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Studies on heterosis and Inbreeding depression in Sponge Gourd [*Luffa cylindrica* (Roem.) L.]

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Abstract
The present investigation was carried out to study the extent of heterosis and inbreeding depression through six generation mean analysis (P_1, P_2, F_1, F_2, B_1 and B_2 derived) of four crosses for yield and yield contributing character in sponge gourd [*Luffa cylindrica* (Roem.) L.]. The material was evaluated in a Compact Family Block Design with three replications at Main Vegetable Research Station Farm, Anand Agricultural University, Anand during *Kharif* 2021. The magnitude of heterosis revealed that, the cross combination ASGS 19-11 × Pusa Chikni showed positively heterosis over better and mid parent. The inbreeding depression were positively and negatively lower significant indicate that the presence of vigour in F_2.

Keywords: Generation mean, heterosis, inbreeding depression, sponge gourd

Introduction
Sponge gourd [*Luffa cylindrica* (Roem.) L.] is an important cucurbitaceous vegetable crop and it is a highly cross pollinated crop can be grown both as *Kharif* and summer seasons vegetable which are grown throughout the year except extreme winter. Genus Luffa which belongs to Cucurbitaceae family is a tropical or sub tropical vine. Luffa cylindrica is a diploid with 26 chromosomes (2n=26) commonly called as ghia tori, smooth luffa, sponge gourd, loofa, vegetable sponge, bath sponge or dishcloth gourd, climbingokra and chinese okra. Luffa has nine species out of which *Luffa acutangula* (L.) Roxb., *L. cylindrica* (Roem.) L., *L. echinta* Roxb., *L. graveolens*, *L. tuberose* Roxb., *L. umbellata* are found in India. *Luffa acutangula* (ridge gourd) and *Luffa cylindrica* (sponge gourd) are grown throughout India in tropical and subtropical climate. In Gujarat area under cucurbits are about 0.91 lakh ha having annual production of 14.38 lakh tones (Anon, 2019) [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. The hybrids give higher yield than the varieties due to the presence of hybrid vigour (heterosis) for fruit yield and yield components. Therefore, the estimation of heterosis and inbreeding depression is of immense importance for the development of hybrids in sponge gourd.

Material and Method
Plant Material
Crosses *viz.*, Pusa Sneha × ASGS 19-01, Pusa Sneha × ASGS 19-04, ASGS 19-07 × ASGS 19 12 and ASGS 19-11 × Pusa Chikni were made between seven parents by manual emasculation and pollen transfer. F_1 plants were selfed to obtain seed for the F_2 generation and backcrossed with their respective parents to generate B_1 and B_2 generations. Thus, a total of six generations were obtained.

Field trial
The six basic generations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2 of each of the four families were raised in a compact family block design with three replications during Kharif 2021. Each replication was divided into four compact blocks each consists of single family and blocks were consisted of six plots comprised of six basic generations of each family. The families were assigned to each block and six generations of a family were randomly alloted to individual plot within the block. The plots of various generations were sown in different number of rows i.e., parents and

F_1 in two row; B_1 and B_2 in four rows and F_2 in eight rows. Each row was 5.0 m long with 2.0 m and 1.0 m inter and intra row spacing, respectively. The each row accommodated five plants. All the recommended agronomical practices and necessary plant protection measures were followed timely to raise a good crop. The observation were recorded for Days to first staminate flower appearance, Days to first pistillate flower appearance, Node number of first female flower, Fruit length (cm), Fruit girth (cm), Fruit weight (g), Fruits per plant, Primary branches per plant, Fruit yield per plant (kg), Moisture content (%), Total phenols (mg/100g), Total soluble sugars (%), Total soluble solids (°Brix), Total acidity (%), Total chlorophyll content (mg/100g), Total antioxidant activity (mg/100g), Total flavonoids (mg/100g) and Total fiber (%).

Result and Discussion

Analysis of variance for yield and yield component showed highly significant differences among the genotypes which indicated that the presence of substantial variability in the material under study and possibility of selection for fruit yield traits in sponge gourd. In the present study, the value of heterosis expressed as percentage increase or decrease over better and mid parent. The data for heterosis over better and mid parent are presented in (Table.1).

Table 1: Magnitude of Heterosis and inbreeding depression (%) for different characters in four crosses of sponge gourd

Crosses	Percent heterosis over		Inbreeding Depression%	Component of heterosis			
	MP%	BP%		(h)	(-i)	(-d)	$\frac{1}{2}$j
Days to first staminate flower appearance							
I	8.87**	6.41**	0.33	5.17**	-2.73	1.03*	-0.84**
II	2.32	1.15	-5.78**	-4.80**	5.47**	0.73	-0.20
III	-1.80	-3.75**	-5.96**	-1.33	0.80	0.93	-0.165
IV	-0.57	-1.35	-6.91**	-7.30**	7.13**	0.40	-0.085
Days to first pistillate flower appearance							
I	6.80**	4.43**	-2.95**	0.70	1.60	1.20**	-0.985**
II	1.13	-1.10	-3.12*	-2.87*	3.27*	0.73	0.035
III	-1.39	-3.28*	-4.71**	-0.10	-0.40	0.67	0.015
IV	-1.97*	-2.79*	-7.76**	-7.37**	6.67**	0.33	-0.015
Node number of first female flower							
I	7.08	-1.53	-1.56	1.67	-0.53	0.27	0.565
II	4.72	0.38	1.50	-	-	-	-
III	3.85	-1.92	-5.66	3.30	-2.67	-1.27	1.115**
IV	4.58	4.21	6.14*	7.20	-6.33**	-0.07	0.00
Fruit length							
I	6.70	3.39	-1.63	-17.32**	19.00**	1.55**	-0.375
II	32.01**	23.81**	18.19**	-	-	-	-
III	4.60	3.35	-26.83**	-28.13**	29.39**	4.93**	-2.30**
IV	26.56**	25.34**	-6.47	-8.81*	15.90**	1.59	-0.93
Fruit girth							
I	-14.48**	-18.41**	-7.19*	-	-	-	-
II	7.91*	0.67	1.90	-2.32*	3.27**	-1.06**	0.965**
III	-11.17**	-13.45**	-3.10	2.74*	-4.12**	-0.81*	0.57*
IV	-2.37	-4.63	10.88**	2.56*	-2.85**	-0.33	0.02
Fruit weight							
I	-22.94**	-26.20**	-14.40**	-	-	-	-
II	14.97	-1.34	6.23	-	-	-	-
III	-17.81**	-19.29**	-25.60**	0.30	-29.13	-11.70	4.365
IV	9.05	-0.20	7.22	-	-	-	-
Crosses	Percent heterosis over		Inbreeding Depression%	Component of heterosis			
	MP%	BP%		(h)	(-i)	(-d)	$\frac{1}{2}$j
Fruits per plant							
I	-4.20*	-7.69**	1.54	-	-	-	-
II	0.82	-3.53	6.50**	3.00	-2.87	-1.63**	1.185**
III	6.67**	3.82*	14.71**	8.27**	-7.13**	0.10	-0.235
IV	0.88	-5.59**	11.76**	2.63	-2.47	-0.20	0.75*
Primary branches per plant							
I	0.81	-3.13	5.24	2.57**	-2.53**	-1.03**	0.435*
II	3.28	-1.56	7.54	2.93**	-2.80**	-0.90**	0.35
III	-1.52	-8.45	6.54	2.07*	-2.13*	0.97**	-0.65**
IV	0.81	-3.12	-17.74	-	-	-	-
Fruit yield per plant							
I	-27.56**	-28.80**	-13.23**	-	-	-	-
II	14.59	-5.26	11.71	0.27	0.06	-0.29	0.385**
III	-14.41**	-16.02**	-7.59	1.31*	-1.72**	-0.16	0.055
IV	10.94	8.26	18.15**	1.79**	-1.47**	-0.17	0.050
Moisture content							

I	-0.10	-1.05**	-1.08**	-4.05**	3.96**	-0.12	0.51**
II	-0.61**	-1.04**	3.39**	12.17**	-12.75**	-0.04	-0.19**
III	0.20*	-0.02	0.64**	0.33	-0.14	0.04	0.085
IV	-0.33**	-0.42*	-0.50**	-1.45**	1.14**	0.34	-0.205
Total phenols							
I	-3.20**	-7.73**	-4.81**	3.52**	-4.00**	-0.01	-0.36*
II	-0.43	-9.62**	0.49	-1.49	1.43	-1.11**	0.225*
III	2.91**	-1.64	12.03**	5.03**	-4.60**	-0.28	0.485*
IV	-1.76	-6.38**	0.53	8.07**	-8.35**	1.10*	-0.165
Total soluble sugars							
I	2.28**	-4.52**	5.32**	0.34**	-0.30**	0.01	0.015
II	0.23	-0.76	3.52*	0.52**	-0.51**	-0.06	0.025
III	-0.89	-4.80**	6.53**	0.48**	-0.49**	-0.20**	0.075**
IV	4.94**	-7.46**	1.08	-0.30*	0.38**	-0.05	-0.075**
Crosses	Percent heterosis over		Inbreeding Depression%	Component of heterosis			
	MP%	BP%		(h)	(-i)	(-d)	$\frac{1}{2}$j
Total soluble solids							
I	-0.29	-1.27*	-0.39	-	-	-	-
II	-0.29	-1.27*	-0.29	-0.09	0.073	0.07	-0.06**
III	-0.22	-1.14*	-0.47	-0.10	0.09	0.08*	-0.06**
IV	0.14	-0.85	-0.54	-0.10	0.11	-0.09*	0.07**
Total acidity							
I	1.75	-4.06	1.18	0.03**	-0.03**	0.001	0.005**
II	0.89	-5.37**	1.53	0.03**	-0.03**	0.001	0.005**
III	1.22	0.56	-1.23	0.02**	-0.02*	-0.001	0.00
IV	2.48*	-4.68**	1.31	-0.02*	0.02**	-0.02**	0.002
Total chlorophyll content							
I	-20.24**	-26.30**	-20.14**	2.30**	-2.95**	-0.23**	0.245**
II	25.63**	6.66**	10.83**	1.27**	-0.35	-0.62**	0.625**
III	2.76**	2.55**	-5.69*	2.43**	-2.33**	0.09	-0.04
IV	16.37**	11.11**	3.54	2.34**	-1.63**	0.45*	-0.12
Total antioxidant activity							
I	23.99**	20.68**	14.40**	-15.13**	30.64**	-6.91**	2.57*
II	-5.77**	-9.39**	-33.73**	-68.94**	64.88**	-6.58**	4.695**
III	-1.71**	-3.84**	-4.73**	2.68	-4.08	0.71	-1.26**
IV	-2.31**	-3.89**	20.32**	63.17**	-65.23**	-1.52	0.035
Total flavonoids							
I	7.14**	5.64**	4.80**	0.06	1.10	1.13**	-0.68**
II	-2.58	-3.42**	-22.10**	-12.42**	12.00**	1.08**	-0.615**
III	1.21	-2.23*	4.03**	5.82**	-5.57**	0.42	0.155
IV	12.25**	12.17**	31.36**	27.39**	-24.86**	3.00**	-1.51**
Total fiber							
I	-0.73**	-1.14**	0.69**	0.12	-0.20**	-0.03**	-0.005*
II	-0.20**	-0.23**	0.27	-	-	-	-
III	1.70**	0.92**	1.19**	0.03	0.14**	0.16**	-0.045**
IV	1.45**	0.82**	0.93**	-0.17*	0.31**	0.12**	-0.03**

*, ** Significant at 5% and 1% level of significance, respectively.
Where, I = Pusa Sneha × ASGS 19-01
II = Pusa Sneha × ASGS 19-04
III = ASGS 19-07 × ASGS 19-12
IV = ASGS 19-11 × Pusa Chikni

Days to first staminate flower appearance

The estimates of relative heterosis ranged from -1.80 (ASGS 19-07 × ASGS 19-12) to 8.87% (Pusa Sneha × ASGS 19-01). Significant positive relatives heterosis was observed in Pusa Sneha × ASGS 19-01 (8.87%) for days to first staminate flower appearance. For heterobeltiosis, the estimates ranged from -3.75 (ASGS 19-07 × ASGS 19-12) to 6.41% (Pusa Sneha × ASGS 19-01). The cross ASGS 19-07 × ASGS 19-12 depicted significant negative heterobeltiosis for this trait, while cross Pusa Sneha × ASGS 19-01 showed significant positive heterobeltiosis (6.41%) for this trait. The estimates of inbreeding depression varied from -6.91 (ASGS 19-11 × Pusa Chikni) to 0.33 6.41% (Pusa Sneha × ASGS 19-01). All the crosses showed significant negative estimates of inbreeding depression except for cross Pusa Sneha × ASGS 19-01, indicated late flowering in F_2 population in comparison to F_1 generations. Similar result were also obtained by Sonavale *et al*. (2013) [8] for relative heterosis. While, similar results for heterobeltiosis were reported by Sonavale *et al*. (2013) [8], Chauhan *et al*. (2019) [2] and Lakhnotra *et al*. (2019) [5]. This result of inbreeding depression is in line with the report of Dhumal *et al*. (2019) [4] in ridge gourd.

Days to first pistillate flower appearance

The estimates of relative heterosis ranged from -1.97 (ASGS 19-11 × Pusa Chikni) to 6.80% (Pusa Sneha × ASGS 19-01). Significant positive relatives heterosis was observed in cross Pusa Sneha × ASGS 19-01 (6.80%), while cross ASGS 19-11

× Pusa Chikni (-1.97%) had significant negative relatives heterosis was observed for this trait. The values of heterosis over better parent ranged from -3.28 (ASGS 19-07 × ASGS 19-12) to 4.43% (Pusa Sneha × ASGS 19-01). Cross ASGS 19-07 × ASGS 19-12 (-3.28%) and cross ASGS 19-11 × Pusa Chikni (-2.79%) exhibited significant negative heterobeltiosis, while cross Pusa Sneha × ASGS 19-01 (4.43%) displayed significant positive heterobeltiosis. The estimates of inbreeding depression varied from -7.76 (ASGS 19-11 × Pusa Chikni) to -2.95% (Pusa Sneha × ASGS 19-01). All the crosses showed significant negative estimates of inbreeding depression. The present results are agreement with the finding of Sonavale *et al*. (2013) [8], Chauhan *et al*. (2019) [2] and Reddy *et al*. (2019) [6] for relative heterosis, and with the finding of Sonavale *et al*. (2013) [8], Chauhan *et al*. (2019) [2], Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5] for heterobeltiosis.

Node number of first female flower

The estimates of relative heterosis in four crosses ranged from 3.85 (ASGS 19-07 × ASGS 19-12) to 7.08% (Pusa Sneha × ASGS 19-01). For heterobeltiosis, the estimates ranged from -1.92 (ASGS 19-07 × ASGS 19-12) to 4.21% (ASGS 19-11 × Pusa Chikni) for this trait. The estimates of inbreeding depression observed in F2 generations ranged from -5.66 (ASGS 19-07 × ASGS 19-12) to 6.14% (ASGS 19-11 × Pusa Chikni). Crosses ASGS 19-11 × Pusa Chikni exhibited significant positive inbreeding depression. The present finding are in concurrence with the results of Reddy *et al*. (2019) [6] who reported relative heterosis. While, similar result for heterobeltiosis were reported by Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5].

Fruit length

The estimates of relative heterosis ranged from 4.60 (ASGS 19-07 × ASGS 19-12) to 32.01% (Pusa Sneha × ASGS 19-04). Significant positive relatives heterosis was observed in two crosses *viz*., cross Pusa Sneha × ASGS 19-04 (32.01%) and cross ASGS 19-11 × Pusa Chikni (26.56%), while cross Pusa Sneha × ASGS 19-01 (6.70%) and cross ASGS 19-07 × ASGS 19-12 (4.60%) had non-significant positive estimate of relative heterosis. Positive and significant heterobeltiosis was exhibited by the crosses Pusa Sneha × ASGS 19-04 (23.81%) and ASGS 19-11 × Pusa Chikni (25.45%) which is most desirable for such trait. Whereas, cross Pusa Sneha × ASGS 19-01 (3.39%) and ASGS 19-07 × ASGS 19-12 (3.35%) depicted non-significant positive heterobeltiosis. The estimates of inbreeding depression observed in F2 generations ranged from -26.83 (ASGS 19-07 × ASGS 19-12) to 18.19% (Pusa Sneha × ASGS 19-04). Crosses Pusa Sneha × ASGS 19-04 (18.19%) depicted significant positive inbreeding depression, while Crosses ASGS 19-07 × ASGS 19-12 (-26.83%) exhibited significant negative inbreeding depression. The similar results reported by Chauhan *et al*. (2019) [2] and Reddy *et al*. (2019) [6] for relative heterosis. While Chauhan *et al*. (2019) [2], Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5] have similar results for heterobetiosis. This result of inbreeding depression is in line with the report of Dhumal *et al*. (2019) [4] in ridge gourd.

Fruit girth

The minimum and maximum values of relative heterosis were -14.48 (Pusa Sneha × ASGS 19-01) and 7.91% (Pusa Sneha × ASGS 19-04), respectively. Two crosses *viz*., cross Pusa Sneha × ASGS 19-01 (-14.48%) and cross ASGS 19-07 × ASGS 19-12 (-11.17%). exhibited significant negative relative heterosis, while crosses Pusa Sneha × ASGS 19-04 (7.91%) displayed significant positive relative heterosis for fruit girth. Heterobeltiosis ranged from -18.41 (Pusa Sneha × ASGS 19-01) to 0.67% (Pusa Sneha × ASGS 19-04). Out of four crosses, cross Pusa Sneha × ASGS 19-01 (-18.41%) and cross ASGS 19-07 × ASGS 19-12 (-13.45%) depicted significant negative heterobeltiosis, whereas cross Pusa Sneha × ASGS 19-04 (0.67%) showed significant positive heterobeltiosis. The significant negative heterobeltiosis in cross Pusa Sneha × ASGS 19-01and cross ASGS 19-07 × ASGS 19-12 denoted the drastic reduction of fruit girth in F_1 generation over their respective better parent value. The estimates of inbreeding depression ranged from -7.19 (Pusa Sneha × ASGS 19-01) to 10.88% (ASGS 19-11 × Pusa Chikni) per cent. Cross Pusa Sneha × ASGS 19-01 (-7.19%) depicted significant negative inbreeding depression, while crosses ASGS 19-11 × Pusa Chikni (10.88%) displayed significant positive inbreeding depression for fruit girth. For heterobeltiosis, similar results were obtained by Lakhnotra *et al*. (2019) [5]. The above result is in conformity with the finding of Dhumal *et al*. (2019) [4] in ridge gourd.

Fruit weight

The estimates of relative heterosis in different crosses varied from -22.94 (Pusa Sneha × ASGS 19-01) to 14.97% (Pusa Sneha × ASGS 19-04). Cross Pusa Sneha × ASGS 19-01 (-22.94%) and cross ASGS 19-07 × ASGS 19-12 (-17.81%) exhibited significant negative heterotic effects. The estimates of heterobeltiosis observed for the character ranged from -26.20 (Pusa Sneha × ASGS 19-01) to -0.20% (ASGS 19-11 × Pusa Chikni). Out of four crosses, cross Pusa Sneha × ASGS 19-01 (-26.20%) and cross ASGS 19-07 × ASGS 19-12 (-19.29%) depicted significant negative heterobeltiosis effect. The estimates of inbreeding depression varied from -25.60 (ASGS 19-07 × ASGS 19-12) to 7.22% (ASGS 19-11 × Pusa Chikni). Significant negative estimates for inbreeding depression were observed in crosses Pusa Sneha × ASGS 19-01 (-14.40%) and cross ASGS 19-07 × ASGS 19-12 (-25.60%). Similar results were also obtained by Reddy *et al*. (2019) [6] for relative heterosis. While, similar results for heterobeltiosis were reported by Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5]. This result of inbreeding depression is in line with the report of Dhumal *et al*. (2019) [4] in ridge gourd.

Fruits per plant

The fruits per plant directly related with the fruit yield, hence higher fruits per plant is desirable. The estimates of relative heterosis ranged from -4.20 (Pusa Sneha × ASGS 19-01) to 6.67% (ASGS 19-07 × ASGS 19-12). Significant positive relatives heterosis was observed in cross ASGS 19-07 × ASGS 19-12 (6.67%), while cross Pusa Sneha × ASGS 19-01 (-4.20%) had significant negative relatives heterosis was observed in fruits per plant. The values of heterosis over better parent ranged from -7.69 (Pusa Sneha × ASGS 19-01) to 3.82% (ASGS 19-07 × ASGS 19-12). All the crosses, except cross ASGS 19-07 × ASGS 19-12, depicted negative heterobeltiosis and crosses Pusa Sneha × ASGS 19-01 (-7.69%), ASGS 19-07 × ASGS 19-12 (3.82%) and ASGS 19-11 × Pusa Chikni (-5.59%) had significant estimates for

heterobeltiosis. The minimum and maximum values of inbreeding depression were observed with Pusa Sneha × ASGS 19-01 (1.54%) and ASGS 19-07 × ASGS 19-12 (14.71%) respectively. The rest of crosses also exhibited significant positive inbreeding depression which is not desired for the said character. The present results are agreement with the finding of Reddy *et al*. (2019) [6] for relative heterosis. While, similar results for heterobeltiosis were reported by Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5]. The above result is in conformity with the finding of Dhumal *et al*. (2019) [4] in ridge gourd.

Primary branches per plant

The estimates of relative heterosis in four crosses ranged from -1.52 (ASGS 19-07 × ASGS 19-12) to 3.28% (Pusa Sneha × ASGS 19-04). All the crosses showed non-significant relative heterosis. The estimates of heterobeltiosis varied from -8.45 (ASGS 19-07 × ASGS 19-12) to -1.56% (Pusa Sneha × ASGS 19-04). The estimates of inbreeding depression ranged from -17.74 (ASGS 19-11 × Pusa Chikni) to 7.54% (Pusa Sneha × ASGS 19-04). All the crosses except cross ASGS 19-11 × Pusa Chikni showed positive estimates of inbreeding depression.

Similar results were also obtained by Reddy *et al*. (2019) [6] for relative heterosis. While, similar results for heterobeltiosis were reported by Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5].

Fruit yield per plant

For fruit yield per plant estimates of various heterotic effects were low to moderate. The estimates of relative heterosis varied from -27.56 (Pusa Sneha × ASGS 19-01) to 14.59% (Pusa Sneha × ASGS 19-04). Significant negative relative heterosis observed in cross Pusa Sneha × ASGS 19-01 (-27.56%), cross ASGS 19-07 × ASGS 19-12 (-14.41%), while cross Pusa Sneha × ASGS 19-04 (14.59%) and cross ASGS 19-11 × Pusa Chikni (10.94%) had non-significant positive estimate of relative heterosis. The minimum and maximum values of heterobeltiosis were -28.80 (Pusa Sneha × ASGS 19-01) and 8.26% (ASGS 19-11 × Pusa Chikni), respectively. Significant negative heterobeltiosis was observed in crosses Pusa Sneha × ASGS 19-01 (-28.80%), ASGS 19-07 × ASGS 19-12 (-16.02%). For cross ASGS 19-11 × Pusa Chikni, heterobeltiosis was positive and non-significant. The estimates of inbreeding depression observed in F_2 generations ranged from -13.23 (Pusa Sneha × ASGS 19-01) to 18.15% (ASGS 19-11 × Pusa Chikni). Crosses Pusa Sneha × ASGS 19-01 (-13.23%) exhibited significant negative inbreeding depression, while crosses ASGS 19-11 × Pusa Chikni (18.15%) depicted significant positive inbreeding depression. The results are in harmony with the finding of Sanandia *et al*. (2008), Sonavane *et al*. (2013) [8], Reddy *et al*. (2019) [6] and Lakhnotra *et al*. (2019) [5] for relative heterosis and heterobeltiosis. This result of inbreeding depression is in line with the report of Dhumal *et al*. (2019) [4] in ridge gourd.

Moisture content

The estimates of relative heterosis in four crosses ranged from -0.61 (Pusa Sneha × ASGS 19-04) to 0.20% (ASGS 19-07 × ASGS 19-12). Cross Pusa Sneha × ASGS 19-04 (-0.61%) and cross ASGS 19-11 × Pusa Chikni (-0.33%) exhibited significant negative relative heterosis for this character. The estimates of heterobeltiosis varied from -1.05 (Pusa Sneha × ASGS 19-01) to -0.02% (ASGS 19-07 × ASGS 19-12). Significant negative estimates of heterobeltiosis were observed in all crosses except for cross ASGS 19-07 × ASGS 19-12. The estimates of inbreeding depression observed in F2 generations ranged from -1.08 (Pusa Sneha × ASGS 19-01) to 3.39% (Pusa Sneha × ASGS 19-04). Crosses Pusa Sneha × ASGS 19-01 (-1.08%) and ASGS 19-11 × Pusa Chikni (-0.50%) exhibited significant negative inbreeding depression, while crosses Pusa Sneha × ASGS 19-04 (3.39%) and ASGS 19-07 × ASGS 19-12 (0.64%) depicted significant positive inbreeding depression.

Total phenols

The estimates of relative heterosis ranged from -3.20 (Pusa Sneha × ASGS 19-01) to 2.91% (ASGS 19-07 × ASGS 19-12). Significant positive relatives heterosis was observed in cross ASGS 19-07 × ASGS 19-12 (2.91%), while cross Pusa Sneha × ASGS 19-01 (-3.20%) had significant negative relatives heterosis was observed in total phenols. Heterobeltiosis ranged from -9.62 (Pusa Sneha × ASGS 19-04) to -1.64% (ASGS 19-07 × ASGS 19-12). Out of four crosses, cross Pusa Sneha × ASGS 19-01 (-7.73%), cross Pusa Sneha × ASGS 19-04 (-9.62%) and cross ASGS 19-11 × Pusa Chikni (-6.38%) depicted significant negative heterobeltiosis, whereas cross ASGS 19-07 × ASGS 19-12 (-1.64%) showed non-significant negative heterobeltiosis. The estimates of inbreeding depression observed in F_2 generations ranged from -4.81 (Pusa Sneha × ASGS 19-01) to 12.03% (ASGS 19-07 × ASGS 19-12). Crosses ASGS 19-07 × ASGS 19-12 (12.03%) depicted significant positive inbreeding depression, while Crosses Pusa Sneha × ASGS 19-01 (-4.81%) exhibited significant negative inbreeding depression.

Total soluble sugars

The minimum and maximum values of relative heterosis were -0.89 (ASGS 19-07 × ASGS 19-12) and 4.94% (ASGS 19-11 × Pusa Chikni), respectively. Two crosses *viz*., cross Pusa Sneha × ASGS 19-01 (2.28%) and cross ASGS 19-11 × Pusa Chikni (4.94%) exhibited significant positive relative heterosis. For this character, heterobeltiosis varied from -7.46 (ASGS 19-11 × Pusa Chikni) to -0.76% (Pusa Sneha × ASGS 19-04). Out of four crosses, cross Pusa Sneha × ASGS 19-01 (-4.52%), cross ASGS 19-07 × ASGS 19-12 (-4.80%) and cross ASGS 19-11 × Pusa Chikni (-7.46%) depicted significant negative heterobeltiosis, whereas cross Pusa Sneha × ASGS 19-04 (-0.79%) showed non-significant negative heterobeltiosis. The estimates of inbreeding depression varied from 1.08 (ASGS 19-11 × Pusa Chikni) to 6.53% (ASGS 19-07 × ASGS 19-12). Significant positive estimates for inbreeding depression were observed in all crosses except cross ASGS 19-11 × Pusa Chikni showed non-significant positive heterobeltiosis. For relative heterosis and heterobeltiosis, similar results were obtained by Chittora *et al*. (2018) in ridge gourd.

Total Soluble Solids

For this character, relative heterosis ranged from -0.29 (Pusa Sneha × ASGS 19-01 and Pusa Sneha × ASGS 19-04) to 0.14% (ASGS 19-11 × Pusa Chikni). Non-significant negative relative heterosis was observed for all crosses except cross ASGS 19-11 × Pusa Chikni (0.14%). The estimates of heterobeltiosis observed for the character ranged from -1.27 (Pusa Sneha × ASGS 19-01 and Pusa Sneha × ASGS 19-04)

to -0.85% (ASGS 19-11 × Pusa Chikni). Out of four crosses, cross Pusa Sneha × ASGS 19-01 (-1.27%) cross Pusa Sneha × ASGS 19-04 (-1.27%) and cross ASGS 19-07 × ASGS 19-12 (-1.14%) depicted significant negative heterobeltiosis effect. For total soluble solids, the values of inbreeding depression ranged from -0.54 (ASGS 19-11 × Pusa Chikni) to -0.29% (Pusa Sneha × ASGS 19-04). Negative inbreeding depression was observed in all four crosses for total soluble solids. For relative heterosis and heterobeltiosis, similar results were obtained by Reddy *et al*. (2019) [6].

Total acidity

Relative heterosis ranged from 0.89 (Pusa Sneha × ASGS 19-04) to 2.48% (ASGS 19-11 × Pusa Chikni). Crosses Pusa Sneha × ASGS 19-01, Pusa Sneha × ASGS 19-04 and ASGS 19-07 × ASGS 19-12 showed non-significant positive relative heterosis were cross ASGS 19-11 × Pusa Chikni indicated significant positive heterosis for total acidity. Heterobeltiosis ranged from -5.37 (Pusa Sneha × ASGS 19-04) to 0.56% (ASGS 19-07 × ASGS 19-12). Out of four crosses, cross Pusa Sneha × ASGS 19-04 (-5.37%) and cross ASGS 19-11 × Pusa Chikni (-4.68%) depicted significant negative heterobeltiosis. The estimates of inbreeding depression ranged from -1.23 (ASGS 19-07 × ASGS 19-12) to 1.53% (Pusa Sneha × ASGS 19-04). All the crosses except cross ASGS 19-07 × ASGS 19-12 showed positive estimates of inbreeding depression.

Total chlorophyll content

The minimum and maximum values of relative heterosis were -20.24 (Pusa Sneha × ASGS 19-01) and 25.63% (Pusa Sneha × ASGS 19-04), respectively. Three crosses *viz*., cross Pusa Sneha × ASGS 19-04 (25.63%), cross ASGS 19-07 × ASGS 19-12 (2.76%) and cross ASGS 19-11 × Pusa Chikni (16.37%) exhibited significant positive relative heterosis, while crosses Pusa Sneha × ASGS 19-01 (-20.24%) displayed significant negative relative heterosis for total chlorophyll content. The estimates of Heterobeltiosis ranged from -26.30 (Pusa Sneha × ASGS 19-01) to 11.11% (ASGS 19-11 × Pusa Chikni). Cross Pusa Sneha × ASGS 19-04 (6.66%), cross ASGS 19-07 × ASGS 19-12 (2.55%) and cross ASGS 19-11 × Pusa Chikni (11.11%) exhibited significant positive heterobeltiosis, while Pusa Sneha × ASGS 19-01 (-26.30%) displayed significant negative heterobeltiosis. The estimates of inbreeding depression observed in F_2 generations ranged from -20.14 (Pusa Sneha × ASGS 19-01) to 10.83% (Pusa Sneha × ASGS 19-04). Crosses Pusa Sneha × ASGS 19-01 (-20.14%) and ASGS 19-07 × ASGS 19-12 (-5.69%) exhibited significant negative inbreeding depression, while cross Pusa Sneha × ASGS 19-04 (10.83%) depicted significant positive inbreeding depression.

Total antioxidant activity

The values of relative heterosis varied from -5.77 (Pusa Sneha × ASGS 19-04) to 23.99% (Pusa Sneha × ASGS 19-01). Three crosses *viz*., cross Pusa Sneha × ASGS 19-04 (-5.77%), cross ASGS 19-07 × ASGS 19-12 (-1.71%) and cross ASGS 19-11 × Pusa Chikni (-2.31%) exhibited significant negative relative heterosis, while crosses Pusa Sneha × ASGS 19-01 (23.99%) displayed significant positive relative heterosis for total antioxidant activity. The values of heterosis over better parent ranged from -9.39 (Pusa Sneha × ASGS 19-04) to 20.68% (Pusa Sneha × ASGS 19-01). Cross Pusa Sneha × ASGS 19-04 (-9.39%), cross ASGS 19-07 × ASGS 19-12 (-3.84%) and cross ASGS 19-11 × Pusa Chikni (-3.89%) exhibited significant negative heterobeltiosis, while cross Pusa Sneha × ASGS 19-01 (20.68%) displayed significant positive heterobeltiosis. The estimates of inbreeding depression observed in F_2 generations ranged from -33.73 (Pusa Sneha × ASGS 19-04) to 20.32% (ASGS 19-11 × Pusa Chikni). Crosses Pusa Sneha × ASGS 19-01 (14.40%) and ASGS 19-11 × Pusa Chikni (20.32%) exhibited significant positive inbreeding depression, while crosses Pusa Sneha × ASGS 19-04 (-33.73%) and ASGS 19-07 × ASGS 19-12 (-4.73%) depicted significant negative inbreeding depression.

Total flavonoids

The estimates of relative heterosis ranged from -2.58 (Pusa Sneha × ASGS 19-04) to 12.25% (ASGS 19-11 × Pusa Chikni). Significant positive relative heterosis was observed in two crosses *viz*., cross Pusa Sneha × ASGS 19-01 (7.14%) and cross ASGS 19-11 × Pusa Chikni (12.25%), while cross Pusa Sneha × ASGS 19-04 (-2.58%) and cross ASGS 19-07 × ASGS 19-12 (1.21%) had non-significant estimate of relative heterosis. The estimates of heterobeltiosis ranged from -3.42 (Pusa Sneha × ASGS 19-04) to 12.17% (ASGS 19-11 × Pusa Chikni). Cross Pusa Sneha × ASGS 19-04 (5.64%) and cross ASGS 19-11 × Pusa Chikni (12.17%) exhibited significant positive heterobeltiosis, while cross Pusa Sneha × ASGS 19-04 (-3.42%) and cross ASGS 19-07 × ASGS 19-12 (-2.23%) displayed significant negative heterobeltiosis. The estimates of inbreeding depression varied from -22.10 (Pusa Sneha × ASGS 19-04) to 31.36% (ASGS 19-11 × Pusa Chikni). All the crosses showed significant positive estimates of inbreeding depression except for cross Pusa Sneha × ASGS 19-04 depicted significant negative inbreeding depression.

Total fiber

The minimum and maximum values of relative heterosis were -0.73 (Pusa Sneha × ASGS 19-01) and 1.70% (ASGS 19-07 × ASGS 19-12). Two crosses *viz*., cross ASGS 19-07 × ASGS 19-12 (1.70%) and cross ASGS 19-11 × Pusa Chikni (1.45%) exhibited significant positive relative heterosis, while crosses Pusa Sneha × ASGS 19-01 (-0.73%) and Pusa Sneha × ASGS 19-04 (-0.20%) displayed significant negative relative heterosis for total fiber. For this character, heterobeltiosis varied from -1.14 (Pusa Sneha × ASGS 19-01) to 0.92% (ASGS 19-07 × ASGS 19-12). Cross ASGS 19-07 × ASGS 19-12 (0.92%) and cross ASGS 19-11 × Pusa Chikni (0.82%) exhibited significant positive heterobeltiosis, while crosses Pusa Sneha × ASGS 19-01 (-1.14%) and Pusa Sneha × ASGS 19-04 (-0.23%) displayed significant negative heterobeltiosis. The estimates of inbreeding depression ranged from 0.69 (Pusa Sneha × ASGS 19-01) to 1.19% (ASGS 19-07 × ASGS 19-12). All the crosses showed significant positive estimates of inbreeding depression except cross Pusa Sneha × ASGS 19-04 (0.27%).

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