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Studies on Heterosis in Brinjal (*Solanum melongena* L.)

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A B S T R A C T

The present investigation was conducted to find out the heterosis in brinjal. The yield and yield attributing characters, viz. days to 50% flowering, number of primary branches plant^{-1}, plant height, fruit length, fruit diameter, number of marketable fruits plant^{-1}, weight of marketable fruits plant^{-1}, number of unmarketable fruits plant^{-1}, weight of unmarketable fruits plant^{-1}, total number of fruits plant^{-1}, total yield plant^{-1} and total yield ha^{-1} were worked out through line x tester analysis involving ten lines and three testers. All the thirty hybrids with their parents were grown in RBD with three replications at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar during 2013-14 and 2014-15 and pooled analysis was carried out for relative heterosis, heterobeltiosis and economic heterosis. For days to 50% flowering, maximum negative relative heterosis, heterobeltiosis and economic heterosis were shown by BB85 x Pant Samrat, BRLVAR 6 x DBL02 and PB 71 x DBL02, respectively. For total number of fruits plant^{-1}, high magnitude of relative heterosis and heterobeltiosis were shown by Swarn Syamli x Pant Rituraj and economic heterosis was shown by the PB 66 x Pant Samrat. For total yield plant^{-1}, high magnitude of relative heterosis and heterobeltiosis were shown by IBWL 2001-1 x Pant Rituraj and maximum economic heterosis was shown by SMB115 x DBL02. As regards to economic heterosis, the hybrids SMB115 x DBL02, PB 66 x Pant Samrat and IBWL 2001-1 x Pant Rituraj were observed as promising hybrids for different yield characters and can be exploited as commercial hybrids.

Keywords

Brinjal, Economic heterosis, Heterosis, Heterobeltiosis.

Article Info

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Introduction

Brinjal (*Solanum melongena* L) is an important vegetable crop of India and is grown throughout the year. However, it is widely cultivated in both temperate and tropical regions of the globe mainly for its immature fruits as vegetables (Rai *et al.*, 1995). Globally, India is the largest producer of vegetables and ranks second in production of brinjal or eggplant. However, the present production and productivity of eggplant is not enough to meet the nutritional security of increasing population. Additionally, there are also regional preferences for fruit shape, size, taste, colour etc as these traits vary significantly with the type of eggplant cultivar. The fruits of eggplant are widely consumed in various culinary preparations and are rich source of protective nutrients (Hedges and Lister, 2007). Eggplant contains a higher content of free reducing sugars, anthocyanin, phenols, glycoalkaloids (solasodine) and amide proteins. Bitterness in eggplant is due to the presence of saponins and glycoalkaloids (Mariola *et al.*, 2013).

Eggplant is well known for its medicinal properties and has also been recommended as an excellent remedy for liver complaints and diabetic patients (Tiwari *et al.*, 2009). Due to the multiple health benefits of eggplant, which include anti-oxidant, anti-diabetic, hypotensive, cardioprotective and hepatoprotective effects, the demand for eggplant has been on a rapid and steady rise in the recent years (Ojiewo *et al.*, 2007). Heterosis breeding has become the widely used breeding method for increasing productivity of the important solanaceous vegetable crops including brinjal. Ease of handling the flowers during artificial emasculation and pollination and realization of higher number of hybrid seeds per effective pollination causes higher yield of hybrids. Lack of appropriate hybrids for specific area and purpose is the major problem in popularizing the hybrids of brinjal. In the present investigation, thirteen parents were selected on the basis of divergence. They were mated in line × tester mating design to raise hybrids and relative heterosis, heterobeltiosis and standard heterosis was measured for different yield attributes.

Materials and Methods

Field experiment was conducted at Vegetable Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand), India. The University lies in south of the Shivalik range of Himalayas. It falls in humid sub-tropical zone locally known as *'Tarai'* situated at latitude of 29° North, longitude of 79.3^0 East and altitude of 243.84 meters above mean sea level (MSL).The materials for the present investigation comprised of 13 genotypes of Brinjal including 10 lines and 3 testers from germplasm maintained at Vegetable Research Centre. The 13 parental lines were agronomically and morphologically diverse. The genotypes were Swarn Syamli, PB71, BARI, SMB115, BB85, BRLVAR6, IBWL2001-1, PB66, LC7, PB70, Pant Samrat, Pant Rituraj and DBL-02. Out of thirteen genotypes, the ten were used as female (lines), viz. Swarn Syamli,PB71, BARI, SMB115, BB85, BRLVAR6, IBWL2001-1, PB66, LC7, PB70 and three as male (testers), viz. Pant Samrat, Pant Rituraj DBL-02. Crossing was made in line × tester mating design statistical analysis was done as per Kempthorne (1957) model to evaluate the 30 hybrids along with 13 parents for different yield attributes. Hybrids were evaluated for two successive years in 20013-14 and 2014-15 autumn-winter season and pooled analysis was carried out. The layout of the experiment was Randomized Block Design with three replications. Each plot consisted of 10 plants planted at a distance of 75 cm × 60 cm. Data were taken from randomly selected 5 plants from each replication. Pooled magnitude of heterosis over mid-parent (MP), better-parent (BP) and standard parent (SP) were calculated.

Results and Discussion

Pooled data of two years indicated that coefficient of variation (CV) was in the range of 5.42 to 24.52 (Table 1). This indicated that the precision of experiment was within the accepted normal limit of coefficient of variation. The general means for days to 50% flowering was 69.95 and range for the same was 60.67 (in parent DBL02 and cross PB71 × DBL02) to 84.00 (BRLVAR6). The number of primary branches per plant showed the range of 2.20 (PB71) to 5.33 (PB70 × DBL02) with general mean 3.52. For plant height general mean was 80.99 and mean value ranges from 61.43 (DBL02) to 92.54 (PB70 × Pant Rituraj). General mean of 15.37 and it ranged from 7.00 (Swarn Syamli) to 24.49 (BARI × DBL02) for fruit length and for fruit diameter the range 29.83 (IBWL2001-1) to 83.82 (PB70) with general

mean 50.24. General mean for number of marketable and unmarketable fruits per plant was 17.19 and 4.75, respectively. It ranged from 8.04 (Swarn Syamli) to 37.41 (PB66 × Pant Samrat) for number of marketable fruits per plant and 2.32 (PB 70 × DBL02) to 11.09 (PB66 × Pant Samrat) for number of unmarketable fruits per plant. General mean for weight of marketable and unmarketable fruits per plant were 1.46 and 0.48 kg, respectively. Whereas, the range of mean value for weight of marketable fruits per plant was 0.79 Kg (BB85) to 2.49 Kg (SMB115 × DBL02) and for weight of unmarketable fruits per plant was 0.12 Kg (Swarn Syamli × pant Samrat) to 0.87 Kg (IBWL2001-1 × Pant Rituraj). For total number of fruits per plant general mean 21.94 and ranged from 10.63 (Swarn Syamli) to 48.49 (PB66 × Pant Samrat) and for total yield per plant general mean 1.94 and it ranged from 0.98 Kg (BB85) to 3.15 Kg (SMB 115 × DBL02). General mean 430.17 and it ranged 216.10 (BB85) to 700.91 (SMB115 × DBL02) for total yield per hectare.

Wide range of variability existed among parents and their F_1 hybrids for different traits under study. Table 2, 3 and 4 represent per cent heterosis over mid, better and standard parent, respectively. Out of the 30 hybrids, the significant desirable heterotic effects over their respective mid, better and standard parent were noticed in 16, 19 and 21 crosses for days to 50% flowering, 23, 22 and 18 crosses for primary branches per plant, 18, 16 and 11 crosses for plant height, 18, 21 and 25 crosses for fruit length, 19, 21 and 24 crosses for fruit diameter, 27, 18 and 20 crosses for number of marketable fruits per plant, 26, 24 and 22 crosses for weight of marketable fruits per plant, 28, 29 and 28 crosses for number of unmarketable fruits per plant, 30, 28 and 28 crosses for weight of unmarketable fruits per plant, 22, 20 and 20 crosses for total number of fruits per plant, 26, 26 and 24 crosses for total yield per plant and 27, 26 and 26 for total yield/ hectare. The best significant hybrids for different traits with respect to heterosis over mid parent, better parent and check variety are presented in Table 5.

In case of days to 50% flowering where negative heterosis is desirable 7, 19 and 5 crosses showed negative significant relative, heterobeltiosis and economic heterosis, respectively. Maximum negative relative heterosis was observed in cross BB85 × Pant Samrat (-7.43%), maximum negative heterobeltiosis in BRLVAR6 × DBL02 (-19.44%) and maximum negative economic heterosis was recorded in PB71 × DBL02 (-7.85%), which was in conformity with the study of Singh *et al.*,(2002), Ansari *et al.*, (2009), Das *et al.*, (2009) and Biswas *et al.*, (2013).

For number of primary branches per plant 12, 7 and 16 crosses showed positive significant relative heterosis, heterobeltiosis and economic heterosis, respectively. Best cross with positive relative heterosis was BRLVAR6 × Pant Samrat (81.48%), again BRLVAR6 × Pant Samrat (56.38%) was best for heterobeltiosis, best cross for economic heterosis was PB 70 × DBL02 (70.21%). These findings are similar with the results of Das *et al.*, (2009) and Dubey *et al.*, (2014).

The results on heterosis for plant height indicated existence of positive significant relative heterosis, heterobeltiosis and economic heterosis 18, 10 and 10 crosses, respectively. Maximum positive relative heterosis was observed in cross Swarn Syamli × Pant Rituraj (23.22%) again maximum heterobetiosis was shown by the cross Swarn Syamli × Pant Rituraj (19.15%) and maximum economic heterosis was observed in PB70 × Pant Samrat (16.50%). Das *et al.*, (2009) and Biswas *et al.*, (2013) reported similar results.

Table.1 Mean performance of hybrids and their parents for twelve characters

Genotypes	Days to 50% flowering	No. of primary branches plant^{-1}	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits plant^{-1}	No. of unmarketable fruits plant^{-1}	Wt. of marketable fruits plant^{-1} (kg)	Wt. of unmarketable fruits plant^{-1} (kg)	Total no. of fruits plant^{-1}	Total yield plant^{-1} (kg)	Total yield hectare^{-1} (q)
Swarn Syamli×Pant Samrat	69.50	4.36	85.76	12.85	37.76	28.81	2.75	0.97	0.12	31.55	1.09	242.03
Swarn Syamli ×Pant Rituraj	73.66	3.13	86.66	11.34	76.64	17.75	3.69	1.53	0.41	21.44	1.94	432.02
Swarn Syamli ×DBL 02	64.83	2.73	75.20	14.65	49.02	17.96	7.77	1.61	0.67	25.74	2.29	508.44
PB 71×Pant Samrat	64.16	4.40	92.43	15.24	41.72	22.97	4.74	1.54	0.55	27.71	2.10	466.28
PB 71×Pant Rituraj	66.66	3.83	90.30	12.31	57.86	19.74	4.38	1.72	0.61	24.11	2.33	518.05
PB 71×DBL 02	60.66	3.53	76.90	19.55	43.54	9.54	3.66	0.94	0.34	13.20	1.28	284.45
BARI×Pant Samrat	74.00	3.46	80.96	18.69	41.08	19.03	5.22	1.16	0.39	24.25	1.55	344.21
BARI×Pant Rituraj	79.16	3.13	83.40	19.51	41.14	13.97	4.60	1.32	0.43	18.56	1.75	389.32
BARI×DBL 02	74.00	3.30	82.33	24.49	33.44	16.61	6.02	1.28	0.39	22.63	1.67	370.34
SMB 115×Pant Samrat	71.16	3.96	87.63	14.63	34.22	20.75	6.93	1.55	0.59	27.67	2.14	475.70
SMB 115×Pant Rituraj	74.00	3.70	76.33	10.76	62.91	20.51	4.13	1.57	0.45	24.64	2.01	447.65
SMB 115×DBL 02	68.16	2.66	77.80	18.08	39.71	32.14	7.23	2.49	0.66	39.37	3.15	700.91
BB 85×Pant Samrat	62.33	3.26	78.23	14.42	41.93	27.88	6.61	1.51	0.44	34.49	1.95	433.50
BB 85×Pant Rituraj	69.16	2.83	84.93	11.46	66.77	15.27	5.17	1.49	0.52	20.44	2.01	447.25
BB 85×DBL 02	62.16	3.56	82.93	17.05	42.23	22.65	5.67	1.54	0.53	28.32	2.07	459.10
BRLVAR 6×Pant Samrat	76.00	4.90	86.43	17.16	44.92	20.24	4.69	1.68	0.48	24.93	2.16	480.99
BRLVAR 6×Pant Rituraj	79.66	4.40	92.53	14.51	70.77	16.53	4.56	2.15	0.71	21.09	2.86	635.80
BRLVAR 6×DBL 02	67.66	4.20	84.56	14.90	31.21	15.41	4.99	1.38	0.48	20.40	1.86	413.56
IBWL 2001-1×Pant Samrat	62.83	3.03	86.26	15.77	31.20	21.88	7.02	1.43	0.48	28.91	1.91	424.96
IBWL 2001-1×Pant Rituraj	68.50	2.56	82.53	16.13	67.48	18.42	4.90	2.06	0.87	23.31	2.93	652.06
IBWL 2001-1×DBL 02	64.83	2.93	76.96	21.12	33.25	14.97	5.61	1.17	0.52	20.58	1.68	374.01
PB 66×Pant Samrat	64.00	4.03	80.46	19.62	39.04	37.41	11.09	2.29	0.77	48.49	3.06	680.54
PB 66×Pant Rituraj	67.50	3.16	80.03	17.09	56.31	20.24	6.59	1.83	0.62	26.83	2.46	546.29
PB 66×DBL 02	63.16	3.60	74.46	17.77	47.61	14.64	5.31	1.75	0.75	19.95	2.50	555.77

Conti….

Genotypes	Days to 50% flowering	No. of primary branches/plant	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits plant^{-1}	No. of unmarketable fruits plant^{-1}	Wt. of marketable fruits plant^{-1} (kg)	Wt. of unmarketable fruits plant^{-1} (kg)	Total no. of fruits plant^{-1}	Total yield plant^{-1} (kg)	Total yield hectare^{-1} (q)
LC 7×Pant Samrat	71.17	3.90	73.30	16.16	51.37	16.37	3.28	1.78	0.40	19.65	2.18	483.67
LC 7×Pant Rituraj	78.00	2.90	78.70	12.10	67.48	13.09	2.98	1.96	0.52	16.07	2.48	550.59
LC 7×DBL 02	72.17	3.77	78.43	17.87	50.16	10.18	2.39	1.67	0.47	12.56	2.14	475.89
PB 70×Pant Samrat	69.00	3.60	86.33	20.12	42.24	12.16	2.80	1.32	0.33	14.96	1.64	365.55
PB 70×Pant Rituraj	77.83	4.10	92.54	12.82	73.11	9.15	3.26	1.73	0.73	12.41	2.45	545.36
PB 70×DBL 02	66.50	5.33	81.23	16.57	54.11	9.67	2.32	1.28	0.42	11.99	1.71	379.16
Swarn Syamli	69.33	3.13	68.23	7.00	73.05	8.04	2.59	1.42	0.28	10.63	1.70	377.74
PB 71	63.50	2.20	92.07	12.47	56.61	14.53	3.34	1.22	0.32	17.87	1.54	342.29
BARI	78.50	4.33	80.60	23.87	33.28	9.51	3.60	1.02	0.38	13.11	1.40	311.79
SMB 115	70.33	2.80	87.33	11.55	48.58	18.87	4.93	1.50	0.50	23.80	2.00	443.44
BB 85	68.83	4.17	73.70	11.71	42.93	15.84	3.99	0.79	0.19	19.83	0.98	217.00
BRLVAR 6	84.00	2.27	79.10	14.54	59.68	10.20	2.74	0.91	0.26	12.94	1.17	260.52
IBWL 2001-1	69.00	3.27	66.77	13.56	29.83	19.37	3.56	0.94	0.18	22.92	1.12	249.76
PB 66	65.50	3.77	81.10	19.55	43.69	22.58	7.73	1.45	0.66	30.31	2.11	468.66
LC 7	79.33	2.70	75.10	14.02	79.64	8.95	2.35	1.26	0.38	11.30	1.64	364.49
PB 70	78.17	3.57	88.68	14.27	83.82	10.99	4.86	1.62	0.75	15.85	2.37	527.13
Pant Samrat	65.83	3.13	79.43	20.26	35.59	19.54	5.78	1.12	0.34	25.32	1.46	323.62
Pant Rituraj	72.33	4.27	72.43	8.41	69.32	8.97	3.79	0.85	0.29	12.76	1.14	253.06
DBL 02	60.67	3.37	61.43	20.64	33.85	15.96	4.71	0.94	0.29	20.67	1.24	274.62
General Mean	69.95	3.52	80.99	15.74	50.24	17.19	4.75	1.46	0.48	21.94	1.94	430.17
C.V.	5.45	9.38	9.55	9.21	8.46	16.72	24.58	15.11	23.35	13.31	11.42	11.78
S.E.	1.56	0.13	3.16	0.59	1.73	1.17	0.48	0.09	0.05	1.19	0.09	20.69
C.D. 5%	4.34	0.38	8.81	1.65	4.83	3.27	1.33	0.25	0.13	3.32	0.25	57.68
C.D. 1%	5.72	0.50	11.61	2.18	6.38	4.31	1.75	0.33	0.17	4.38	0.33	76.05

Table.2 Estimation of per cent relative heterosis (over mid parent)

Hybrids	Days to 50% flowering	No. of primary branches plant^{-1}	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits plant^{-1}	Wt. of marketable fruits plant^{-1}	No. of unmarketable fruits plant^{-1}	Wt. of unmarketable fruits plant^{-1}	Total no. of fruits plant^{-1}	Total yield plant^{-1} (kg)	Total yield/hectare (q)
Swarn Shyamli × Pant Samrat	2.84	39.36**	16.16**	-5.69	-30.47**	108.90**	-23.71**	-34.28**	-60.56**	75.58**	-30.97**	-30.98**
Swarn Shyamli × Pant Rituraj	4.00*	-15.32**	23.22**	47.25**	7.67**	108.76**	35.72**	15.54**	41.76**	83.33**	36.95**	36.97**
Swarn Shyamli × DBL02	-0.26	-15.90**	15.99**	6.03	-8.28*	49.73**	36.94**	112.92**	133.06**	64.47**	55.89**	55.88**
PB71 Pant Samrat	-0.77	65.00**	7.79*	-6.87	-9.48*	34.81**	32.02**	4.10	68.35**	28.33**	40.00**	40.04**
PB71 × Pant Rituraj	-1.84	18.56**	9.79**	17.98**	-8.10**	67.96**	66.81**	22.69**	98.15**	57.42**	73.99	74.03**
PB71 × DBL 02	-2.28	26.95**	0.20	18.11**	-3.73	-37.42**	-12.69	-9.15**	9.41**	-31.52**	-7.80	-7.78
BARI × Pant Samrat	2.54	-7.14	1.19	-15.29**	19.31**	31.04**	8.34	11.34**	8.40**	26.23**	8.35	8.34
BARI × Pant Rituraj	4.97**	-27.13**	9.00*	20.90**	-19.81**	51.17**	41.82**	24.32**	26.84**	43.49**	37.84**	37.85**
BARI × DBL02	6.35**	-14.29**	15.94**	10.05**	-0.36	30.45**	30.38**	44.87**	14.45**	33.99**	26.30**	26.31**
SMB115 × Pant Samrat	4.53**	33.71**	5.10	-7.97*	-18.69**	8.03	18.68**	29.38**	40.84**	12.68**	24.03**	24.03**
SMB115 × Pant Rituraj	3.74*	4.72	-4.44	7.89	6.71*	47.37**	33.57**	-5.43*	13.49**	34.78**	28.52**	28.54**
SMB115 × DBL02	4.07*	-13.51*	4.59	12.38**	-3.66	84.59**	104.10**	49.94**	67.53**	77.08**	95.16**	95.22**
BB85 × Pant Samrat	-7.43**	-10.50*	2.18	-9.78*	6.80	57.60**	58.61**	35.36**	66.74**	52.79**	60.36**	60.37**
BB85 × Pant Rituraj	-2.01	-32.81**	16.24**	14.02*	18.97**	23.13**	82.28**	32.78**	117.44**	25.44**	90.25**	90.30**
BB85 × DBL02	-3.99*	-5.31	22.74**	5.46	10.00*	42.48**	77.59**	30.37**	119.83**	39.88**	86.77**	86.77**
BRLVAR6 × Pant Samrat	1.45	81.48**	9.04**	-1.33	-5.70	36.11**	65.43**	10.12**	62.27**	30.32**	64.71**	64.68**
BRLVAR6 × Pant Rituraj	1.92	34.69**	22.13**	26.56**	9.71**	72.49**	144.89**	39.64**	156.00**	64.14**	147.54**	147.59**
BRLVAR6 × DBL02	-6.45**	49.11**	20.35**	-15.28**	-33.26**	17.82*	48.97**	33.97**	73.24**	21.40**	54.54**	54.56**
IBWL2001-1 × Pant Samrat	-6.80**	-5.21	18.01**	-6.72	-4.61	12.50*	39.27**	50.52**	83.52**	19.85**	48.22**	48.23**
IBWL2001-1 × Pant Rituraj	-3.07*	-31.86**	18.58**	46.87**	36.11	30.00**	130.84**	33.23**	265.79**	30.66**	159.31**	159.36**
IBWL2001-1 × DBL02	0.00	-11.56*	20.07**	23.52**	4.41	-15.26*	24.04*	35.73**	115.81**	-5.59	42.65**	42.65**
PB66 × Pant Samrat	-2.54	16.91**	0.25	-1.39	-1.52	77.60**	78.71**	64.21**	54.09**	74.35**	71.79**	71.79**
PB66 × Pant Rituraj	-2.06	-21.16**	4.26	22.33**	-0.36	28.27**	60.11**	14.38**	30.45**	24.55**	51.38**	51.39**
PB66 × DBL02	0.13	0.93	4.49	-11.52**	22.80**	-24.02**	46.72**	-14.67**	56.60**	-21.74**	49.55**	49.55**
LC7 × Pant Samrat	-1.95	33.71**	-5.13	-5.71	-10.83**	14.90	49.37**	-19.35**	11.31**	7.31	40.59**	40.58**
LC7× Pant Rituraj	2.86*	-16.75**	6.69	7.94	-9.40**	46.12**	85.91**	-2.99	54.33**	33.59**	78.30**	78.31**
LC7 × DBL02	3.10*	24.18**	14.89**	3.10	-11.61**	-18.28*	51.70**	-32.42**	39.91**	-21.40**	48.95**	48.92**
PB70× Pant Samrat	-4.17**	7.46	2.71	16.55**	-29.26**	-20.32**	-3.84	-47.45**	-39.79**	-27.33**	-14.07**	-14.06**
PB70× Pant Rituraj	3.43*	4.68	14.87**	13.10*	-4.52	-8.29	40.03**	-24.64**	39.20**	-13.24	39.78**	39.80**
PB70 × DBL02	-4.20**	53.85**	8.23*	-5.08	-8.02*	-28.22**	0.07	-51.47**	-18.81**	-34.32**	-5.41	-5.42

Table.3 Estimation of per cent heterobeltiosis (over better parent)

Hybrids	Days to 50% flowering	No. of primary branches plant^{-1}	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits plant^{-1}	Wt. of marketable fruits plant^{-1}	No. of unmarketable fruits plant^{-1}	Wt. of unmarketable fruits plant^{-1}	Total no. of fruits plant^{-1}	Total yield plant^{-1} (kg)	Total yield/hectare (q)
Swarn Syamli × Pant Samrat	0.24	39.36**	7.97*	-36.54**	-48.30**	47.42**	-31.72**	-52.41**	-63.69**	24.64**	-35.92**	-35.93**
Swarn Syamli × Pant Rituraj	1.84	-26.56**	19.65**	34.95**	4.92	97.94**	8.41	-2.81	39.55**	67.99**	14.36*	14.37*
Swarn Syamli × DBL02	-6.49**	-18.81**	10.21*	-28.99**	-32.89**	12.58	14.00	64.95**	128.98**	24.51**	34.61**	34.60**
PB71 Pant Samrat	-2.53	40.43**	0.40	-24.77**	-26.29**	17.54**	26.53**	-17.86**	63.99**	9.46	36.18**	36.23**
PB71 × Pant Rituraj	-7.83**	-10.16*	-1.92	-1.24	-16.53**	35.80**	41.23**	15.33**	89.80**	34.92**	51.33**	51.35**
PB71 × DBL 02	-4.46*	4.95	-16.47**	-5.26	-23.08**	-40.21**	-22.66**	-22.39**	4.99*	-36.15**	-16.91*	-16.90*
BARI × Pant Samrat	-5.73**	-20.00**	0.45	-21.70**	15.44*	-2.59	3.61	-9.61**	2.09	-4.19	6.37	6.36
BARI × Pant Rituraj	0.85	-27.69**	3.47	-18.26**	-40.66**	46.86**	29.67**	21.18**	12.07**	41.58**	24.87**	24.87**
BARI × DBL02	-5.73**	-23.85**	2.15	2.60	-1.20	4.09	25.31*	27.80**	1.31	9.50	18.77*	18.78*
SMB115 × Pant Samrat	1.18	26.60**	0.34	-27.76**	-29.56**	6.18	3.57	19.91**	18.48**	9.31	7.27	7.27
SMB115 × Pant Rituraj	2.30	-13.28**	-12.60**	-6.77	-9.26**	8.71	4.43	-16.33**	-9.63**	3.52	0.94	0.95
SMB115 × DBL02	-3.08	-20.79**	-10.92**	-12.38**	-18.27**	70.34**	66.06**	46.62**	33.60**	65.43**	58.01**	58.06**
BB85 × Pant Samrat	-9.44**	-21.60**	-1.51	-28.82**	-2.33	42.66**	35.34**	14.46**	29.35**	36.23**	33.95**	33.96**
BB85 × Pant Rituraj	-4.38*	-33.59**	15.24**	-2.05	-3.68	-3.57	76.30**	29.48**	77.78**	3.08	76.68**	76.74**
BB85 × DBL02	-9.69**	-14.40**	12.53**	-17.36**	-1.63	41.95**	63.35**	20.41**	79.46**	37.04**	67.19**	67.17**
BRLVAR6 × Pant Samrat	-9.52**	56.38**	8.81*	-15.27**	-24.74**	3.57	50.29**	-18.82**	43.22**	-1.53	48.65**	48.63**
BRLVAR6 × Pant Rituraj	-5.16**	3.12	16.98**	-0.11	2.08	62.09**	135.78**	20.25**	140.80**	63.02**	144.04**	144.05**
BRLVAR6 × DBL02	-19.44**	24.75**	6.91	-27.81**	-47.70**	-3.44	46.80**	5.94*	62.65**	-1.30	50.57**	50.59**
IBWL2001-1 × Pant Samrat	-8.94**	-7.14	8.60*	-22.15**	-12.33*	11.99	28.15**	21.59**	41.79**	14.18**	31.31**	31.32**
IBWL2001-1 × Pant Rituraj	-5.30**	-39.84**	13.94**	18.98**	-2.66	-4.90	119.29**	29.04**	197.73**	1.71	157.59**	157.67**
IBWL2001-1 × DBL02	-6.04**	-12.87*	15.28**	2.33	-1.79	-22.71**	23.94*	19.07**	75.38**	-10.22	36.20**	36.19**
PB66 × Pant Samrat	-2.78	7.08	-0.78	-3.13	-10.65*	65.63**	58.49**	43.45**	16.28**	59.97**	45.21**	45.21**
PB66 × Pant Rituraj	-6.68**	-25.78**	-1.32	-12.52**	-18.78**	-10.40	26.90**	-14.75**	-5.93**	-11.51**	16.57**	16.56**
PB66 × DBL02	-3.56	-4.42	-8.18*	-13.87**	8.97	-35.17**	21.13**	-31.33**	13.07**	-34.19**	18.59**	18.59**
LC7 × Pant Samrat	-10.29**	24.47**	-7.72*	-20.23**	-35.50**	-16.22*	40.79**	-43.29**	5.58**	-22.40**	32.71**	32.70**
LC7× Pant Rituraj	-1.68	-32.03**	4.79	-13.66**	-15.27**	46.00**	55.17**	-21.49**	37.26**	25.94**	51.06**	51.06**
LC7 × DBL02	-9.03**	11.88	4.44	-13.44**	-37.02**	-36.21**	32.35**	-49.38**	24.65**	-39.21**	30.59**	30.56**
PB70× Pant Samrat	-11.73**	0.93	-2.65	-0.69	-49.61**	-37.76**	-18.73**	-51.60**	-56.36**	-40.92**	-30.66**	-30.65**
PB70× Pant Rituraj	-0.43	-3.91	4.35	-10.12*	-12.77**	-16.72	6.56	-32.93**	-3.24**	-21.69**	3.46	3.46
PB70 × DBL02	-14.93**	49.53**	-8.40*	-19.74**	-35.44**	-39.40**	-20.90**	-52.23**	-43.50**	-41.97**	-28.06**	-28.07**

Table.4 Estimation of per cent economic heterosis (over check i.e. Pant Samrat)

Hybrids	Days to 50% flowering	No. of primary branches plant^{-1}	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits plant^{-1}	Wt. of marketable fruits plant^{-1}	No. of unmarketable fruits plant^{-1}	Wt.of unmarketable fruits plant^{-1}	Total no. of fruits plant^{-1}	Total yield plant^{-1} (kg)	Total yield hectare^{-1} (q)
Swarn Shyamli × Pant Samrat	5.57**	39.36**	7.97*	-36.54**	6.12	47.42**	-13.57	-52.41**	-63.69**	24.64**	-25.20**	-25.21**
Swarn Shyamli × Pant Rituraj	11.90**	0.00	9.11*	-43.99**	115.38**	-9.15	37.21**	-36.16**	21.16**	-15.31**	33.48**	33.50**
Swarn Shyamli × DBL02	-1.52	-12.77	-5.33	-27.65**	37.75**	-8.07	44.29**	34.57**	99.61**	1.66	57.12**	57.11**
PB71 Pant Samrat	-2.53	40.43**	16.37**	-24.77**	17.25**	17.54**	38.01**	-17.86**	63.99**	9.46	44.04**	44.08**
PB71 × Pant Rituraj	1.27	22.34**	13.68**	-39.20**	62.60**	1.01	54.05**	-24.24**	79.97**	-4.75	60.06**	60.08**
PB71 × DBL 02	-7.85**	12.77	-3.19	-3.47	22.35**	-51.18**	-15.65	-36.68**	-0.44	-47.87**	-12.12	-12.10
BARI × Pant Samrat	12.41**	10.64	1.93	-7.73*	15.44*	-2.59	3.61	-9.61**	15.54**	-4.19	6.37	6.36
BARI × Pant Rituraj	20.25**	0.00	4.99	-3.67	15.60*	-28.52**	18.34	-20.40**	26.84**	-26.67**	20.3**	20.30**
BARI × DBL02	12.41**	5.32	3.65	20.90**	-6.02	-14.99*	14.36	4.27*	14.65**	-10.60*	14.43	14.44
SMB115 × Pant Samrat	8.10**	26.60**	10.32**	-27.76**	-3.84	6.18	38.95**	19.91**	73.61**	9.31	46.99**	47.00**
SMB115 × Pant Rituraj	12.41**	18.09**	-3.90	-46.87**	76.76**	4.98	40.11**	-28.57**	32.41**	-2.67	38.33**	38.33**
SMB115 × DBL02	3.54	-14.89*	-2.06	-10.73**	11.58	64.50**	122.80**	25.17**	95.76**	55.53**	116.52**	116.59**
BB85 × Pant Samrat	-5.32**	4.26	-1.51	-28.82**	17.81**	42.66**	35.34**	14.46**	29.35**	36.23**	33.95**	33.96**
BB85 × Pant Rituraj	5.06**	-9.57	6.92	-43.39**	87.62**	-21.84**	33.32**	-10.51**	54.37**	-19.26**	38.20**	38.20**
BB85 × DBL02	-5.57**	13.83*	4.41	-15.80**	18.66**	15.92*	37.48**	-1.76	56.44**	11.88*	41.87**	41.86**
BRLVAR6 × Pant Samrat	15.44**	56.38**	8.81*	-15.27**	26.21**	3.57	50.29**	-18.82**	43.22**	-1.53	48.65**	48.63**
BRLVAR6 × Pant Rituraj	21.01**	40.43**	16.49**	-28.33**	98.85**	-15.40*	92.64**	-21.01**	109.08**	-16.68**	96.45**	96.47**
BRLVAR6 × DBL02	2.78	34.04**	6.46	-26.44**	-12.30*	-21.14**	23.54*	-13.56**	41.79**	-19.42**	27.77**	27.79**
IBWL2001-1 × Pant Samrat	-4.56*	-3.19	8.60*	-22.15**	-12.33*	11.99	28.15**	21.59**	41.79**	14.18**	31.31**	31.32**
IBWL2001-1 × Pant Rituraj	4.05*	-18.09**	3.90	-20.37**	89.62**	-5.75	84.26**	-15.24**	158.51**	-7.91	101.49**	101.49**
IBWL2001-1 × DBL02	-1.52	-6.38	-3.11	4.26	-6.58	-23.40**	4.31	-2.86	52.89**	-18.72**	15.57*	15.57*
PB66 × Pant Samrat	-2.78	28.72**	1.30	-3.13	9.70	91.43**	104.83**	92.01**	128.32**	91.56**	110.28**	110.29**
PB66 × Pant Rituraj	2.53	1.06	0.76	-15.60**	58.22**	3.56	64.00**	14.11**	84.71**	5.96	68.80**	68.81**
PB66 × DBL02	-4.05*	14.89*	-6.25	-12.24**	33.78**	-25.07**	56.55**	-8.08**	122.00**	-21.19**	71.73**	71.74**
LC7 × Pant Samrat	8.10**	24.47**	-7.72*	-20.23**	44.35**	-16.22*	59.07**	-43.29**	17.71**	-22.40**	49.47**	49.46**
LC7× Pant Rituraj	18.48**	-7.45	-0.92	-40.26**	89.61**	-32.99**	75.31**	-48.43**	53.03**	-36.51**	70.14**	70.14**
LC7 × DBL02	9.62**	20.21**	-1.26	-11.81**	40.94**	-47.91**	49.53**	-58.70**	38.97**	-50.37**	47.08**	47.05**
PB70× Pant Samrat	4.81*	14.89*	8.69*	-0.69	18.68**	-37.76**	17.73	-51.60**	-2.91	-40.92**	12.94	12.96
PB70× Pant Rituraj	18.23**	30.85**	16.50**	-36.71**	105.44**	-53.17**	54.37**	-43.52**	115.29**	-50.97**	68.51**	68.52**
PB70 × DBL02	1.01	70.21**	2.27	-18.22**	52.05**	-50.51**	14.59	-59.77**	25.70**	-52.62**	17.17*	17.16*

Table.5 The best significant hybrids for different traits with respect to heterosis over mid parent, better parent and check variety

Character	Heterosis over mid parent	Heterosis over better parent	Heterosis over standard check
Days to 50% flowering	BB85 × Pant Samrat (-7.43%) IBWL2001-1 ×Pant Samrat (-6.80%) BRLVAR6 × DBL02 (-6.45%)	BRLVAR6 ×DBL02 (-19.44%) PB70× DBL02 (-14.93%) PB70 × Pant Samrat(-11.73%)	PB71 × DBL02 (-7.85%) BB85 × DBL02 (-5.57%) BB85 × Pant Samrat (-5.32%)
No. of primary branches plant^{-1}	BRLVAR6× Pant Samrat (81.48%) PB71 × Pant Samrat (65.00%) PB70 × DBL02 (53.85%)	BRLVAR6 × Pant Samrat (56.38%) PB 70 × DBL02 (49.53%) PB71 × Pant Samrat (40. 43%)	PB70 × DBL02 (70.21%) BRLVAR6 × Pant Samrat (56.38%) PB71 × Pant Samrat (40. 43%)
Plant height (cm)	Swarn Syamli × Pant Rituraj (23.22%) BB85 × DBL02 (22.74%) BRLVAR6 × Pant Rituraj (22.13%)	Swarn Syamli × Pant Rituraj (19.15%) BRLVAR6 × Pant Rituraj (16.98%) IBWL 2001-1× DBL02 (15.28%)	PB70 × Pant Samrat (16.50%) BRLVAR6 × Pant Rituraj (16. 49%) PB 71 × Pant Samrat (16. 37%)
Fruit length(cm)	Swarn Syamli × Pant Rituraj (47.25%) IBWL2001-1 ×Pant Rituraj (46.84%) BRLVAR6 × Pant Rituraj (26.56%)	Swarn Syamli × Pant Rituraj (34.95%) IBWL2001-1 ×Pant Rituraj (18.98%)	BARI × DBL02 (20.90%)
Fruit diameter (mm)	PB66 × DBL02 (22.80%) BARI × Pant Samrat (19.31%) BB85 × Pant Rituraj (18.97%)	BARI × Pant Samrat (15.44%)	Sawarn Syamli × Pant Rituraj (115.38%) PB70 × Pant Rituraj (105.44%) BRLVAR6 × Pant RIturaj (95.85%)
No. of marketable fruits plant^{-1}	Swarn Syamli × Pant Samrat (108.90%) Swarn Syamli × Pant Rituraj (108.76%) SMB115 × DBL 02 (84.59%)	Swarn Syamli × Pant Rituraj (97.94%) SMB115 × DBL02 (70.34%) PB66 × Pant Samrat (65.63%)	PB66 × Pant Samrat (91.43%) SMB115 × DBL02 (64.50%) Swarn Syamli × Pant Samrat (47.42%)
Wt. of marketable fruits plant^{-1}	BRLVAR6 × Pant Rituraj (144.89%) IBWL2001-1 × Pant Rituraj (130.84%) SMB115 × DBL02 (104.10%)	BRLVAR6 × Pant Rituraj (135.78%) IBWL2001-1 × Pant Rituraj (119.29%) BB85 × Pant Rituraj (76.30%)	SMB115 × DBL02 (122.80%) PB66 × Pant Samrat (104.83%) BRLVAR6 × Pant Rituraj (92.64%)
No. of unmarketable fruits plant^{-1}	PB70 × DBL02 (-51.41%) PB70 × Pant Samrat (-47.45%) Swarn Syamli × Pant Samrat (-34.28%)	Swarn Syamli × Pant Samrat (-52.41%) PB70 × DBL02 (-52.23%) PB70 × Pant Samrat (-51.60 %)	PB70 × DBL02 (-59.77%) LC7 × DBL02 (-58.70%) Swarn Syami × Pant Samrat (-52. 41%)
Wt. of unmarketable fruits plant^{-1}	Swarn Syamli × Pant Samrat (-69.56%) PB70 × Pant Samrat (-39.79%) PB70 × DBL02 (18.81%)	Swarn Syamli × Pant Samrat (-63.69%) PB 70 × Pant Samrat (-56.36%) PB70 × DBL02 (-43.50%)	Swarn Syamli × Pant Samrat (-63.67%)
Total no. of fruits plant^{-1}	Swarn Syamli × Pant Rituraj (83.33%) SMB115 × DBL02 (77.08%) Swarn Syamli × Pant Samrat (75.58%)	Swarn Syamli × Pant Rituraj (67.99%) SMB115 × DBL02 (65.73%) BRLVAR6 × Pant Rituraj (63.02%)	PB66 × Pant Samrat (91.56%) SMB115 × DBL02 (55.53%) BB85 × Pant Samrat (36.23%)
Total yield plant^{-1} (kg)	IBWL2001-1 × Pant Rituraj (159.31%) BRLVAR6 × Pant Rituraj (147.54%) SMB115 × DBL02 (95.16%)	IBWL2001-1 × Pant Rituraj (157.59%) BRLVAR6 × Pant Rituraj (144.04%) BB85 × Pant Rituraj (76.68%)	SMB115 × DBL02 (116.52%) PB66 × Pant Samrat (110.28%) IBWL2001-1× Pant Rituraj (101.49%)
Total yield ha^{-1} (q)	IBWL2001-1 × Pant Rituraj (159.30%) BRLVAR6 × Pant Rituraj (144.05%) SMB115 × DBL02 (95.22%)	IBWL2001-1 × Pant Rituraj (157.67%) BRLVAR6 × Pant Rituraj (144.05%) BB85 × Pant Rituraj (76.74%)	SMB115 × DBL02 (116.59%) PB66 × Pant Samrat (110.29%) IBWL2001-1× Pant Rituraj (101.49%)

Fruit length exhibited positive significant relative heterosis, heterobeltiosis and economic heterosis 13, 2 and 1 cross, respectively. Maximum positive relative heterosis was recorded in cross Swarn Syamli × Pant Rituraj (47.25%), again maximum heterobetiosis was shown by the cross Swarn Syamli × Pant Rituraj (34.95%) and maximum economic heterosis was observed in BARI × DBL02 (20.90%). Similar results were reported by Ansari *et al.,* (2009), Das *et al.,* (2009), Biswas *et al.,* (2013) and Kumar *et al.,* (2013). Fruit diameter exhibited positive significant relative heterosis, heterobeltiosis and economic heterosis with 6, 1 and 22 crosses, respectively. Maximum positive relative heterosis was recorded in cross PB66 × DBL02 (22.80%), maximum heterobeltiosis in BARI × Pant Samrat (15.44%) and maximum economic heterosis was recorded in Sawarn Syamli × Pant Rituraj (115.38%).The result was in agreement with earlier studies Ashwani and Khandelwal (2003) and Das *et al.,* (2009).

Results revealed that 21, 11 and 6 crosses showed significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively. Highest magnitude of relative heterosis, heterobeltiosis and standard heterosis was recorded in crosses Swarn Syamli × Pant Samrat (108.90%), Swarn Syamli × Pant Rituraj (97.94%) and PB66 × Pant Samrat (91.43%), respectively. Ansari *et al.,* (2009) and Biswas *et al.,* (2013) quoted similar results.

For weight of marketable fruits per plant 25, 20 and 22 crosses exhibited positive relative heterosis, heterobeltiosis and economic heterosis, respectively. Highest magnitude of relative heterosis, heterobeltiosis and standard heterosis was recorded in crosses BRLVAR6 × Pant Rituraj (144.89%), BRLVAR6 × Pant Rituraj (135.78%) and SMB115 × DBL02 (122.80%) respectively. Similar result was reported by Biswas (2013).

For number of unmarketable fruits per plant negative heteorsis is desirable and 9, 14 and 20 crosses exhibited significant negative relative heterosis, heteorbeltiosis and economic heterosis respectively. Highest negative magnitude of relative heterosis, heterobeltiosis and standard heterosis was recorded in crosses PB70 × DBL02 (-51.41%), Swarn Syamli × Pant Samrat (-52.41%) and PB70 × DBL02 (-59.77%) respectively. These results are in agreement with the findings of Kumar and Pathania (2003).

For weight of unmarketable fruits per plant also negative heterosis is desirable and 3, 6 and 1 cross combination showed significant negative relative heterosis, heteorbeltiosis and economic heterosis, respectively. Highest negative magnitude of relative heterosis, heterobeltiosis and standard heterosis was recorded in cross Swarn Syamli × Pant Samrat (-9.56%), Swarn Syamli × Pant Samrat (-63.69%) and Swarn Syamli × Pant Samrat (-63.67%) respectively.

These observations were in close agreements with Kumar and Pathania (2003).

Total number of fruits plant^{-1} exhibited positive significant relative heterosis, heterobeltiosis and economic heterosis with 22, 12 and 5 crosses, respectively. Maximum positive relative heterosis was recorded in cross Swarn Syamli × Pant Rituraj (83.33%), maximum positive heterobeltiosis was again showed by cross Swarn Syamli × Pant Rituraj (67.99%) and maximum positive economic heterosis was exhibited by cross PB66 × Pant Samrat (91.56%). Ashwani and Khandelwal (2003) and Biswas *et al.,* (2013) reported similar results. Yield in any crop is the final product of different yield components. This ultimate produce in the plant is expressed through mutual balancing of characters. Total yield plant^{-1} exhibited positive significant relative heterosis, heterobeltiosis and

economic heterosis with 24, 22 and 25 crosses, respectively. Maximum positive relative heterosis was recorded in cross IBWL2001-1 × Pant Rituraj (159.31%), maximum positive heterobeltiosis in again same cross IBWL2001-1 × Pant Rituraj (157.59%) and maximum positive economic heterosis was shown by cross SMB115 × DBL02 (116.52%). These findings are in agreement with the results of Ansari *et al.*, (2009) and Biswas *et al.*, (2013). For number of marketable fruits per plant and total number of fruits per plant, cross PB66 × Pant Samrat has high *per se* performance as well as it showed maximum economic heterosis for above traits. Whereas for weight of marketable fruits per plant, total yield per plant and yield per hectare cross, SMB115 × DBL02 has high *per se* performance and maximum economic heterosis for above mentioned traits.

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