Exploitation of heterobeltiosis and economic heterosis for horticultural yield, and its attributes and biochemical traits in pumpkin (*Cucurbita moschata* Duch. ex. Poir) under salt affected soil

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Pumpkin crop can be improved by exploitation of heterosis. This study was carried out during three different seasons, *Kharif*, 2015 (E_1), *Rabi* 2015–16 (E_2) and summer-season, 2016 (E_3) in Eastern Uttar Pradesh, India. The objective was to find out the magnitude of heterobeltiosis, economic heterosis and suitable cross-combination for higher quality fruit yield in pumpkin. Fifteen F_1 hybrids were developed through diallel mating design of six parental lines excluding reciprocals. The evolution of hybrids revealed significant heterobeltiosis as well as economic heterosis for all the traits in all three seasons independently (E_1, E_2 and E_3) and combined. Crosses $P_1 \times P_5$, $P_4 \times P_6$ and $P_1 \times P_2$ may be exploited as commercial hybrids for profitable yield in pumpkin. Significant heterobeltiosis and economic heterosis indicates the importance of heterosis breeding for the developing high yield hybrids.

Keywords: Diallel mating, fruit yield, heterobeltiosis, pumpkin, β-carotene.

PUMPKIN (*Cucurbita moschata* Duch. ex. Poir), originated in central Mexico and is one of the most important vegetable crops of the family Cucurbitaceae grown throughout the world. It provides better nutrition to consumers and higher returns to farmers. Pumpkin is a herbaceous annual, sexually propagated vegetable with chromosome number $2n = 2x = 40$.

Based on commercial significance, the cultivated *Cucurbita* sp. ranks among the 10 leading vegetable crops worldwide. China and India lead the world production and other major producers are the US, Egypt, Mexico, Ukraine, Cuba, Italy, Iran and Turkey. The three economically important species, *Cucurbita pepo*, *C. moschata*, and *Cucurbita maxima* are highly polymorphic in fruit characteristics, inspiring much research in their genetics, although most such studies have been in *C. pepo* and *C. maxima*. The colour of pumpkin is due to orange pigments. The main nutrients are lutein and both α- and β-carotene, the latter of which is a precursor of vitamin A. Pumpkins are versatile for cooking. Most parts of the pumpkin are edible, including fleshy shell, seeds, leaves and even flowers. In the United States and Canada, pumpkin is a popular Halloween and Thanksgiving staple. Pumpkin purée can be frozen for later use. Pumpkin is relatively high in energy and carbohydrates and a good source of vitamins, especially high caretenoid pigments and minerals. It may certainly contribute to the nutritional status of people, particularly the vulnerable groups, with respect to vitamin A requirement. Night-blindness is a serious problem in South Asian countries. Encouraging the masses to consume more pumpkin can easily solve the problem.

Pumpkin crop can be improved by assessing the genetic variability and exploitation of heterosis. Because of the monoecious nature of the crop, large flower size, ease of pollination, high proportion of fruit set of pollinated female flowers, large number of seeds per fruit and low seed rate required per unit area, pumpkin is highly amenable for heterosis breeding. During the last three decades considerable studies have been done on hybrid vigour in pumpkin and a high amount of heterosis has been reported[1–6]. Several hybrids have been released by public and private sectors for its commercial cultivation. The area under F_1 hybrids is growing fast, which has helped to enhance the productivity and production of this crop.

The present study was carried out at the main experiment station, Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (UP), India, during *Kharif*, 2015 (E_1), *Rabi* 2015–16 (E_2) and *Zaid* (E_3) of 2016. The experimental farm falls under humid subtropical climate and is located between 24.47° and 26.56°N lat and 82.12° and 83.58°E long at an altitude of 113 m amsl. The experimental farm had saline alkali soil with pH above 8.

The experimental materials comprised of six promising and diverse inbreds and varieties of pumpkin selected on the basis of genetic variability from the germplasm stock maintained in the laboratory. The selected parental lines, i.e. Narendra Upkar (P_1), NDPK-120 (P_2), Narendra Agrim (P_3), NDPK-39-2 (P_4), Kashi Harit (P_5) and NDPK-11-3 (P_6) were raised and crossed in all possible combinations, excluding reciprocals, during *Zaid*, 2015 to get 15 F_1 hybrid seeds for the study of heterobeltiosis and economic heterosis.

The experiments were conducted in randomized block design (RBD) with three replications to assess the performance of 15 F_1 hybrids and 6 parents. The treatments were planted in rows spaced 3 m apart with a plant to plant spacing of 0.5 m. The seeds were sown on 23 July 2015, 7 November 2015 and 26 March 2016 for *Kharif*, *Rabi* and *Zaid* crops respectively. All recommended agronomic practices and plant protection measures were followed.

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Observations were recorded for 14 economic traits including biochemical analysis, viz. days to first female flower anthesis, days to first male flower anthesis, node number to first male flower appearance, node number to first female flower appearence, days to first fruit harvest, vine length (m), internodal length (cm), number of primary branches per plant, fruit weight (kg), number of fruits per plant, equatorial circumference of fruit (cm), polar circumference of fruit (cm), flesh thickness (cm), fruit yield per plant (kg), dry matter content (%), total soluble solids (°B), reducing sugars (%), non-reducing sugars (%), total sugars (%), ascorbic acid (mg/100 g) and β-carotene (mg/100 g). In addition to these characters fruit shape and fruit colour were also observed.

Ascorbic acid content was estimated at marketable green fruit stage by '2,6-dichlorophenol-indophenol visual titration method' as described[7]. Reducing sugars were estimated by Fehling 'A' and 'B' solution method[8]. Non-reducing sugars were calculated by deducting the quantity of reducing sugars from total invert sugars and multiplied by a factor 0.95. The results were expressed as per cent non-reducing sugars.

Total sugars were calculated by adding the quantity of reducing and non-reducing sugars. The results were expressed as total sugars in percentage.

A quantity of 100 g of fresh fruit was taken, cut into small pieces and kept in oven at 60 ± 2°C for 8–10 h per day till the fruit was completely dry. Dry matter percentage was calculated as

$$\text{Dry matter (\%)} = \frac{\text{Dry matter of fruit (g)}}{\text{Fresh weight of fruit (g)}} \times 100.$$

Total soluble solids (TSS) of fresh fruit juice for each line and F_1 were determined with the help of hand refractometer (Erma, Japan) of 0–32% range. The values were collected at 20°C and expressed as per cent TSS of fresh fruit juice.

β-carotene content was determined in mature fruit sample using the method developed[9].

The magnitude of heterosis was studied using various quantitative and fruit quality traits. Heterosis is expressed as per cent increase or decrease in the mean values of F_1's (hybrid) over better-parent (heterobeltiosis) and standard variety (standard heterosis)[10]. The formula used for estimation of heterosis is

$$\text{(a) Heterobeltiosis (\%)} = ((\overline{F_1} - \overline{BP})/\overline{BP}) \times 100,$$

$$\text{(b) Standard heterosis (\%)} = ((\overline{F_1} - \overline{SV})/\overline{SV}) \times 100,$$

where $\overline{F_1}$ is the mean value of F_1, $\overline{BP}$ the mean value of better-parent and $\overline{SV}$ is the mean value of standard variety. The significance of heterosis was tested by t tests as

$$t\text{ (heterobeltiosis)} = (\overline{F_1} - \overline{BP})/\text{SE},$$

$$t\text{ (standard heterosis)} = (\overline{F_1} - \overline{SV})/\text{SE},$$

SE of heterosis over better-parent and standard variety = square root 2MSe/r, where Me is the error mean of square, r the number of replications and SE is the standard error of the treatments mean and (t) is the table value of (t) at 5% or 1% level of significance at error of degree of freedom.

The calculated value t was compared with table value t at error d.f. at 5% and 1% level of probability for testing the significance of heterosis.

The exploitation of heterosis requires an intensive evaluation of germplasm to find diverse donors with high nicking of genes and identify heterotic crosses. In the present study the estimates of heterosis over better parent (BP), and standard variety (SV)/economic parent Narendra Agrim were calculated for fifteen F_1's in three seasons (E_1, E_2 and E_3) and also over all seasons (pooled).

Table 1 reveals that nature and magnitude of heterosis differed for different traits and over seasons in various hybrid combinations. A wide range of variations in positive and negative direction of heterosis were also recorded in all the three seasons (E_1, E_2 and E_3 pooled). Table 1 also reveals that crosses exhibiting significant and positive heterosis estimates for fruit yield also exhibited significant heterosis for other important yield, yield attributing traits and biochemical traits. In contrast none of the crosses showed significant and desirable heterosis for all traits.

Hybrids with heterosis for earliness produce first fruit earlier compared to parents, thereby increasing production and productivity per unit area and fetch good prices by early produce supply in the market. A close examination of heterosis values for five maturity traits, i.e. days to first male and female flower anthesis, node number to first male and female flower appearance and days to first fruit harvest, revealed 12 and 15 hybrids for days to first male flower anthesis, 9 and 5 hybrids for days to first female flower anthesis, 12 and 15 hybrids for node number to first male flower appearance, 6 and 13 hybrids for node number to first male flower appearance, 10 and 7 hybrids for days to first fruit harvest in pooled exhibited significant and desirable heterosis in respect to better and standard parent respectively. However, top ranked crosses for fruit yield were almost at par for earliness and thereby showed good scope for early hybrids.

Our study also revealed that at least one parent (P_1, P_2, P_4 and P_6) with early maturity was invariably involved in the top three F_1 hybrids ($P_1 \times P_2$, $P_1 \times P_5$ and $P_4 \times P_6$) for fruit yield over better parent and standard parent (Narendra Agrim) in pooled cohort. Further the early maturing parents as well as crosses were directly associated with high magnitude of heterosis. Therefore, it can be concluded that either parents, P_1, P_2, P_4 and P_6 or any two of

Table 1. Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Narendra Agrim over seasons (pooled)

	Heterosis % in pooled analysis					
Trait	Days to first male flower anthesis		Days to first female flower anthesis		Node no. to first male flower appears	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	–10.03*	–23.19**	–10.66**	–3.46**	–10.03*	–23.19**
$P_1 \times P_3$	–21.07**	–27.14**	–0.78	–0.78	–21.07**	–27.14**
$P_1 \times P_4$	–20.96**	–27.55**	–8.34**	–0.96	–20.96**	–27.55**
$P_1 \times P_5$	–21.90**	–27.92**	–13.73**	–10.72**	–21.90**	–27.92**
$P_1 \times P_6$	–14.12**	–24.07**	0.61	2.63*	–14.12**	–24.07**
$P_2 \times P_3$	–12.69**	–25.46**	–0.85	–0.85	–12.69**	–25.46**
$P_2 \times P_4$	4.70	–10.62**	–8.23**	–0.23	4.70	–10.62**
$P_2 \times P_5$	–6.03	–19.78**	–4.36**	–1.02	–6.03	–19.78**
$P_2 \times P_6$	7.70	–8.05*	–3.39**	–1.45	7.70	–8.05**
$P_3 \times P_4$	–16.23**	–23.21**	2.02	2.02	–16.23**	–23.21**
$P_3 \times P_5$	–25.85**	–31.42**	–4.74**	–4.74**	–25.85**	–31.42**
$P_3 \times P_6$	–23.86**	–32.68**	–1.08	–1.08	–23.86**	–32.68**
$P_4 \times P_5$	–19.45**	–26.16**	–5.65**	–2.36*	–19.45**	–26.16**
$P_4 \times P_6$	–17.72**	–27.25**	–9.84**	–8.03**	–17.72**	–27.25**
$P_5 \times P_6$	–11.61**	–21.85**	–1.59	0.38	–11.61**	–21.85**
No. of crosses with significant (+) heterosis	0	0	0	1	0	0
No. of crosses with significant (–) heterosis	12	15	9	5	12	15
Range of heterosis	–25.85 to 7.70	–32.68 to –8.05	–13.73 to 2.02	–10.72 to 2.02	–25.85 to 7.70	–32.68 to –8.05

	Heterosis % in pooled analysis					
Trait	Node no. to first female flower appears		Days first fruit harvest		Number of primary branches per plant	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	16.16**	–13.07**	–10.07**	–3.75**	19.83**	71.34**
$P_1 \times P_3$	16.02**	–13.18**	–3.84**	–3.84**	24.18**	77.57**
$P_1 \times P_4$	24.13**	–7.11*	–11.24**	–5.00**	18.82**	69.91**
$P_1 \times P_5$	27.33**	–4.72	–13.96**	–11.42**	19.78**	71.28**
$P_1 \times P_6$	13.42**	–15.13**	–0.32	0.19	10.68**	58.26**
$P_2 \times P_3$	–11.17**	–18.38**	–0.15	–0.15	20.62**	45.79**
$P_2 \times P_4$	–0.56	–8.63**	–6.98**	–0.05	36.55**	65.05**
$P_2 \times P_5$	–11.43**	–18.62**	–3.82**	–0.97	26.83**	61.99**
$P_2 \times P_6$	–8.53**	–15.95**	–4.04**	–3.56**	10.61**	53.89**
$P_3 \times P_4$	–19.47**	–19.72**	2.46**	2.46**	62.11**	76.76**
$P_3 \times P_5$	–21.09**	–27.41**	–7.81**	–7.81**	49.17**	90.53**
$P_3 \times P_6$	–17.07**	–19.40**	1.11	1.11	9.09**	51.78**
$P_4 \times P_5$	–3.06	–10.83**	–2.78**	0.09	52.34**	94.58**
$P_4 \times P_6$	–10.71**	–13.22**	–6.85**	–6.38**	55.35**	116.14**
$P_5 \times P_6$	3.92	–4.40	1.24	1.76	38.15**	92.21**
No. of crosses with significant (+) heterosis	5	0	1	1	15	15
No. of crosses with significant (–) heterosis	6	13	10	7	0	0
Range of heterosis	–21.09 to 27.33	–27.41 to –4.40	–13.96 to 2.46	–11.42 to 2.46	9.01 to 62.11	45.79 to 116.14

(Contd)

Table 1. (*Contd*)

	Heterosis % in pooled analysis					
Trait	Number of primary branches per plant		Equatorial circumference of fruit (cm)		Polar circumference of fruit (cm)	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	15.02**	47.63**	22.49**	9.47**	13.75**	11.89**
$P_1 \times P_3$	3.93	33.39**	12.15**	12.15**	6.37*	6.37*
$P_1 \times P_4$	16.12**	49.03**	13.73**	5.57*	20.65**	12.74**
$P_1 \times P_5$	17.09**	50.29**	12.93**	2.17	11.65**	0.25
$P_1 \times P_6$	14.76**	49.22**	23.33**	12.21**	19.78**	8.89**
$P_2 \times P_3$	26.22**	40.04**	–5.30*	–5.30*	–4.56	–4.56
$P_2 \times P_4$	36.48**	52.56**	12.30**	4.24	5.91*	4.18
$P_2 \times P_5$	13.63**	40.90**	16.86**	5.73*	14.10**	12.23**
$P_2 \times P_6$	12.41**	46.17**	9.95**	0.03	15.84**	13.94**
$P_3 \times P_4$	41.86**	58.58**	2.30	2.30	10.93**	10.93**
$P_3 \times P_5$	38.41**	71.63**	–5.14*	–5.14*	13.26**	13.26**
$P_3 \times P_6$	16.42**	51.38**	6.78**	6.78**	8.98**	8.98**
$P_4 \times P_5$	42.90**	77.21**	19.64**	11.06**	17.86**	10.14**
$P_4 \times P_6$	44.77**	88.24**	13.90**	5.73*	13.01**	5.61
$P_5 \times P_6$	27.01**	65.15**	26.41**	15.01**	21.87**	10.79**
No. of crosses with significant (+) heterosis	14	15	12	9	14	10
No. of crosses with significant (–) heterosis	0	0	2	2	0	0
Range of heterosis	3.93 to 44.71	40.04 to 88.24	–5.30 to 26.41	–5.30 to 15.01	–4.56 to 21.87	–4.56 to 13.94

	Heterosis % in pooled analysis					
Trait	Flesh thickness (cm)		Internodal length (cm)		Vine length (m)	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	10.79*	–5.71	–7.39*	–17.91**	9.71	–0.52
$P_1 \times P_3$	1.96	1.96	–16.34**	–16.34**	14.47	14.47
$P_1 \times P_4$	10.22*	–6.20	3.18	–2.52	28.45**	16.47*
$P_1 \times P_5$	3.70	–0.37	–22.67**	–23.10**	–4.68	–13.57
$P_1 \times P_6$	6.61	4.00	1.08	–16.60**	19.62*	8.46
$P_2 \times P_3$	–10.24*	–10.24*	12.02**	–0.71	7.48	7.48
$P_2 \times P_4$	18.03**	0.20	12.55**	–0.24	–0.03	–11.70
$P_2 \times P_5$	3.44	–0.61	–0.13	–11.47**	25.46*	–15.51*
$P_2 \times P_6$	–5.23	–7.55	4.25	–13.99**	52.47**	2.68
$P_3 \times P_4$	–0.41	–0.41	–17.43**	–21.99**	–21.27*	–21.27**
$P_3 \times P_5$	2.78	2.78	–20.89**	–21.33**	–25.98**	–25.98**
$P_3 \times P_6$	–6.12	–6.12	14.09**	–5.87*	–18.13*	–18.13*
$P_4 \times P_5$	3.65	–0.41	10.80**	4.69	–12.40	–22.62**
$P_4 \times P_6$	1.13	–1.35	–16.37**	–31.00**	23.45**	9.05
$P_5 \times P_6$	–5.02	–7.35	24.93**	3.07	28.33**	–20.25**
No. of crosses with significant (+) heterosis	3	0	5	0	6	1
No. of crosses with significant (–) heterosis	1	1	6	10	3	6
Range of heterosis	–10.24 to 18.03	–10.24 to 2.78	–20.89 to 24.93	–31.00 to 4.69	–25.98 to 52.47	–25.98 to 16.47

*,**Significant at 5% and 1% probability levels respectively.

(*Contd*)

Table 1. (*Contd*)

	Heterosis % in pooled analysis					
Trait	Average fruit weight (kg)		Number of fruits per plant		Fruit yield per plant (kg)	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	–2.97	0.82	94.96**	46.08**	107.86**	47.86**
$P_1 \times P_3$	0.68	0.68	13.80*	13.80*	14.75	14.75
$P_1 \times P_4$	–0.78	–6.46	8.71	32.33**	7.80	23.88**
$P_1 \times P_5$	16.68**	6.97	9.01*	56.59**	47.59**	67.27**
$P_1 \times P_6$	8.53*	–0.51	33.51**	17.19**	69.83**	16.40*
$P_2 \times P_3$	–5.56	–1.87	–4.06	–4.06	–5.37	–5.37
$P_2 \times P_4$	–13.90**	–10.54**	–16.44**	1.72	–20.19**	–8.28
$P_2 \times P_5$	–20.66**	–17.56**	–24.07**	9.07	–20.17**	–9.52
$P_2 \times P_6$	–10.14**	–6.63	38.90**	21.92**	60.21**	13.97
$P_3 \times P_4$	–16.09**	–16.09**	–6.08	14.33**	–16.36**	–3.89
$P_3 \times P_5$	–15.80**	–15.80**	–2.13	40.59**	4.59	18.54*
$P_3 \times P_6$	–24.98**	–24.98**	15.28**	15.28**	–13.22**	–13.22
$P_4 \times P_5$	–11.11**	–16.20**	–23.30**	10.17**	–19.32**	–7.29
$P_4 \times P_6$	–5.83	–11.21**	44.13**	75.45**	35.56**	55.78**
$P_5 \times P_6$	3.78	–18.27**	–13.96**	23.59**	–11.60	0.19
No. of crosses with significant (+) heterosis	2	0	7	12	5	6
No. of crosses with significant (–) heterosis	7	8	4	0	5	0
Range of heterosis	–24.98 to 16.68	–24.98 to 6.97	–23.30 to 94.96	–4.06 to –75.45	–20.19 to 107.86	–13.22 to 67.27

	Heterosis % in pooled analysis					
Trait	Dry matter content (%)		Total soluble solids		Total sugars (%)	
Crosses	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	–5.15	19.89**	34.22**	13.12**	14.56**	18.86**
$P_1 \times P_3$	10.65**	27.14**	12.91**	12.91**	12.12*	16.33**
$P_1 \times P_4$	1.18	16.25**	20.78**	9.99*	19.71**	24.20**
$P_1 \times P_5$	3.38	18.79**	36.03**	17.95**	10.22*	14.36**
$P_1 \times P_6$	1.46	16.58**	14.62**	1.49	–2.45	2.73
$P_2 \times P_3$	–3.91	21.46**	14.30**	14.30**	29.61**	29.61**
$P_2 \times P_4$	3.15	30.37**	22.48**	11.55**	8.08	2.02
$P_2 \times P_5$	–2.30	23.49**	33.39**	15.66**	25.60**	19.69**
$P_2 \times P_6$	1.14	27.84**	26.52**	12.03**	1.62	7.02
$P_3 \times P_4$	12.55**	15.80**	9.55***	9.55	12.02*	12.02*
$P_3 \times P_5$	29.34**	29.34**	16.05**	16.05**	14.70**	14.70**
$P_3 \times P_6$	17.16**	17.16**	3.24	3.24	–6.67	–1.71
$P_4 \times P_5$	8.00*	11.12**	19.99**	9.28*	1.30	–3.46
$P_4 \times P_6$	10.46**	13.65**	28.23**	16.79**	–6.87	–1.93
$P_5 \times P_6$	22.83**	20.01**	33.07**	17.83**	1.87	7.29
No. of crosses with significant (+) heterosis	7	15	14	12	8	8
No. of crosses with significant (–) heterosis	0	0	0	0	0	0
Range of heterosis	–3.91 to 29.34	11.12 to 30.37	3.24 to 36.03	1.49 to 17.95	–6.87 to 29.61	–3.46 to 29.61

(*Contd*)

Table 1. (*Contd*)

Trait	Heterosis % in pooled analysis							
	Reducing sugar (%)		Non-reducing sugars (%)		Ascorbic acid (mg/100g)		β-carotene (mg/100 g)	
Crosses	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	14.68*	25.89**	–2.03	8.96	38.46**	38.33**	–10.35**	–10.35**
$P_1 \times P_3$	18.40*	18.40*	2.87	14.40	13.43**	13.43**	–17.94**	–32.61**
$P_1 \times P_4$	33.08**	29.87**	5.29	17.09*	38.80**	21.07**	–4.59	–21.66**
$P_1 \times P_5$	34.29**	31.06**	–16.06*	–6.65	15.73**	5.30	15.74**	–4.96
$P_1 \times P_6$	–5.36	2.80	–6.27	4.23	22.70**	9.71**	–11.47**	–11.47**
$P_2 \times P_3$	27.17**	39.60**	12.14	12.14	17.53**	17.53**	–28.21**	–30.67**
$P_2 \times P_4$	–0.36	9.37	2.61	–6.98	24.66**	24.54**	–18.19**	–20.99**
$P_2 \times P_5$	31.48**	44.33**	–9.68	–10.82	20.83**	20.72**	31.46**	26.97**
$P_2 \times P_6$	21.59**	33.46**	–24.44**	–23.57**	–2.27	–2.36	–5.93*	–5.93*
$P_3 \times P_4$	34.95**	34.95**	–17.03*	–17.03*	–2.21	–2.21	–28.09**	–28.09**
$P_3 \times P_5$	40.17**	40.17**	–16.98*	–16.98*	–4.39	–4.39	–42.92**	–42.92**
$P_3 \times P_6$	0.65	9.33	–16.51*	–15.55*	6.00	6.00	23.73**	–11.87**
$P_4 \times P_5$	11.78	3.46	–11.02	–12.14	31.95**	20.06**	38.94**	1.79
$P_4 \times P_6$	3.55	12.48	–20.91**	–20.00*	47.08**	31.50**	33.92**	–1.89
$P_5 \times P_6$	7.46	16.73*	–0.76	0.38	21.57**	10.61**	6	2
No. of crosses with significant (+) heterosis	9	10	0	1	11	10	8	9
No. of crosses with significant (–) heterosis	0	0	6	5	0	0	–42.92 to 38.94	–42.92 to 26.97
Range of heterosis	–5.36 to 40.17	2.80 to 44.35	–24.44 to 12.14	–23.57 to 17.09	–4.39 to 47.08	–4.39 to 38.33	16.34**	12.36**

*,**Significant at 5% and 1% probability levels respectively.

them may be a better choice in heterosis breeding programme intended to breed high yielding hybrids with earliness trait. The present observations agree with the findings in bottle gourd[11,12].

Among crosses for fruit yield, few showed positive and significant heterobeltiosis for quality traits, viz. dry matter, T.S.S., total sugars, reducing and non-reducing sugar, ascorbic acid, and β-carotene. For instance, out of six crosses which exhibited significant heterobeltiosis for fruit yield, only one cross for dry matter, all crosses for total soluble solids, two crosses for total sugars, three crosses for reducing sugars, four crosses for ascorbic acid and four for β-carotene content showed significant and desirable heterosis. The number of crosses, showing significant standard heterosis for quality traits and fruit yield, was generally larger in number than the crosses for significant better parent heterosis. This showed negative association for heterosis between fruit yield and quality traits. Five crosses over better parent and six crosses over standard parents showed significant heterosis over seasons for fruit yield (Table 1). Increased yield in crosses of pumpkin observed is in conformity with other findings[1–5]. The improvement in heterosis for yield component may not necessarily increase yield. The increased fruit yield may result from increase in one or more component traits. In the present study, the best performing heterobeltiotic F_1 ($P_1 \times P_2$) for yield common over seasons also showed significant and top ranked heterobeltiosis for number of fruits per plant over seasons. This hybrid also showed significant and desirable heterosis for a number of primary branches per plant, equatorial circumference of fruit, polar circumference of fruit, and flesh thickness. All crosses showed significant standard heterosis for a number of fruits per plant in pooled analysis. Among top heterotic crosses some of the parents were more frequently involved. The above findings indicate that some inbreds had more heterotic capability compared to others. The performance of hybrids depends upon the heterotic capability of parents involved and from an economic point of view, it will be useful to select and utilize parental inbreds with strong heterotic capability for important economic traits associated with yield in order to achieve higher gains in F_1 hybrids through exploitation of heterosis.

Table 1 shows five best crosses on the basis of desirable and significant heterobeltiosis, *per se* performance and common crosses among them for 21 traits. Pooled analysis revealed that $P_1 \times P_2$, $P_4 \times P_6$, $P_2 \times P_6$, $P_1 \times P_6$ and $P_3 \times P_6$ were common crosses on the basis of *per se* performance and of these, common crosses for fruit yield per plant $P_1 \times P_2$ and $P_1 \times P_5$ were also common for *per se* performance, better parent heterosis for fruit yield and some other traits studied. Standard heterosis of five best cross combinations along with *per se* performance and common crosses for other different characters are present in Table 1. The extent of heterosis in five best crosses

(35.56–107.86%) for fruit yield per plant revealed that there is great scope for improving pumpkin yield through heterosis breeding.

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Estimates of losses caused in paddy due to rice hispa, *Dicladispa armigera* (Oliver) (Coleoptera: Chrysomelidae)

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Studies were undertaken for two consecutive years (*kharif* 2015 and 2016) at the CSK Himachal Pradesh Krishi Vishvidyalaya, Rice and Wheat Research Centre, Malan (Himachal Pradesh, India) under field conditions using paddy variety 'Kasturi Basmati'. Losses in paddy due to rice hispa, *Dicladispa armigera* (Oliver) were quantified in terms of release density (number of adults per tiller) and phenological stages of crop. Results revealed that both these aspects significantly influenced leaf damage as well as yield of paddy. Early stage release (20 DAT, days after transplanting) contributed to maximum leaf damage (69.9 PLDI (per cent leaf damage index)) and at the same time exerted a significant negative influence on various yield components, viz. number of tillers, panicles, grains and grain weight (g) for which the respective regression coefficients were 5.82, 5.73, 441.4 and 8.06, respectively (per 4 rice hills).

Keywords: Grain number, grain weight, hispa release density, leaf damage, panicles, tillers, yield components.

MANY insect-pests of paddy continue to be the key biotic constraint in achieving its potential production. With the changing insect-pest scenario, many minor pests are now emerging as pests of major importance. Rice hispa, *Dicladispa armigera* (Oliver) (Coleoptera: Chrysomelidae) is one among them. It was earlier a pest of sporadic occurrence, but has now been reported to cause severe losses, especially in Bangladesh, India and Nepal[1,2]. In India, losses in rice (28–100%) due to this pest were recorded by various studies in different rice growing states[2–4]. Though the losses were quantified in different studies, limited studies provide the exact estimates. Hence this study was undertaken to quantify yield losses caused due to rice hispa based on release density and phenological stage of paddy crop.

Yield losses were assessed in terms of the relationship of hispa density and phenological stage of paddy (cv. Kasturi Basmati) at the experimental farm of CSKHPKV Rice and Wheat Research Centre, Malan (Himachal Pradesh) for two *kharif* seasons (2015 and 2016). The experiment was carried out by dividing the experimental field into three major plots (or ranges, measuring

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