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Exploitation of heterosis in sponge gourd [*Luffa cylindrica* (L.) Roem.]

Venugopala Reddy M, MG Patil, Shekharagouda Patil*
Department of Horticulture, University of Agricultural Sciences, Raichur, Karnataka, India

Abstract
The present investigation was conducted in 36 crosses, which were developed by using nine parents to study the heterosis for yield parameters in sponge gourd. Maximum standard heterosis for fruit length was observed in SG-4 × KRCCH-2 (19.44 %), for fruit diameter in SG-6 × Swarna Prabha (-21.13 %), for average fruit weight in SG-5 × KRCCH-1 (13.37 %), for number of fruits per plant in Kulgod local × Pusa Chikni (66.04 %), for fruit yield per plant in Kulgod local × Pusa Chikni (100.74 %) and for number of seeds per fruit in SG-6 × KRCCH-1 (-42.66 %). The three best performing F_1 hybrids *viz*., the cross Kulgod local × Pusa Chikni (100.74 %) followed by SG-5 × SG-3 (95.11 %) and Kulgod local × KRCCH-1 (70.08 %) exhibited the highest standard heterosis for total fruit yield per plant in order of merit.

Keywords: sponge gourd, heterosis, fruit yield per plant and genotypes variability

Introduction

Sponge gourd [*Luffa cylindrica* (L.) Roem.] is one of the most important cucurbitaceous vegetable crops grown extensively throughout the tropical and sub-tropical regions of the world. It is commonly called as smooth luffa, climbing okra, dishcloth gourd and Chinese okra.

This crop has a long history of cultivation in the tropical countries of Asia and Africa (Oboh and Aluyor, 2009) [10]. *Luffa* is a diploid species with 26 chromosomes (2n = 26). *Luffa* belongs to cucurbitaceous family and it is a cross-pollinated crop (Bal, *et al*., 2004) [3] widely cultivated in *kharif* and summer seasons in India. The family Cucurbitaceae comprises of the largest group of summer vegetables. All together there are two well defined subfamilies, eight tribes, about 118 genera and 825 species in this family. Out of these, approximately 20 species belonging to nine genera are under cultivation (Jeffrey, 1990) [5].

Most of the cucurbitaceous vegetables, including sponge gourd are usually cultivated in relatively small area for local consumption and hence exact area and production are unknown. Cucurbits share about 5.6 per cent of the total vegetable production of India (Rai and Rai, 2006) [12]. According to FAO estimate, cucurbits are cultivated in an area of about 5.46 lakh ha having annual production of 5.40 lakh tonnes. The productivity of this crop is 10.52 tonnes per hectare (Anon., 2016) [1]. The main cucurbits producing countries are China, Korea, India, Japan, Nepal and Central America. In India, major cucurbits growing states are U. P., Punjab, Bihar, Jharkhand, Gujarat, Rajasthan, Haryana, Karnataka and Delhi.

Sponge gourd being a monoecious and cross pollinated crop, it exhibits considerable heterozygosity in population and does not suffer much due to inbreeding depression resulting in natural variability in the population. Thus provides ample scope for utilization of hybrid vigour on commercial scale to increase the production and productivity. In spite of the availability of wide range of genetic variability in plant and fruit characters and also produce large number of hybrid seed at reasonable cost, very little work has been done to exploit the hybrid vigour in this crop. One of the methods to achieve quantum jump in yield in heterosis breeding. Hence, an attempt was made to study the heterosis in different crosses over the mid parent, better parent and commercial check or standard parent to develop and identify the suitable best performing hybrids.

Material and Methods

The present investigation entitled "Heterosis studies in sponge gourd [*Luffa cylindrica* (L.) Roem.]" Conducted during *Kharif* season, 2017 at the Horticulture farm of Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Karnataka, India-584104.

Nine diverse parents (Kulgod local, SG-4, SG-6, SG-5, SG-3, Pusa Chikni, KRCCH-2, Swarna Prabha, KRCCH-1, KRCCH-1) were crossed in a diallel fashion (excluding reciprocals) for generating the 36 F_1 hybrids. All the nine parents, 36 hybrids and one standard check were grown in a randomized block design with three replications.

Observation were recorded on 22 characters *viz*., vine length, number of leaves per plant, internodal length, number of branches per plant, leaf area, days to first female flower appearance, node at which first female flower appeared, sex ratio, days to first harvest, days to last harvest, fruiting period, fruit set, fruit length, fruit diameter, average fruit weight, number of fruits per plant, fruit yield per plant, number of seeds per fruit, rind thickness, flesh thickness, total soluble solids and physiological loss of weight in sponge gourd.

Estimation of heterosis

Heterosis was calculated as percentage of F_1 performance in the desirable direction over mid parent, better parent and commercial check or standard parent (Anisha) was computed for each character using following formula.

1. Relative heterosis (%):

$$\text{Per cent heterosis over mid parent (MP)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

2. Heterobeltiosis (%):

$$\text{Per cent heterosis over better parent (BP)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

3. Standard heterosis (%):

$$\text{Pi Per cent heterosis over check/standard parent (SC)} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,
F_1 = Mean value of the F_1
MP= Mean performance of parents
BP= Mean performance of better parent
SC= Mean performance of standard check

Results and Discussion

The magnitude of heterosis was calculated as per cent increase or decrease of F_1 values over the mid parent (MP), better parent (BP) and standard parent (SP). The hybrid 'Anisha' was used as check or standard parent. The negative estimates of heterosis were considered desirable for the traits *viz*., internodal length, days to anthesis of first female flower, node number at which first female flower appeared, days to first harvest, number of seeds per fruit and physiological loss of weight. However, for rest of the characters studied positive estimates of heterosis was consider desirable.

A perusal of data presented in Table 1 - 2 revealed that maximum standard heterosis for fruit length in SG-4 × KRCCH-2 (19.44%), for fruit diameter in SG-6 × Swarna Prabha (-21.13%), for average fruit weight in SG-5 × KRCCH-1 (13.37%), for number of fruits per plant in Kulgod local × Pusa Chikni (66.04%), for fruit yield per plant in Kulgod local × Pusa Chikni (100.74%) and for number of seeds per fruit in SG-6 × KRCCH-1 (-42.66 %). Among 36 crosses, the top three ranking cross combinations based on average heterosis, heterobeltiosis and economic heterosis for the yield characters are given in Table 1-2. In cross combinations, Kulgod local × Pusa Chikni (90.16%), SG-4 × KRCCH-1 (62.63%) and Kulgod local × KRCCH-1 (58.89 %) exhibited the significant relative heterosis for yield per plant whereas crosses Kulgod local × Pusa Chikni (78.27%), Kulgod local × KRCCH-1 (47.17%) and SG-4 × KRCCH-1 (40.23%) exhibited over better parent and Kulgod local × Pusa Chikni (100.74%), SG-5 × SG-3 (95.11%) and Kulgod local × KRCCH-1 (70.08%) over standard parent. The cross Kulgod local × Pusa Chikni was the best performing cross based on *per se* performance for yield per plant and had average heterosis for yield and yield attributing characters in sponge gourd. The significant variations in the yield traits mainly may be due to variability between the parents and non-additive gene action and also may be due to high specific combining ability in the crosses. Similar results have also been reported in cucumber (Hutchins, 1939 and Singh *et al.*, 1970) [6, 16]; muskmelon (Mishra and Seshadri, 1985) [8]; bittergourd (Singh *et al*., 2000) [14] and bottle gourd (Jankiram and Sirohi, 1989) [4]. The highest yielding hybrids also registered for the earliness and setting the fruit at the minimum nodal position. This result suggests that from economic point of view, it is useful to select parental lines having one or more economic character in order to achieve high yield in the F_1 hybrids through heterosis breeding. For fruit length, Kulgod local × Pusa Chikni (45.39%), Pusa Chikni × Swarna Prabha (38.71 %) and SG-4 × Pusa Chikni (34.54%) were the best three hybrids over mid parent. The hybrids registered significant positive heterobeltiosis were Kulgod local × Pusa Chikni (20.66%), SG-4 × KRCCH-2 (18.49%) and Kulgod local × Swarna Prabha (15.65%). The crosses SG-4 × KRCCH-2 (19.44%) and Kulgod local × Pusa Chikni (16.64%) reported significant positive heterosis over the check parent. High heterosis for this trait was also noted by Hutchins (1939) [6], Singh *et al.*, (1970) [16], Mishra and Seshadri (1985) [8], Jankiram and Sirohi (1989) [4] and Singh *et al.* (2000) [14] in cucurbits which support the present findings. Besides recording high heterosis for this trait, they also recorded contribution of this character in increasing the yield potential of a cross. The extent of heterosis over the three best crosses for total yield per plant (58.89 - 90.16% over mid parent; 40.23 - 78.27% over better parent and 70.08 - 100.74% over check variety) revealed that there was a great scope of realizing higher yield in sponge gourd through heterosis breeding. Relative heterosis besides epistatic effect also indicates presence of dominace effects (intra allelic interaction), while heterobeltiosis is indicative of over dominace. In such situation economic heterosis or mean performance of a cross is more reliable criteria for identifying a commercially valuable cross. The crosses showing high heterosis for yield and also exhibiting high heterosis for different yield contributing characters by Kulgod local × Pusa Chikni and Kulgod local × KRCCH-1 are more suitable because has strong heterotic capability compared to other ones during hybridization process. These crosses may be further tested and recommended for commercial cultivation to boost the fruit yield per unit area of sponge gourd.

Table 1: Estimation of heterosis for average fruit weight and number of fruits per plant in sponge gourd

Cross	Average fruit weight			Number of fruits/plant		
	MP	BP	SC	MP	BP	SC
Kulgod local × SG-4	31.57**	24.39**	3.15	-31.01**	-33.33**	-14.01
Kulgod local × SG-6	27.47**	23.50**	-2.72	-20.93	-26.05*	2.17
Kulgod local × SG-5	48.67**	44.59**	6.81	-24.10*	-36.16**	12.56
Kulgod local × SG-3	14.20*	-4.33	4.63	-26.91*	-32.67**	-3.86
Kulgod local × Pusa Chikni	24.73**	24.71**	-7.84	37.62**	37.21**	66.04**
Kulgod local × KRCCH-2	20.27*	7.44	-20.64**	35.70**	22.89	47.83**
Kulgod local × Swarna Prabha	3.78	-4.77	-15.77*	-12.45	-18.66	14.01
Kulgod local × KRCCH-1	38.89**	27.39**	-5.89	30.25*	13.25	36.23*

SG-4 × SG-6	1.67	-0.88	-17.80**	-4.88	-8.04	27.05
SG-4 × SG-5	45.35**	33.85**	11.00	-20.73*	-31.37**	21.01
SG-4 × SG-3	8.84	-4.32	4.64	-8.45	-12.87	24.40
SG-4 × Pusa Chikni	29.62**	22.56**	1.64	-15.94	-18.54	5.07
SG-4 × KRCCH-2	-17.93*	-30.21**	-42.13**	3.62	-8.99	17.39
SG-4 × Swarna Prabha	-22.22**	-24.65**	-33.35**	-11.87	-15.39	18.60
SG-4 × KRCCH-1	43.79**	25.33**	3.93	47.07**	24.21*	60.22**
SG-6 × SG-5	-35.73**	-39.39**	-52.26**	-27.65**	-35.48**	13.77
SG-6 × SG-3	-13.06*	-25.22**	-18.21**	-0.18	-1.79	40.22*
SG-6 × Pusa Chikni	-32.36**	-34.45**	-48.36**	-7.18	-12.94	20.29
SG-6 × KRCCH-2	36.37**	18.49*	-6.67	-1.43	-15.91	16.18
SG-6 × Swarna Prabha	-1.85	-7.22	-17.94**	-9.57	-10.22	25.85
SG-6 × KRCCH-1	53.10**	36.46**	7.49	9.36	-10.14	24.15
SG-5 × SG-3	12.06	-8.20	0.40	-7.17	-16.00	48.12**
SG-5 × Pusa Chikni	33.85**	30.14**	-3.83	-25.59**	-37.26**	10.63
SG-5 × KRCCH-2	40.54**	28.76**	-10.11	-20.46*	-38.22**	8.94
SG-5 × Swarna Prabha	30.39**	16.65*	3.17	-41.54**	-47.53**	-7.49*
SG-5 × KRCCH-1	72.50**	62.41**	13.37**	-12.02	-33.84**	16.67
SG-3 × Pusa Chikni	12.23	-5.97	2.84	-15.03	-21.50	12.08
SG-3 × KRCCH-2	12.95	-13.52*	-5.42	-11.37	-25.39*	6.52
SG-3 × Swarna Prabha	6.47	-3.72	5.31	-11.05	-11.86	25.85
SG-3 × KRCCH-1	15.15*	-9.97	-1.54	-17.42	-33.01**	-4.35
Pusa Chikni × KRCCH-2	34.60**	20.21*	-11.16	15.36	4.19	26.09
Pusa Chikni × Swarna Prabha	13.14	3.84	-8.15	-11.40	-17.46	15.70
Pusa Chikni × KRCCH-1	29.64**	18.89*	-12.14	28.19*	11.18	34.54*
KRCCH-2 × Swarna Prabha	-19.92*	-33.66**	-41.32**	-10.60	-24.18*	6.28
KRCCH-2 × KRCCH-1	63.36**	58.67**	-2.19	55.70**	48.76**	45.17**
Swarna Prabha × KRCCH-1	-19.08*	-31.34**	-39.27**	-14.16	-29.86**	-1.69
S.Em±	10.903	12.589	12.589	1.896	2.189	2.189
C.D. @ 5%	22.133	25.558	25.558	3.848	4.444	4.444
C.D. @ 1%	28.705	33.146	33.146	4.991	5.763	5.763

*, ** Significant at 5% and 1% level, respectively MP, BP and SC represent heterosis values over mid, Better and standard parent/check, respectively.

Table 2: Estimation of heterosis for fruit yield per plant and number of seeds per fruit in sponge gourd

Cross	Fruit yield per plant			Number of seeds/fruit		
	MP	BP	SC	MP	BP	SC
Kulgod local × SG-4	11.18	2.83	1.32	0.46	-1.35	-10.33
Kulgod local × SG-6	-5.43	-5.83	-7.22	14.67	0.98	-8.21
Kulgod local × SG-5	0.50	-5.74	-7.13	-3.80	-13.73	-21.58
Kulgod local × SG-3	-24.06**	-41.14**	5.41	10.98	4.95	-4.60
Kulgod local × Pusa Chikni	90.16**	78.27**	100.74**	-21.69	-26.66	-33.33**
Kulgod local × KRCCH-2	-4.98	-9.83	-1.05	20.76	17.63	12.78
Kulgod local × Swarna Prabha	-31.71**	-46.40**	-7.31	2.40	-2.61	-11.47
Kulgod local × KRCCH-1	58.89**	47.17**	70.08**	-13.96	-19.71	-15.77
SG-4 × SG-6	10.53	2.63	0.27	-24.09	-32.07*	-40.48**
SG-4 × SG-5	16.91	15.17	-0.60	10.27	0.52	-11.92
SG-4 × SG-3	-17.73*	-39.63**	8.11	13.75	9.46	-4.08
SG-4 × Pusa Chikni	-0.86	-13.57	-2.68	11.62	6.35	-6.81
SG-4 × KRCCH-2	-16.65	-26.53*	-19.37	3.03	-1.40	-5.46
SG-4 × Swarna Prabha	-30.72**	-48.59**	-11.08	34.72**	30.40*	14.27
SG-4 × KRCCH-1	62.63**	40.23**	62.06**	-26.04*	-32.13**	-28.80*
SG-6 × SG-5	8.16	1.85	-0.49	18.82	16.40	-16.04
SG-6 × SG-3	2.32	-20.92**	41.60**	13.93	5.62	-14.43
SG-6 × Pusa Chikni	7.49	0.38	13.03	-5.00	-11.08	-29.44*
SG-6 × KRCCH-2	18.75	12.24	23.17	15.39	-0.66	-4.76
SG-6 × Swarna Prabha	-38.70**	-52.03**	-17.05	10.26	1.65	-16.64
SG-6 × KRCCH-1	8.28	-0.10	15.46	-34.13**	-45.34**	-42.66**
SG-5 × SG-3	47.04**	8.96	95.11**	-5.64	-10.81	-27.74*
SG-5 × Pusa Chikni	16.79	3.15	16.15	50.06**	43.23**	13.66*
SG-5 × KRCCH-2	11.11	-0.75	8.91	-10.32	-21.42	-24.66
SG-5 × Swarna Prabha	-23.94**	-42.99**	-1.41	34.30*	26.21	3.50
SG-5 × KRCCH-1	-3.30	-15.54	-2.39	-27.13*	-38.51**	-35.50**
SG-3 × Pusa Chikni	-33.71**	-46.01**	-3.33	15.74	14.56	-7.19

SG-3 × KRCCH-2	-47.30**	-57.50**	-23.91	20.79	11.43	6.84
SG-3 × Swarna Prabha	-36.56**	-37.64**	11.66	28.44*	27.66	4.70
SG-3 × KRCCH-1	-26.95**	-39.90**	7.62	18.65	5.14	10.30
Pusa Chikni × KRCCH-2	20.74*	19.21	34.23**	6.73	-2.47	-6.49
Pusa Chikni × Swarna Prabha	-13.76	-28.81**	23.12	15.19	13.33	-7.06
Pusa Chikni × KRCCH-1	-21.24*	-22.25*	-10.14	0.30	-11.92	-7.60
KRCCH-2 × Swarna Prabha	-37.11**	-48.60**	-11.10	14.44	6.17	1.79
KRCCH-2 × KRCCH-1	-12.88	-15.08	-1.85	4.33	-0.16	4.74
Swarna Prabha × KRCCH-1	-43.29**	-52.69**	-18.19	3.33	-7.94	-3.43
S.Em±	0.160	0.185	0.185	31.160	35.981	35.981
C.D. @ 5%	0.325	0.375	0.375	63.258	73.044	73.044
C.D. @ 1%	0.421	0.486	0.486	82.040	94.732	94.732

*, ** Significant at 5% and 1% level, respectively MP, BP and SC represent heterosis values over mid, better and standard parent/check, respectively.

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