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Research Article

Heterosis and inbreeding depression studies in pumpkin (*Cucurbita moschata* Duch. ex Poir.)

V. Jansi[1*], V. Rajasree[1], R. Kumar, S. Praneetha[1] and S. Rajeswari[2]
[1]Department of Vegetable Crops, Horticulture College and Research Institute, TNAU, Coimbatore-641003, India.
[2]Centre for Plant Breeding and Genetics, Agriculture College and Research Institute, TNAU, Coimbatore-641003, India
***E-Mail** :jansi1512@gmail.com

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Abstract
The investigation was carried out in pumpkin (*Cucurbita moschata* Duch. ex. Poir.) to study the heterosis and inbreeding depression for yield and yield contributing characters in three possible crosses (Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas) involving four parents (Odisha local, Rajasthan local, Ambili and Pusa Viswas) with four generations (P_1, P_2, $F_1$and F_2) in randomized block design with four replications. Relative heterosis and heterobeltiosis was found to be significant and negative for days to open first female flower, number of node at which first female flower appeared, vine length, fruit weight, fruit polar diameter, fruit equatorial diameter and sex ratio. Positive relative heterosis was observed for number of fruits per vine for most of the crosses. Hence heterosis breeding can be exploited for production of more number of fruits per vine. Significant positive heterobeltiosis was also observed for days to first female flower appearance, fruit weight, fruit equatorial diameter, fruit yield per vine and fruit yield per plot in cross II Rajathan local x Pusa Viswas. The significant inbreeding depression for all the yield characters except number of fruits per vine was observed.

Keywords
Heterosis, Inbreeding depression, Pumpkin.

Introduction

Pumpkin (*Cucurbita moschata* Duch. ex Poir) is a cucurbit vegetable grown throughout the tropical and subtropical countries including India. The pumpkin has a chromosome number of 2n=40, is a vigorous, annual, running or trailing vine with large, bristly leaves and large individual yellow flowers. Pumpkin is known for its high carotene content in the fruit. Pumpkin is a very good source of vitamin A (972 IU/100g of edible portion) which is particularly important for the supply of antioxidants and especially carotenoids in foods (Hidaka *et al*.1986). The area under pumpkin cultivation in India is reported to be 72,000 ha with production of 15,82,000 tonnes (National Horticulture Board 2016-17). Pumpkin is being a monoecious and highly cross pollinated crop, it has ample scope for successful exploitation of hybrid vigour. Information on the magnitude of heterosis in different cross combination is a basic requisite for identifying crosses that exhibit high degree of exploitable heterosis. Hence, the present study was undertaken with an objective to study the magnitude of heterosis in different crosses and its confirmation through inbreeding depression in F_2 generation and then utilization in future crop improvement programmes.

Materials and Methods

The present experiment was carried out at Orchard, Department of Vegetable Crops, Horticulture college and research institute, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu during the period January to April 2018 in four replications adopting randomized block design. Crop was maintained as per the crop production guide recommendation (TNAU 2013). The experimental material consisted of three F_1 hybrids (Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas) and their F_2 with parents Odisha local, Rajasthan local, Ambili and Pusa Viswas.

Observations were taken during the evaluation of F_1 hybrids (Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas) and their F_2 with parental lines Odisha local, Rajasthan local, Ambili and Pusa Viswas. Following observations were recorded during evaluation of F^s_1 and parents. Days to anthesis of first female flower nodal position of first female flower, number of primary branches per vine, fruit weight, fruit polar diameter, fruit equatorial diameter, number of fruits per vine, fruit yield per vine, fruit yield per plot, sex ratio and final vine length.

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The mean values of parents and hybrids of those four replications for each character were taken for the estimation of heterosis in terms of two parameters, relative heterosis and heterosis over the better parent (heterobeltiosis) (Table 1 & 2).

$$\text{Relative Heterosis } (H_1\%) = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis } (H_2\%) = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F}_1$ = mean value of the F_1 hybrid.

$\overline{MP}$ = mean value of the parents (P_1 and P_2) of a hybrid = $\{(\overline{p}_1 + \overline{p}_2)/2\}$

$\overline{BP}$ = mean value of the batter parent of the two parents used in the respective cross combination.

The standard errors and calculated 't' value for relative heterosis (H_1) and heterobeltiosis (H_2) were computed as below.

$$\text{S.E. of } H_1 = \sqrt{V_{F1} + (\{V_{P1} + V_{P2}\}/2)}$$

$$\text{S.E. of } H_2 = \sqrt{V_{F1} + V_{BP}}$$

$$\text{t for } H_1 = \frac{\overline{F}_1 - \overline{MP}}{S.E.of\,(H_1)}$$

$$\text{t for } H_2 = \frac{\overline{F}_1 - \overline{BP}}{S.E.of\,(H_2)}$$

The test of significance of the relative heterosis and heterobeltiosis was carried-out by comparing the calculated value of ‘t’ with the tabulated value of 't' at 5% and 1% levels of significance.

$$\text{Inbreeding depression (I.D)} = \frac{\overline{F}_1 - \overline{F}_2}{\overline{F}_1} \times 100$$

Where,

$\overline{F}_1$ = mean value of F_1 generation

$\overline{F}_2$ = mean value of F_2 generation

The test of significance for inbreeding depression was done as under:

$$\text{S. E. of I. D.} = \sqrt{S.E_{F1} + S.E_{F2}}$$

Results and Discussion

Pumpkin is a highly cross pollinated crop and a suitable mechanism to produce hybrid seed on commercial sale is available. Study on heterosis is useful for deciding the direction of future breeding programme and to identify the cross combination which are promising in conventional breeding programme. Heterosis over the mid-parental (relative heterosis) and better parent value (heterobeltiosis) were calculated for each cross combination. Inbreeding depression was calculated from the data of F_1 and F_2 generations.

The percentage values of relative heterosis, heterobeltiosis and inbreeding depression are furnished in table 2. The character wise results and discussion are highlighted here under. The parent with early flowering was considered as better parent because early flowering is a desirable character in pumpkin. The significant positive inbreeding depression indicating that F_2 was earlier than respective F_1 parent. Such crosses are expected to throw desirable segregants, which may be handled through pedigree method. The relative heterosis was ranged from -12.04 per cent (Ambili x Pusa Viswas) to 1.03 per cent (Rajasthan local x Pusa Viswas). Out the three crosses, cross Ambili x Pusa Viswas expressed significant and negative relative heterosis, suggested the presence of dominance gene effects in this cross. Cross Ambili x Pusa Viswas has been expressed significant and negative heterobeltiosis (–5.19 %). Negative estimation of heterosis and heterobeltiosis for the traits has also been reported by by Tamilselvi and Jansirani (2016) and Ahmed *et al*. (2017) in pumpkin; Singh *et al*. (2012) and Ghuge *et al*. (2016) in bottle gourd; Bairwa *et al*. (2017) in ridge gourd and Thakur *et al*. (2017) in cucumber. This may be due to presence of more dominance genes for earliness. Out of three crosses, two crosses *viz.*, Rajasthan local x Pusa Viswas (5.37 %) and Ambili x Pusa Viswas (–8.87 %) showed significant inbreeding depression. These results indicated that in F_2 decreased over F_1 generation. The significant inbreeding depression for this trait was also observed by Singh *et al*. (2015) in cucumber; Yadav and Kumar (2012) in bottle gourd (Table 2).

Heterosis over the mid-parental value was ranged from –18.99 per cent (Odisha local x Pusa Viswas) to 2.56 per cent (Ambili x Pusa Viswas). Among the three crosses, Odisha local x Pusa Viswas expressed significant and negative relative heterosis. Similar results were also observed for this trait by Podder *et al*. (2010) in snake gourd; Bairwa *et al*. (2017) in ridge gourd. The heterobeltiosis ranged from –5.88 per cent (Odisha local x Pusa Viswas) to 16.25 per cent (Rajasthan local x Pusa Viswas). Negative heterosis for nodal position of first female flower reported in this study indicates that F_1 hybrids can be produced with earliness and more yield. These findings was also in line with Kaur and Dhall (2017) and Thakur *et al*. (2017) in cucumber; Bairwa *et al*. (2017) in ridge gourd; Ghuge *et al*. (2016) in bottle gourd. The estimate of inbreeding depression in F_2 ranged

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from –81.25 per cent (Odisha local x Pusa Viswas) to -29.03 per cent (Rajasthan local x Pusa Viswas). All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas exhibited significant and negative inbreeding depression. Significant and negative inbreeding depression for nodal position of first female flower was also observed by Singh *et al*. (2015) in cucumber (Table 2).

Relative heterosis ranged from 24.22 per cent (Rajasthan local x Pusa Viswas) to 45.88 per cent (Ambili x Pusa Viswas). All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and positive relative heterosis. The heterobeltiosis ranged from 20.45 per cent (Rajasthan local x Pusa Viswas) to 40.91 per cent (Ambili x Pusa Viswas). All the hybrids showed significant and positive heterobeltiosis. Significant positive heterobeltiosis for this trait was also found by Singh *et al*. (2012) and Ghuge *et al*. (2016) in bottle gourd; Ahsan *et al*. (2011) in snake gourd. The minimum (-1.62 %) and maximum (8.56 %) values of inbreeding depression were observed in Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas. Significant inbreeding depression for this trait was also observed by Yadav and Kumar (2012) in bottle gourd (Table 2).

Relative heterosis was ranged from -23.58 per cent (Rajasthan local x Pusa Viswas) to -61.10 per cent (Ambili x Pusa Viswas) for fruit weight. All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative relative heterosis. The heterobeltiosis ranged from -22.58 per cent (Rajasthan local x Pusa Viswas) to -60.60 per cent (Ambili x Pusa Viswas) showed significant and negative heterobeltiosis. All the hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative heterobeltiosis. Similar results was also observed for this trait by Thakur *et al*. (2017) and Kaur and Dhall (2017) in cucumber; Mamun *et al*. (2016) in bitter gourd. Since negative heterosis was observed for fruit weight, selection for small sized fruits of consumer preference is possible in F_1 generation. The inbreeding depression ranged from 14.41 % (Rajasthan local x Pusa Viswas) to -57.07 % (Odisha local x Pusa Viswas) for all the crosses of this study. All the crosses resulted significant inbreeding depression for this trait. Here selection for small fruit size can be exercised through transgressive segregants. Significant inbreeding depression for fruit weight was also observed by Singh *et al*. (2015) in cucumber; Yadav and Kumar (2012) in bottle gourd (Table 2).

Heterosis with respect to the mid-parental value varied from -10.54 per cent (Rajasthan local x Pusa Viswas) to -38.18 per cent (Ambili x Pusa Viswas). All the three hybrids viz., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative heterosis. The heterobeltiosis ranged from -27.71 per cent (Ambili x Pusa Viswas) to 14.78 per cent (Odisha local x Pusa Viswas). Among the three crosses, Odisha local x Pusa Viswas exhibited significant and positive heterobeltiosis due the presence of dominance gene effects in this cross. Similar results was also observed for this trait by Selvi *et al*. (2014) in pumpkin; Ahsan *et al*. (2011) in snake gourd. The estimates of inbreeding depression observed in F_2 ranged from -31.69 per cent (Ambili x Pusa Viswas) to 16.19 per cent (Rajasthan local x Pusa Viswas). Among the three hybrids Rajasthan local x Pusa Viswas exhibited significant inbreeding depression for fruit polar diameter (Table 2).

Two crosses Rajasthan local x Pusa Viswas (-20.74 %) and Ambili x Pusa Viswas (-16.70 %) showed significant and negative heterosis for this trait. All the three hybrids *viz*., Odisha local x Pusa Viswas (-15.64 %), Rajasthan local x Pusa Viswas (-35.62 %) and Ambili x Pusa Viswas (-27.07 %) expressed significant and negative heterobeltiosis. Significant negative heterobeltiosis was also observed in pumpkin for this trait by Selvi *et al*. (2014). The inbreeding depression ranged from12.38 % (Odisha local x Pusa Viswas) to -42.53 % (Rajasthan local x Pusa Viswas). All the crosses resulted significant inbreeding depression for this trait. Significant inbreeding depression for fruit diameter was also observed by Singh *et al*. (2015) in cucumber; Yadav and Kumar (2012) in bottle gourd (Table 2).

All the three hybrids *viz*., Odisha local x Pusa Viswas (14.02 %), Rajasthan local x Pusa Viswas (15.89 %) and Ambili x Pusa Viswas (36.00 %) showed highly significant and positive relative heterosis. Among the hybrids Odisha local x Pusa Viswas (24.49 %) and Ambili x Pusa Viswas (21.43 %) showed highly significant and positive heterobeltiosis. Positive heterosis and heterobeltiosis for this trait was also observed by Ahmed *et al*. (2017) and Selvi *et al*. (2014) in pumpkin. The inbreeding depression ranged from 2.49 % in Rajasthan local x Pusa Viswas to 13.97 % in Ambili x Pusa Viswas. The inbreeding depression for number of fruits per vine was relatively minimum which was confirmed by Yadav and Kumar (2012) in bottle gourd (Table 2).

Relative heterosis ranged from -34.47 per cent (Ambili x Pusa Viswas) to 4.17 per cent (Rajasthan local x Pusa Viswas). Two crosses, Odisha local x Pusa Viswas and Ambili x Pusa Viswas showed significant and negative relative heterosis. Out of three crosses, two cross Odisha local x Pusa Viswas and Ambili x Pusa Viswas showed significant and negative heterosis and heterobeltiosis. Significant negative heterobeltiosis and heterosis for this character was also observed by Karipcin and Inal (2017) in summer squash; Ahmed *et al*. (2017) in pumpkin; Kaur and Dhall (2017) in cucumber. The inbreeding depression ranged from 15.93 % (Rajasthan local x Pusa Viswas) to -31.16 % (Odisha local x Pusa Viswas). All the crosses resulted minimum inbreeding depression for this trait. Hence, selection for maximum fruit yield can be exercised through transgressive segregants as well as through hybrids. The same results were also observed by Singh *et al*. (2015) in cucumber; Yadav and Kumar (2012) in bottle gourd (Table 2).

The percentage relative heterosis ranged from -32.74 per cent (Ambili x Pusa Viswas) to 3.98 per cent (Rajasthan local x Pusa Viswas). Odisha local x Pusa Viswas and Ambili x Pusa Viswas showed significant and negative heterosis. The ranged for heterobeltiosis was from -33.26 per cent (Ambili x Pusa Viswas) to 2.86 per cent (Rajasthan local x Pusa Viswas). All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative heterobeltiosis. Similar results was also observed for this trait by Thakur *et al*. (2017) in cucumber. Inbreeding depression varied from -24.48 per cent (Odisha local x Pusa Viswas) to 14.60 per cent (Rajasthan x Pusa Viswas) (Table 2).

The relative heterosis was ranged from -31.24 per cent (Rajasthan local x Pusa Viswas) to -23.94 per cent (Odisha local x Pusa Viswas). All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative heterosis. The maximum heterobeltiosis was in Odisha local x Pusa Viswas (-2.42 %) and it was minimum in Rajasthan local x Pusa Viswas (-21.25 %). All the three hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative heterobeltiosis. Inbreeding depression values were found from -8.69 per cent (Ambili x Pusa Viswas) to -12.05 per cent (Rajasthan local x Pusa Viswas). All the three Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant and negative inbreeding depression. The results indicated that F_2 decreased over F_1 generation (Table 2).

The relative heterosis ranged from -4.63 per cent (Odisha local x Pusa Viswas) to 4.71 per cent (Ambili x Pusa Viswas). Two crosses viz., Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas showed significant and positive heterosis. Positive heterosis was also observed for vine length by Ghuge *et al*. (2016) in bottle gourd. The range for heterobeltiosis was from -6.04 per cent (Rajasthan local x Pusa Viswas) to 0.51 per cent (Ambili x Pusa Viswas). Two crosses viz., Rajasthan local x Pusa Viswas and Odisha local x Pusa Viswas showed significant and positive heterobeltiosis. Inbreeding depression values were found from -6.16 per cent (Rajasthan local x Pusa Viswas) to -9.61 per cent (Odisha local x Pusa Viswas). All the hybrids *viz*., Odisha local x Pusa Viswas, Rajasthan local x Pusa Viswas and Ambili x Pusa Viswas expressed significant inbreeding depression (Table 2). Significant inbreeding depression for this trait was also observed by Yadav and Kumar (2012) in bottle gourd.

Since small flat type fruits are preferred by the consumers, one can also exploit the heterosis breeding to produce F_1 hybrids as in the case of Ambili x Pusa Viswas which harness maximum heterosis for fruit number and negative heterosis for earliness and weight. This as a whole implies the existence of scope for using these different populations in the long range for further improvement by adopting appropriate breeding methods as suggested and discussed. However, as a short term programme, the crosses which have exhibited significant desirable heterobeltiosis and heterosis can be further tested along with commercially viable hybrids across different seasons and locations for their worthiness for commercial cultivation.

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Table 1. Mean performance of parents, F_1's and F_2's of all characters

Sr. No	Cross / Characters	P_1	P_2	F_1	F_2	SE±	CD at 5%
I	**Days to first female flowering**						
	Cross I	43.60	51.20	47.00	46.73	1.32	2.81
	Cross II	45.80	51.20	49.00	46.37	1.22	2.60
	Cross III	44.30	51.20	42.00	45.73	1.08	2.30
II	**Nodal position of the first female flower**						
	Cross I	7.80	7.70	6.40	11.60	0.55	1.17
	Cross II	10.30	7.70	9.30	12.00	0.37	0.78
	Cross III	7.90	7.70	8.00	11.50	0.42	0.89
III	**Number of primary branches per vine**						
	Cross I	12.20	13.20	16.20	14.99	0.61	1.30
	Cross II	12.40	13.20	15.90	16.16	0.52	1.10
	Cross III	12.30	13.20	18.60	17.01	0.55	1.17
IV	**Fruit weight (kg)**						
	Cross I	4.05	4.11	2.42	3.80	0.15	0.31
	Cross II	4.00	4.11	3.16	2.70	0.21	0.44
	Cross III	4.01	4.11	1.94	2.65	0.18	0.38
V	**Fruit polar diameter (cm)**						
	Cross I	12.72	20.00	14.60	14.89	1.02	2.17
	Cross II	14.07	20.00	15.24	12.77	0.71	0.51
	Cross III	14.94	20.00	10.81	14.24	0.66	1.40
VI	**Fruit equatorial diameter (cm)**						
	Cross I	22.70	16.31	19.15	16.78	0.64	1.36
	Cross II	26.11	16.31	16.81	23.96	0.95	2.02
	Cross III	21.72	16.31	15.84	16.32	0.67	1.42
VII	**Number of fruits per vine**						
	Cross I	5.80	4.90	6.10	6.74	0.30	0.63
	Cross II	5.20	4.90	6.70	6.53	0.28	0.59
	Cross III	5.10	4.90	6.80	5.85	0.40	0.85
VIII	**Fruit yield per vine (kg)**						
	Cross I	23.23	19.93	14.87	19.51	1.07	2.28
	Cross II	20.64	19.93	21.13	17.76	1.29	2.74
	Cross III	20.42	19.93	13.22	15.52	1.84	3.92
IX	**Sex ratio**						
	Cross I	15.31	23.98	14.94	16.33	0.38	0.80
	Cross II	18.58	23.98	14.63	16.40	0.46	0.98
	Cross III	17.38	23.98	14.96	16.26	0.27	0.57
X	**Vine length (m)**						
	Cross I	4.51	4.47	4.28	4.69	0.12	0.25
	Cross II	3.69	4.47	4.20	4.45	0.12	0.25
	Cross III	4.11	4.47	4.30	4.69	0.13	0.27
XI	**Fruit yield per plot (kg)**						
	Cross I	183.43	160.15	123.47	153.47	7.50	15.98
	Cross II	163.69	160.15	168.37	143.78	10.13	21.59
	Cross III	162.62	160.15	108.54	127.08	14.30	30.47

Cross I = Odisha local × Pusa Viswas Cross II = Rajasthan local × Pusa Viswas Cross III = Ambili × Pusa Viswas

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Table 2. Relative heterosis (H1), heterobeltiosis (H2) and inbreeding depression expressed in percentage for eleven characters of pumpkin

Sr. No.	Cross / Characters	Relative Heterosis (H_1)	Heterobeltiosis (H_2)	Inbreeding depression(%)
I	**Days to first female flowering**			
	Cross I	-0.84	7.80**	0.57
	Cross II	1.03	6.99**	5.37**
	Cross III	-12.04**	-5.19**	-8.87**
II	**Nodal position of the first female flower**			
	Cross I	-18.99**	-5.88	-81.25**
	Cross II	1.64	16.25**	-29.03**
	Cross III	2.56	3.90	-43.75**
III	**Number of primary branches per vine**			
	Cross I	27.56**	22.73**	7.46**
	Cross II	24.22**	20.45**	-1.62
	Cross III	45.88**	40.91**	8.56**
IV	**Fruit weight (kg)**			
	Cross I	-40.69**	-29.86**	-57.07**
	Cross II	-23.58**	-22.58**	14.41**
	Cross III	-61.10**	-60.60**	-37.20**
V	**Fruit polar diameter (cm)**			
	Cross I	-10.76**	14.78**	-2.00
	Cross II	-10.54*	8.32	16.19**
	Cross III	-38.18**	-27.71**	-31.69**
VI	**Fruit equatorial diameter (cm)**			
	Cross I	-1.82	-15.64**	12.38**
	Cross II	-20.74**	-35.62**	-42.53**
	Cross III	-16.70**	-27.07**	-3.04
VII	**Number of fruits per vine**			
	Cross I	14.02**	24.49**	-10.52**
	Cross II	15.89**	6.90	2.49
	Cross III	36.00**	21.43**	13.97
VIII	**Fruit yield per vine (kg)**			
	Cross I	-26.42**	-26.54**	-31.16**
	Cross II	4.17	2.37**	15.93**
	Cross III	-34.47**	-41.40**	-17.44**
IX	**Sex ratio**			
	Cross I	-23.94**	-2.42**	-9.27**
	Cross II	-31.24**	-21.25**	-12.05**
	Cross III	-27.65**	-13.92**	-8.69**
X	**Vine length (m)**			
	Cross I	-4.63**	-5.10**	-9.61**
	Cross II	2.95**	-6.04**	-6.16**
	Cross III	4.71**	0.51	-8.95**
XI	**Fruit yield per plot (kg)**			
	Cross I	-28.12**	-32.69**	-24.48**
	Cross II	3.98	2.86	14.60**
	Cross III	-32.74**	-33.26**	-17.08**

Cross I = Odisha local × Pusa Viswas Cross II = Rajasthan local × Pusa Viswas Cross III = Ambili × Pusa Viswas
*Significant at 5% level **Significant at 1% level