50% flowering	60.00	37.00	50.26	12.01	13.01	85.29	22.85
7.	Span of flowering	42.23	35.27	37.63	03.71	04.85	58.69	05.86
8.	Sex ratio (M/F)	37.15	14.93	22.76	22.29	24.35	83.81	42.04
9.	1st female flower appearance node	19.05	06.56	13.03	18.73	19.59	91.44	36.89
10.	Days for anthesis to harvestable maturity	07.45	05.30	06.45	06.95	07.54	85.07	13.21
11.	Length of the fruit (cm)	25.54	11.37	19.49	18.92	20.91	81.86	35.26
12.	Diameter of the fruit (cm)	06.40	04.20	05.21	11.35	12.45	83.06	21.31
13.	Weight of the fruit (g)	184.29	74.96	137.25	14.20	16.49	74.15	25.19
14.	Number of fruits plant^{-1}	18.89	07.41	10.93	22.97	23.61	94.58	46.01
15.	Number of seeds fruit^{-1}	125.32	47.22	90.99	16.31	20.64	62.41	26.54
16.	Seed index (100 seed weight)	13.01	10.73	11.91	04.69	05.20	81.40	08.72
17.	Fruit yield plant^{-1} (kg)	02.26	00.65	01.46	44.16	46.66	89.55	86.08

advance as % of mean (>20%, Johnson et al., 1955) were recorded for number of primary branches, vine length, the number of fruiting nodes on main stem, male to female flower ratio (sex ratio), number of fruits plant^{-1}, fruit yield plant^{-1}, days taken to produce female flower appearance, days to 50% flowering, node at first female flower appearance, length of the fruit, diameter of the fruit, average weight of the fruit and number of seeds fruit^{-1}. It indicates that these traits were controlled by additive gene action and simple selection based on phenotypic performance of them would be effective. Reported similar kind of findings by Singh et al. (2002), Rani (2012) in ridge gourd, Sharama et al. (2017) in sponge gourd. Based on Mahalanobis's method the 45 genotypes were grouped into 7 non-overlapping clusters. Of these7 clusters, cluster- 1 had 18 genotypes, followed by cluster-2 had 12 genotypes, cluster-3 had 9 genotypes, cluster-4had 3 genotypes. The clusters 5, 6 and 7 were single genotype clusters. Inter cluster distances were higher than intra cluster distances (Table 2). Intra cluster D^2 distance was maximum in cluster- 4, followed by cluster-3 and cluster- 2. Inter cluster distance was maximum between cluster- 4 and cluster- 5, followed by cluster-4 and cluster-6, and cluster-4 and cluster-7. Quamruzzaman et al. (2011), Yadav et al. (2016) reported that, for exploitation of higher heterosis in F_1 generation parents taken from distant clusters genotypes are effective.

Table 2: D^2 values for intra and inter cluster distances

	Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5	Cluster-6	Cluster-7
Cluster-1	227.436	1643.740	555.056	2356.755	936.269	1081.514	1568.103
Cluster-2		351.528	1131.590	745.572	3399.356	2853.304	1959.682
Cluster-3			519.616	1775.888	1552.321	1463.971	1445.357
Cluster-4				541.126	5177.897	4034.087	3552.242
Cluster-5					0.000	966.879	1276.876
Cluster-6						0.000	732.866
Cluster-7							0.000

There were considerable differences for cluster means of different quantitative traits (Table 3). Cluster-1 had highest mean value for vine length (3.45 m) followed by 2nd and 4th clusters (3.25 m). Lowest mean value for vine length was 2.74 m by cluster-7. The cluster-2 had highest mean value for number primary branches on main stem (3.89) and lower mean was 2.66 by cluster-1. The cluster-2 recorded highest mean value (5.92) for number of fruiting nodes on main stem, lower mean (3.20) by cluster-5. The cluster-7 was very late in days to male and female flower appearance (47.96, 52.63) early by cluster-4 (37.95, 41.71respectively). For 50% flowering cluster-4 took less days (45.08) and late by cluster-7 (57.50 days from sowing). Male to female flower ratio (sex ratio) ranged from 16.09 to 24.67. Number of days taken from anthesis to maturity was less (6.02) by cluster-4 and late by cluster-6 (6.88). Mean for fruit length was higher in cluster-4 (21.43 cm). Higher mean for fruit diameter was observed in cluster-7 (6.40 cm) and minimum in the cluster-4 (4.95 cm). Weight of fruit ranged from 74.96–159.75 g. Cluster- 6 (18.89) recorded maximum number of fruits plant^{-1}. Inter crossing among genotypes with outstanding mean performance in sponge gourd for crop improvement was reported by Quamruzzaman et al. (2011).

Traits namely fruit yield plant^{-1}, average weight of the fruit, Days to first male flower appearance, sex ratio, the number of fruiting nodes on main stem, length of the fruit, number of fruits plant^{-1} and number of primary branches on main stem were are responsible for highest % contribution towards total genetic divergence (Table 3), these traits should be given more emphasis during hybridization programme.

3.1. Combining ability and heterosis

The estimates of component variance suggested that the estimates of specific combining ability (sca) variance components were larger than the estimates of general combining ability (gca) variance components for most of the characters. This indicated the preponderance of non-additive genes in the control of these characters. However, the magnitude of sca variance components were less than gca variance components for vine length and node of first female flower appearance, which indicating the preponderance of additive genes in the control of these characters. The ratio of gca variance to sca variance is an index of additive per non-additive gene action, the ratio ranged from 0.28 in the case of yield per plant to 2.17 for node of the first female flower appearance. Additive as well as non-additive gene action regulating the different traits. The estimate of GCA effects, *per se* performance of the parents, heterosis and SCA effects of the crosses have been presented in Tables 4, 5 & 6 respectively. Parents with early flowering types were considered better than late flowering ones, therefore, parents with significant negative GCA effects were

Table 3: Mean values of 7 clusters for yield and its contributing characters

Cluster Number	Vine length (m) (at 90 DAS)	No. of primary branches	No. of fruiting nodes on main stem	Days to first male flower appearance	Days to first female flower appearance	Days to 50% flowering	Span of flowering	Sex ratio (M/F)
CL-1	3.45	2.66	3.09	43.99	48.44	52.20	37.52	24.67
CL-2	3.25	3.89	5.92	39.15	42.60	45.58	37.44	20.78
CL-3	3.13	2.78	3.93	43.47	48.60	53.03	38.43	23.29
CL-4	3.25	3.13	4.87	37.95	41.71	45.08	37.30	21.06
CL-5	3.22	2.80	3.20	41.00	46.83	48.50	37.40	21.10
CL-6	3.14	3.60	3.40	46.30	49.23	56.63	37.25	16.09
CL-7	2.74	3.60	5.60	47.96	52.63	57.50	36.49	20.93
% Contribution								
Towards divergence	4.20	5.31	7.27	7.84	3.76	3.48	5.18	7.31

Table 3: Continue...

Cluster Number	1st female flower appearance node	Days for anthesis to harvestable maturity	Average fruit length (cm)	Average diameter of fruit (cm)	Average feight of fruit (g)	No. of ruits plant^{-1}	No. of seeds fruit^{-1}	Seed index (100 seed weight)	Yield plant^{-1} (kg)
CL-1	14.37	6.52	19.99	5.21	136.84	09.19	89.74	11.97	1.25
CL-2	11.18	6.23	20.87	4.99	145.95	12.46	96.89	11.82	1.80
CL-3	13.72	6.63	18.17	5.33	137.89	10.32	91.99	12.04	1.42
CL-4	10.72	6.02	21.43	4.95	159.75	13.41	112.22	12.62	2.14
CL-5	12.83	6.84	16.29	5.12	87.28	07.49	54.99	10.73	0.65
CL-6	13.23	6.88	11.37	6.35	74.96	18.89	47.22	10.73	1.42
CL-7	12.02	6.47	11.41	6.40	79.13	17.27	49.85	10.98	1.37
% Contribution									
Towards divergence	3.15	5.14	6.89	3.54	9.48	5.78	3.43	2.91	15.33

considered more desirable. The estimates of GCA revealed that parent Patna local was the best general combiner for days taken to first female flower appearance, days to 50% flowering and days taken from anthesis to harvestable maturity, followed by parents IC-284795 and IC-336759. Four parents namely IC-284840, IC-355633, IC-544806 and IC-284941 were found poor general combiners as they exhibited significant positive gca effects for the mentioned traits. The performance of genotype on yield is the foremost breeding objective for any crop improvement programme. Therefore, with a focus on earliness combining ability effects of parents regarding yield parameters were also taken into consideration. Being monoecious crop, the ratio of male to female flowers is an important yield attributing trait in sponge gourd as lower ratio has been reported to be associated with higher fruit set and subsequently higher fruit yield (Islam et al., 2012). Similarly, sex ratio also negative gca effect of the genotypes were considered superior. In the present study IC-336759 (-4.36) was found the best general combiner for sex ratio followed by Patna local (-2.33) and IC-284795 (-0.54). Total yield plant^{-1} is a complex trait and is influenced by different yield attributing traits and environmental effects. High and positive GCA effect is the desirable criteria to attribute superiority to genotypes. In the present study, Patna local (1.03) emerged as the best general combiner for fruit yield plant^{-1} followed by IC-336759 (0.74) and IC-284795 (0.34). Out of 28 cross combinations, 15 were showed desirable negative SCA effect for days to first female flower opening, 19 crosses for days taken for fruit maturity and 16 crosses for sex ratio. The best specific combiners 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 combination IC-284840×IC-355633 (-1.58)

Table 4: Estimates of general combining ability (gi) effects, per se performance (in parenthesis) in 8 parents in sponge gourd

Genotype		A	B	C	D	E	F	F	H	I	J	K
		Parents										
1	IC-284795	0.18** (3.80)	0.58** (4.85)	0.91** (7.00)	-1.91** (37.83)	-3.45** (42.30)	-3.29** (51.30)	0.66** (43.85)	-0.54** (18.65)	-1.50** (9.35)	-0.50** (8.50)	1.04** (23.00)
2	IC-336759	0.73** (4.30)	0.48** (5.00)	0.55** (6.90)	-3.02** (35.50)	-2.92** (41.25)	-2.00** (53.00)	4.48** (46.23)	-2.33** (17.35)	-1.51** (8.00)	-0.74** (7.85)	2.94** (25.43)
3	IC-284840	-0.23** (3.20)	0.15** (4.33)	0.65** (6.25)	1.96** (39.50)	1.58** (45.50)	0.74** (54.75)	-0.44** (40.00)	-0.45** (20.65)	-1.02** (10.00)	-0.61** (9.00)	2.18** (21.85)
4	IC-355633	-0.78** (2.25)	-1.16** (2.50)	-1.49** (2.85)	4.19** (48.00)	5.27** (56.35)	5.54** (66.25)	-5.75** (32.65)	4.71** (27.00)	2.33** (16.00)	1.34** (10.50)	-3.36** (11.50)
5	IC-544806	-0.55** (2.50)	-0.62** (3.25)	-1.09** (3.00)	1.54** (43.75)	2.00** (49.00)	1.60** (58.25)	-1.44** (39.00)	2.61** (23.50)	1.62** (14.50)	-0.12** (9.45)	-2.76** (16.50)
6	IC-284941	-0.59** (2.65)	-0.69** (3.00)	-1.12** (3.25)	1.32** (45.25)	3.02** (54.00)	3.45** (65.00)	-4.06** (37.50)	-0.18* (21.33)	2.21** (15.00)	1.69** (10.65)	-5.59** (12.55)
7	VRSG-199	0.19** (3.50)	0.16** (4.00)	0.13** (5.00)	0.43 (41.35)	-0.55** (47.00)	-1.42** (56.00)	-1.08** (39.65)	0.53 (23.00)	0.63** (13.35)	0.37** (9.35)	0.74** (19.65)
8	Patna Local	1.06** (4.80)	1.10** (5.50)	1.45** (7.20)	-4.51** (34.00)	-4.93** (40.00)	-4.60** (49.50)	7.64** (52.00)	-4.36** (14.50)	-2.77** (6.50)	-1.42** (7.00)	4.81** (27.00)
SEm±		0.03	0.04	0.05	0.25	0.14	0.15	0.14	0.09	0.04	0.02	0.06

Table 4: Continue...

Genotype		L	M	N	O	P	Q
		Parents					
1	IC-284795	0.34** (6.75)	7.39** (197.50)	1.40** (13.00)	8.78** (125.00)	0.86** (13.00)	0.34** (2.57)
2	IC-336759	0.82** (7.90)	27.26** (212.00)	2.12** (13.15)	14.60** (120.33)	1.07** (13.30)	0.74** (2.79)
3	IC-284840	-0.66** (5.23)	1.07** (189.35)	-0.18** (10.65)	0.07 (115.00)	-1.71** (9.65)	-0.06** (2.02)
4	IC-355633	-1.01** (6.75)	-41.92** (115.50)	-3.34** (5.36)	-23.64** (60.00)	0.01 (11.00)	-1.02** (0.62)
5	IC-544806	-1.03** (5.35)	-10.69** (165.35)	-2.01** (7.07)	-18.58** (79.67)	-1.06** (10.00)	-0.59** (1.17)
6	IC-284941	-0.65** (6.00)	-28.95** (130.35)	-1.73** (7.21)	-15.23** (75.00)	-1.11** (9.85)	-0.67** (0.94)
7	VRSG-199	-0.31** (4.75)	8.09** (173.33)	0.98** (11.40)	8.96** (110.00)	0.20** (11.50)	0.23** (1.98)
8	Patna Local	2.52** (9.00)	37.74** (235.00)	2.75** (13.58)	25.04** (130.00)	1.74** (14.35)	1.03** (3.19)
SEm±		0.06	0.39	0.06	0.20	0.05	0.013

*, ** Significant at (p=0.05 and (p=0.01) levels; (A)- Vine length (m); (B)-Number of primary branches plant^{-1}; (C)-Number of fruiting nodes on main stem; (D)-Days to first male flower appearance; (E)-Days to 50% flowering; (F)-Days to first female flower appearance; (G)-Span of flowering; (H)-Sex ratio (M/F); (I)- 1st female flower appearance node; (J)- Days for anthesis to harvestable maturity; (K)-Average length of fruit (cm); (L)-Average diameter of fruit (cm); (M)- Average weight of fruit (g); (N)-Number of fruits plant^{-1}; (O)-Number of seeds fruit^{-1}; (P)-Seed index (100 seed weight), (Q)-Average yield plant^{-1} (kg)

Table 5: Estimates of heterosis over better parent (BP) and commercial check (CC) for some major traits studied in sponge gourd

Cross		Days to first female flower appearance		Male to female flower ratio		Days from anthesis to harvestable maturity		Yield plant^{-1} (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×VRSG-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×VRSG-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×VRSG-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-284941×VRSG-199	-27.36**	-9.51**	-23.26**	-1.12	-0.94	72.95**	21.75**	13.17**
6×8	IC-284941×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 (p=0.05) and (p=0.01) levels

was found best specific combiner for days to fruit maturity from anthesis. Cross IC-355633×VRSG-199 (-4.61) was found significantly superior to other crosses for the sex ratio, next best were IC-284795×IC-284840 (-3.18) and IC-355633×IC-284941 (-3.10). Best combiner for total yield plant^{-1} was IC-355633×Patna Local (1.11), next best wereIC-284795×Patna Local (0.77) and IC-336759×Patna Local (0.52).

The results shows that majority of the hybrids showing the best SCA effects, the parents involved were either one or both good general combiners having high and desirable GCA effects. The general combining ability in turn is influenced by *per se* performance of the genotypes. The results suggest that from economic point of view, it is necessary to utilize the early flowering genotypes with higher yield in order to achieve early flowering F1 hybrids

Table 6: *Per se* performance (in parenthesis), estimates of specific combining ability (SCA) effects of hybrids for some important traits in sponge gourd

Genotype		Days to first pistillate flower appearance	Sex ratio (M/F)	Days to harvestable maturity from anthesis	Yield plant^{-1} (kg)
1	IC-284795×IC-336759	-1.12* (35.54)	-2.19** (12.55)	-0.98** (5.63)	0.52** (4.14)
2	IC-284795×IC-284840	-3.51** (37.65)	-3.18** (13.45)	-0.49** (6.25)	0.48** (3.30)
3	IC-284795×IC-355633	-6.00** (38.85)	2.21** (24.00)	-1.24** (7.45)	-0.52** (1.34)
4	IC-284795×IC-544806	1.07* (42.65)	1.57** (21.25)	-0.88** (6.35)	-0.16** (2.13)
5	IC-284795×IC-284941	-2.10** (40.50)	-0.54 (16.35)	1.11** 10.15)	-0.04 (2.18)
6	IC-284795×VRSG-199	0.62 (39.65)	0.05 (17.65)	-0.89** (6.83)	0.26** (3.37)
7	IC-284795×Patna local	-1.30** (33.35)	-2.17** (10.54)	0.07 (6.00)	0.77** (4.68)
8	IC-336759×IC-284840	-2.05** (39.65)	-1.49** (13.35)	-0.05 (6.45)	0.43** (3.66)
9	IC-336759 × IC-355633	-0.23 (45.15)	1.00** (21.00)	-0.45** (8.00)	0.08* (2.35)
10	IC-336759 × IC-544806	-2.11** (40.00)	-1.85** (16.05)	0.16* (7.15)	0.28** (2.98)
11	IC-336759× IC-284941	1.77** (44.90)	-1.46** (13.65)	-0.57** (8.23)	0.20** (2.82)
12	IC-336759 ×VRSG-199	-3.03** (36.54)	-0.17 (15.65)	-0.73** (6.75)	0.44** (3.96)
13	IC-336759 ×Patna local	-1.33** (33.85)	-2.61** (8.32)	-0.34** (5.35)	0.52** (4.84)
14	IC-284840× IC-355633	0.12 (50.00)	0.95** (22.83)	-1.58** (7.00)	-0.71** (0.75)
15	IC-284840×IC-544806	4.54** (51.15)	-1.28** (18.50)	-0.67** (6.45)	-0.05 (1.84)
16	IC-284840×IC-284941	2.62** (50.25)	-1.34** (15.65)	-1.48** (7.45)	0.11* (1.93)
17	IC-284840×VRSG-199	0.48 (44.54)	-0.15 (17.55)	-0.46** (7.15)	0.36** (3.07)
18	IC-284840×Patna local	-0.81 (38.87)	-1.36** (11.45)	-0.01 (5.80)	0.18** (3.69)
19	IC-355633× IC-544806	4.15** (54.45)	4.06** (29.00)	-0.61** (8.46)	-0.09* (0.84)
20	IC-355633×IC-284941	3.68** (55.00)	-3.10** (19.05)	3.68** (14.55)	-0.35* (0.51)
21	IC-355633 xVRSG-199	-2.92** (44.83)	-4.61** (18.25)	1.68** (11.23)	0.25** (2.00)
22	IC-355633×Patna local	-4.37** (39.00)	-0.42 (17.55)	-1.46** (6.30)	1.11** (3.67)
23	IC-544806×IC-284941	-6.90** (41.15)	-0.80** (19.25)	-1.15** (8.27)	0.19** (1.48)
24	IC-544806 xVRSG-199	-0.26 (44.23)	-1.20** (19.55)	-0.59** (7.50)	0.27** (2.45)
25	IC-544806×Patna local	-4.45** (35.65)	-1.85** (14.02)	0.05 (6.35)	-0.05 (2.94)
26	IC-284941×VRSG-199	-6.28** (39.23)	-0.32 (17.65)	0.65** (10.55)	0.30** (2.41)
27	IC-284941×Patna local	-2.67** (38.45)	-0.58* (12.50)	-1.11** (7.00)	0.13** (3.05)
28	VRSG-199×Patna local	1.27** (38.83)	-2.24** (11.55)	-1.21** (5.58)	0.18** (3.98)
SEm±		0.48	0.29	0.08	0.04

*, ** Significant at (p=0.05) and (p=0.01) levels

for exploitation of heterosis. While selecting the parental lines for obtaining early flowering F_1 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 plant^{-1}. Therefore, the parents Patna local, IC-284795 and IC-336759 were found promising for selection and recombination breeding. Report on combining ability of parents and crosses pertaining to earliness in sponge gourd were reported by Islam et al. (2010).

A perusal of the mean performance of parents (Table 4) revealed that among the parents, the genotype Patna local was the earliest in days taken for producing first female flower (40 days), days taken anthesis to harvestable maturity (7 days) and produced the highest total yield plant^{-1}(3.19 kg). It also exhibited lowest sex ratio (14.50). Among the hybrids IC-336759×Patna local was the earliest to produce marketable fruit from anthesis (5.35 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 (8.32) and produced significantly highest total yield plant^{-1}(4.84 kg). Therefore, it is inferred that lower ratio of male and female flowers has positive correlation with total yield plant^{-1}. The result of the characters studied for the estimates of heterosis over better parent and standard check have been presented in Table 5. The expression of heterosis for various characters ranged from significantly large positive effects to significant negative effects. In the present study none of the F1 hybrid was found consistently superior to others for all the characters studied. Out of 28 hybrids, 26 & 17 hybrid combinations exhibited highly significant heterosis over better parent and standard check (Pusa Chickni), respectively for days to first female flower appearance, while 21 cross combinations expressed highly significant heterobeltiosis for days to fruit harvestable maturity from anthesis and 4 crosses documented highly significant heterosis over standard check. 15 crosses recorded highly significant heterosis over respective better parent and 18 crosses over standard check for total yield plant^{-1}. Heterosis for earliness and increased yield in sponge gourd has been very few. Similar reports in sponge gourd reported by Islam et al. (2012).

3.2. Joint effect of GCA, SCA and per se performance

Parents involved in the best specific combinations showed high GCA effect and high *per se* performance for several characters studied. The best fruit yield plant^{-1} was shown by the crosses IC-336759×Patna Local, IC-284795×Patna Local, IC-284795×IC-336759 and these parents recorded significantly very high GCA effects and *per se* performance for the character. In these crosses additive×additive interactions were likely to be predominant. Another significant observation was that in a specific combination one of the parents may be shown high GCA effect with high *per se* performance for the character concerned, in the cross combination IC-355633×Patna Local on fruit yield plant^{-1} had significantly high SCA effects involved at least one good general combiner. In this cross additive×dominant or dominant×additive interactions were likely to be predominant. Another interesting situation was also recorded where the parents involved in a cross showing highest SCA effects exhibited significantly negative GCA effect with very low *per se* performance for the character concerned. This can be demonstrated in case of cross combination 544806×IC-284941 for days to female flower appearance, where these parents showed significantly negative GCA effect and low *per se* performance though their cross combination showed the highest SCA effect. In such situation dominance and dominance×dominance epistatic gene action may be playing a major role. These reports are in line with the findings of Gopal (2011) in Ridge gourd.

4. CONCLUSION

Traits namely fruit yield plant^{-1}, weight of fruit and number of fruiting nodes on main stem had maximum contribution towards genetic divergence, considering these traits in selection of diverse parents during hybridization program manifests high heterosis. Among the parents, Patna Local, IC-336759 and IC-284795 were found to be good general combiners for yield and may be used in a breeding programme for developing high yielding varieties.

5. ACKNOWLEDGEMENT

Authors (J. Suresh Kumar and M.K. Pandit) acknowledge the supports from institutes involved.

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