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Genetics and heterosis for short stature, earliness and high productivity in pumpkin for intensive cultivation

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Abstract

The intensive cultivation of pumpkin demands genetic studies of bush growth, earliness and high yield that was carried out in half diallel including bush and butternut parents. In this study, P-1343 was the best general combiner for short vine, earliness and lower fruit weight; P-41212 was best general combiner for days to 50% male flowering (-1.72) and number of fruits per plant (0.23) and P-10224, was the best general combiner for fruit yield per plant (0.89). Among 36 crosses, high specific combining ability (SCA) in P-41212 × P-6242, PS × P-364, PS× P-1343, P-10224× P-6242, P-41212 × P-2211, P-41212 × P-10224, P-3621 × P-2211 and PS × P-6242 for short vine growth and earliness and in P-6711 × P-10224, PS × P-2211, P-41212 × P-3621, P-41212 × P-1343, P-364 × P-10224 for yield per vine represented the occurrence of both additive and non-additive gene effects with the predominance of non-additive effects (ó²SCA/ ó²GCA >1) for the inheritance of most of these traits in pumpkin and suggested further improvement through heterosis breeding and recurrent selection for high SCA. Among hybrids, PS × P-364 (27.96%), being bush type and early, represented significant and desirable economic heterosis for yield per hectare over PPH-2 and was at par with PPH-1. It could be fit into intensive cultivation after testing in multi-environments.

Key words: Pumpkin, combing ability, heterosis, earliness, yield, intensive cultivation

Introduction

Pumpkin (*Cucurbita moschata* Duch ex Poir.2n=40) is always recognized for its long trailing vines, big flat round to round fruits with conspicuously large seed cavity. This crop has good summer hardiness and better storage life than the various member species of *Cucurbitaceae* family. To adjust more number of vines per unit area dwarf nature of crop should be preferable. In pumpkin, bush nature of vine was found to be controlled by a dominant gene and reported to have tight linkage to some markers (Li et al. 2007). However, this trait in *C. maxima* has been reported to be controlled by two recessive genes and found orthologous to the dwarf genes in *C. pepo* (Denna and Munger 1963). In this crop a variety of fruit shapes and sizes available in the germplasm (Maynard et al. 2002), but, in India, majority genotypes are large fruited and most of the previous work points towards the increase in productivity by concentrating on more vigorous vines and large fruit size. Now days, its fruit size is becoming important trait for consumer acceptability. Usually, it is sold in the market after cutting, which is an unhygienic practice. Moreover, the bigger fruits are difficult to handle in marketing chain. Therefore, small sized fruits are required to counter this problem. Additionally, pumpkin have larger fruit cavity with lesser pulp that cut down the consumer portion. However, butternut segment of pumpkin, available in American and European continent, is characterized with small seed cavity, greater pulp thickness and less number of seeds. Now a day, the pumpkin genotypes with short vines, more number of fruits with greater pulp thickness and higher yield are of great demand due to suitability for intensive cultivation. To identify the genotypes with desirable traits, it is necessary to assess the combining ability (GCA and SCA) and the genetics of yield and its related traits involving bushy and butternut parents with relatively better performance. Many researchers studied the genetic variability, combining ability and heterosis of pumpkin (Bairagi et al. 2005, Pandey et al. 2010), but the improvement of existing germplasm for high yield in intensive cultivation is not documented anywhere. Therefore, the present investigation was initiated to study the combining ability and genetics and heterosis for earliness and high yield in crosses involving parents with different growth habit and fruit traits.

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Materials and Methods

The experimental material comprised of nine parents viz Punjab Samrat (PS, medium round fruit and long vine), P-1343 (Flat round fruit and medium vine), P-2211(medium round fruit and short vine), P-6711(small round fruit and very short vine), P-3621(butternut and short vine), P-41212 (medium round and short vine), P-10224 (very big round fruit and long vine), P-6242(butternut fruit and long vine), P-364 (butternut fruit and short vine) with different growth habit and fruit type. In summer season of 2015, all the parents were raised in crossing block and all possible crosses were made according to diallel mating fashion with the exclusion of reciprocals. Also the individual parents were selfed for their maintenance. All the crosses and parents were harvested separately and seed was stored for the next season crop. In next summer (2016), all the F_1 crosses, their parents and check hybrids (PPH-1 and PPH-2) were raised in randomized block design with three replications as suggested by Snedecor and Cochran (1967). PPH-1 and PPH-2 are extra early short vine hybrids with small sized fruits (750-900g) having thick pulp and recently released in Punjab Agricultural University for commercial cultivation in intensive system. Bush type parents and crosses involving such parents were transplanted at 1.5 × 0.45 m (Row × Plant) spacing on both sides of beds, while vine parents and only vine type crosses were raised at 3 × 0.60 m (Row × Plant) spacing on both side of beds, while maintaining ten plants per replication. The data pertaining to yield and its related traits such as vine length, earliest node to male and female flower, days to 50% male and female flowering, node to first fruit, days to fruit maturity, number of fruits per plant, average fruit weight (kg) and fruit yield per vine (kg) were recorded on five randomly selected plants. The analysis of variance for Randomized Block Design as well as combining ability was done for all the characters as per the method given by Griffing (1956). The data regarding yield and related traits was compiled up and run in BMM software (Singh 1993) for testing the significance of differences for general combing ability (GCA) and specific combining ability (GCA) among parents and F_1 crosses, respectively. The economical heterosis was also estimated over check hybrids (PPH-1 and PPH-2) and stated as percentage gain or loss in the average performance of crosses.

Results and Discussion

Analysis of variance for the experimental design for short vine, earliness and yield related traits highlighted the outcome of highly significant genotypic coefficient of variance for all the traits under exploration. Analysis of variance for combining ability revealed highly significant mean square values for GCA and SCA, where ó^{2}SCA/ ó^{2}GCA were >1 (Table 1). Highly significant genotypic coefficient of variances confirmed the substantial amount of variation for short vine, earliness and yield traits in the parental lines selected for the present investigation. Highly significant mean square values for GCA and SCA indicated the involvement of both additive and non-additive gene effects in the inheritance of the traits under observation. The greater ratio of ó^{2}SCA/ ó^{2}GCA (>1) also suggested that the inheritance of most of the traits were controlled by the preponderance of non-additive gene effects. These results were substantiated with the findings in sponge gourd (Naliyadhara et al. 2010).

GCA of parents: The GCA effects of various earliness and yield traits were presented in Table 2. Medium vine and flat round fruited, P-1343, was best general combiner for earliest node to female flower (-2.43) and 50% female flowering (-5.03), earliest node to male flower (-0.07), node to first fruit (-2.03), days to fruit maturity (-5.17), as well as good general combiner for average fruit weight (-0.45) and average general combiner for number of fruits per plant (0.04). Bushy and butternut parent, P-3621 was best general combiner for earliest node to male flower (-0.07) as well as good general combiner for earliest node to female flower (-1.78) and

Table 1: Analysis of variance for combining ability of characters related to short vine, earliness and yield

Parameters	GCA	SCA	Error	Components of genetic variance		
	d.f. =8	d.f. =36	d.f.=88	σ^2GCA	σ^2SCA	σ^2SCA/ σ^2GCA
Vine length (cm)	12358.4**	4903.19**	62.73	5.06	41.66	8.23
Earliest node to female flower	22.49**	8.16**	0.17	0.01	0.11	11
Days to 50% female flowering	167.85**	46.13**	1.31	0.10	0.86	8.6
Earliest node to male flower	0.13**	0.051**	0.008	0.0007	0.0057	8.14
Days to 50% male flowering	27.42**	5.86**	0.72	0.05	0.47	9.4
Node to 1st fruit	21.73**	5.75**	0.11	0.009	0.075	8.33
Days to fruit maturity	166.39**	25.08**	0.17	0.01	0.11	11
Number of fruits per vine	0.34**	0.14**	0.04	0.003	0.030	10
Average fruit weight (kg)	1.28**	0.54**	0.02	0.001	0.01	10
Fruit yield per vine (kg)	3.51**	1.20**	0.15	0.01	0.10	10

*, ** Significant at 5% and 1% level, respectively.

50% female flowering (-2.39), node to first fruit (-1.66) days to fruit maturity (-3.59), number of fruits per plant (0.13) and average fruit weight (-0.40). Bushy and flat round parent, P-2211, was second best combiner for days to 50% female flowering (-3.18) as well as good general combiner for earliest node to male flower (-0.06) and 50% male flowering (-1.33), node to first fruit (-0.24) and days to fruit maturity (-1.98). Bushy and round fruited, P-6711, was good general combiners for days to 50% female flowering (-1.75), earliest node to male flower (-0.06) and 50% male flowering (-1.36), node to first fruit (-1.06), days to fruit maturity (-3.53), and average fruit weight (-0.19). Butternut and long vine parent, P-6242 was the good combiner for increasing fruit yield per plant (0.63). Bushy and butternut parent P-364 was good general combiner for for earliest node to female flower (-0.47), days to 50% male flowering (-0.05), node to first fruit (-0.26) days to fruit maturity (-0.29), number of fruits per plant (0.22) and average fruit weight (-0.19). A parent with long vigorous vines, P-41212, was best general combiner for days to 50% male flowering (-1.72) and number of fruits per plant (0.23) as well as good general combiner for high fruit yield per plant (0.54). A parent with very big fruits, P-10224, was the best general combiner for fruit yield per plant (0.89)as well as good general combiner for days to 50% female flowering (-1.06) and average general combiner for earliest node to male flower (-0.04), days to 50% male flowering (-0.02). Punjab Samrat was average general combiner for average fruit weight.

GCA effects of parents for vine length, earliest node to male and female flower, days to 50% male and female flowering, node to first fruit, days to fruit maturity, number of fruits per plant, average fruit weight and fruit yield per vine were desirable to initiate breeding programme for early bearing and high yielding short vines in pumpkin. The higher general combining ability (GCA) of different parents for earliness and high yield in a series of cross combinations suggested the greater concentration of predominantly additive genes for these traits that provided a foundation for the improved selections in further generations. Therefore, the parents P-1343, P-3621, P-6711, P-364 and P-2211 had prospective for creating the breeding materials for bushy growth and earliness due to their higher additive genetic variances for vine length, earliest node to male and female flower, days to 50% male and female flowering, node to first fruit and days to fruit maturity. Similarly, the number of fruits can be increased by involving P-41212, P-364 and P-3621 and fruit yield per plant can be improved through using P-10224, P-6242 and P-41212 in the hybridization programme. However, the fruit weight can be reduced with P-1343, P-3621 and P-364. These parents with high GCA for above mentioned traits can also be used in suitable combinations for developing highly heterotic hybrids showing bushy growth, earliness and high yield potential. High estimates of GCA's were earlier presented for long vines, earliness, bigger fruits and high yield in pumpkin (Nisha and Veeraragavathatham 2014 and Tamil Selvi et al. 2015), but this study concentrated on bushy growth with earliness and high yield potential in pumpkin with the emphasis on small fruit size under intensive cultivation.

SCA effects of F_1 hybrids: Among the F_1 hybrids involving bushy and butternut parents (Table 3), the cross, P-41212 × P-6242, was best specific combiner for short vine (-111.72) as well as good specific combiners for earliest node to male (-0.22) and female flower (-1.05), days to 50% female flowering (-4.44), node to first fruit (-1.45) and average fruit weight (-0.32); P-41212 × P-2211, was best specific combiners for earliest node to female flower (-5.06) node to first fruit (-4.16) and days to maturity (-9.66), as well as

Table 2: General combining ability effects of the parents for short vines, earliness and yield traits

Parents	VL(cm)	ENFF	DFFF	ENMF	DFMF	NFF	DFM	NFPV	AFW (kg)	FYPV(kg)
PS	22.30**	0.40**	7.15**	0.25**	3.39**	1.94**	6.55**	-0.13*	-0.006	-0.24*
P-41212	38.52**	1.41**	4.96**	0.09**	-1.72**	1.31*	2.97**	0.23**	0.07	0.54**
P-364	-3.21	-0.47**	0.72*	.00	-0.05	-0.26**	-0.29*	0.22**	-0.19**	-0.16
P-1343	-43.80**	-2.43**	-5.03**	-.07**	-0.42	-2.03**	-5.17**	0.04	-0.45**	-0.74**
P-6711	-9.05**	0.05	-1.75**	-.06*	-1.36**	-1.06*	-3.53**	-0.06	-0.09	-0.22
P-3621	-47.83**	-1.78**	-2.39**	-.07**	1.24**	-1.66**	-3.59**	0.13*	-0.40**	-0.60**
P-10224	35.45**	1.78**	-1.06**	-0.04	-0.02	1.21**	2.82**	-0.02	0.55**	0.89**
P-6242	30.47**	1.27**	0.57	-.01	0.27	0.78**	2.22**	-0.20**	0.44**	0.63**
P-2211	-22.85**	-0.24*	-3.18**	-.06*	-1.33**	-0.24*	-1.98**	-0.22**	0.09*	-0.10
CD at 5%	4.47	0.23	0.64	0.05	0.47	0.19	0.23	0.12	0.08	0.22
CD at 1%	5.86	0.30	0.84	0.06	0.62	0.25	0.31	0.15	0.10	0.29

*, ** Significant at 5% and 1% level, respectively.

Note: VL- vine length, ENFF- early node to female flower, ENMF- early node to male flower, DFFF- days to 50% female flower, DFFF- days to 50% male flower, NFF -node to first fruit, DFM- days to fruit maturity, NFPV-number of fruits per vine, AFW- average fruit weight and FYPV- fruit yield per vine good specific combiner for short vine (-60.65), earliest node to male (-0.22) , days to 50% female (-9.41) and male flowering (-1.67), number of fruits per vine (0.43) and average fruit weight (-0.53); PS × P-1343 was best specific combiners for days to 50% female (-12.41) as well as good specific combiner for short vine (-83.39), earliest node to female flower (-2.45), node to first fruit (-2.76), days to fruit maturity (-9.48) and average fruit weight (-0.55); PS × P-364 was best specific combiner for earliest node to male flower (-0.37) as well as good specific combiners for short vine (-85.00), earliest node to female (-1.81), days to 50% female flowering (-5.26), node to first fruit (-2.62) and days to maturity (-5.24) and average fruit weight (-0.53); PS × P-6242 was good specific combiners for most of the traits such as short vine (-39.44), earliest node to male (-0.36) and female flower (-0.97), days to 50% female flowering (-4.62), node to first fruit (-2.28), days to fruit maturity (-6.18), number of fruits per vine (0.35) and average fruit weight (-0.43); P-41212 × P-10224 was also good specific combiners for most of the traits such as short vine (-51.19), earliest node to female flower (-3.52), days to 50% female flowering (-7.65), node to first fruit (-2.40) days to fruit maturity (-3.87), number of fruits per vine (0.51) and average fruit weight (-0.70; P-3621 × P-2211 was also good specific combiner for most of the traits such as short vine (-50.94), earliest node to female flower (-1.92), days to 50% female flowering (-3.04), node to first fruit (-2.95) days to fruit maturity (-5.18) and average fruit weight (-0.46) as well as average combiners for number of fruits per vine (0.26) and P-10224 × P-6242 was good specific combiners for most of the traits such as short vine (-68.01), earliest node to female flower (-3.64), days to 50% female flowering (-3.95), node to first fruit (-2.06) days to fruit maturity (-7.06), number of fruits per vine (0.77) and average fruit weight (-1.28). However, the cross, P-6711 × P-10224, was the best specific combiner for high yield per vine (2.34), while hybrids PS × P-2211, P-41212 × P-1343, P-41212 × P-3621, P-364 × P-10224 were good specific combiners for this trait.

Among 36 crosses, highly significant SCA effects for short vine were observed in P-41212 × P-6242, PS × P-364, PS× P-1343, P-10224× P-6242, P-41212 × P-2211, P-41212 × P-10224, P-3621 × P-2211 and PS × P-6242, however, P-6711 × P-10224, PS × P-2211, P-41212 × P-3621, P-41212 × P-1343, P-364 × P-10224 were experienced better specific combiners for yield per plant, but cannot be used to improve bush growth and earliness because of poor specific combining ability for short vine and flowering traits. On the other hand, high and significant SCA for short vine, earliness in flowering as well as fruit maturity can help in improvement for high density planting. Moreover, these crosses with small fruits can be harvested earlier at green immature stage that results in multiple harvests. Therefore, the genetics of these should be exploited for the selection of improved hybrids or transgressive segregants having bushy growth habit and bearing early fruits with economical size. The involvement of both poor combiners for days to 50% female flowering, earliest node to male flower, and fruit yield per plant in PS × P-364, for fruit yield per plant in PS × P-1343, for short vine, earliest node to female flower, days to 50% female flowering, days to 50% male flowering, node to first fruit, days to fruit maturity and number of fruits per vine in PS × P-6242, for short vine, earliest node to female flower, days to fruit maturity and average fruit weight in P-41212 × P-10224, for short vine, earliest node to female flower, days to 50% female flowering, node to first fruit, days to fruit maturity and average

Table 3: Specific combining ability effects of F_1 hybrids for traits contributing in bush growth, earliness and yield

F_1 hybrids	VL (cm)	ENFF	DFFF	ENMF	DFMF	NFF	DFM	NFPV	AFW (kg)	FYPV (kg)
PS × P-364	-85.00**	-1.81**	-5.26**	-0.37**	0.20	-2.62**	-5.24**	-0.43*	-0.53**	-0.99*
PS × P-1343	-83.39**	-2.45**	-12.41**	0.39**	3.89**	-2.76**	-9.48**	-0.15	-0.55**	-0.93*
PS × P-6242	-39.44**	-0.97**	-4.62**	-0.36**	3.26**	-2.28**	-6.18**	0.35*	-0.43**	-0.50
PS × P-2211	159.04**	5.70**	5.70**	0.02	1.20	1.50**	5.72**	-0.56**	2.56**	2.09**
P-41212 × P-1343	109.59**	3.96**	1.92*	0.15	-0.64	3.31**	2.24**	0.00	0.90**	1.59**
P-41212 × P-3621	79.89**	5.01**	3.55**	0.38**	-1.95**	4.18**	9.06**	-0.18	0.94**	1.68**
P-41212 × P-10224	-51.19**	-3.52**	-7.65**	-0.12	-0.70	-2.40**	-3.87**	0.51**	-0.70**	-0.94*
P-41212 × P-6242	-111.72**	-1.05**	-4.44**	-0.22**	-0.67	-1.45**	1.30**	-0.43	-0.32**	-1.08*
P-41212 × P-2211	-60.65**	-5.06**	-9.41**	-0.12	-1.67*	-4.16**	-9.66**	0.43*	-0.53**	-0.85
P-364 × P-10224	91.43**	4.78**	5.92**	-0.03	1.62*	4.17**	9.06**	-0.47**	1.19**	1.42**
P-6711 × P-10224	171.60**	3.50**	1.73	0.11	0.59	4.81**	3.96**	-0.01	1.39**	2.34**
P-3621 × P-2211	-50.94**	-1.92**	-3.04**	-0.09	-0.61	-2.95**	-5.18**	0.26	-0.46**	-0.58
P-10224 × P-6242	-68.01**	-3.64**	-3.95**	-0.06	-1.40*	-2.06**	-7.06**	0.77**	-1.28**	-1.55**
CD at 5%	12.72	0.66	1.84	0.15	1.36	0.54	0.67	0.34	0.22	0.89
CD at 1%	16.69	0.87	2.41	0.19	1.79	0.71	0.88	0.45	0.30	1.17

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

fruit weight in P-41212 × P-6242, for node to first fruit and average fruit weight in P-41212 × P-2211, for short vine, earliest node to female flower, node to first fruit, days to fruit maturity, number of fruits per vine and average fruit weight in P-10224 × P-6242 and fruit yield per vine in P-3621 × P-2211 unconcealed high SCA due to the predominance of non-additive gene effects for the inheritance of these traits in mentioned crosses and suggested its exploitation through heterosis breeding for these traits related to short vine and earliness in pumpkin. Similar results of higher SCA's with non-additive gene effects for long vines, bigger fruits, earliness and high yield were earlier presented in pumpkin (Nisha and Veraragavathatham 2014, Hussien and Hamed 2015, Tamil Selvi et al. 2015), but this study explored the genetic effects governing bush growth habit, earliness and high yield in pumpkin under intensive cultivation. The connection of one good or average and one poor combiner for short vine, early node to female flower, days to 50% male flowering, node to first fruit, days to fruit maturity and number of fruit per vine in PS × P-364, for short vine, earliest node to male and female flower, days to 50% male and female flowering, node to first fruit, days to fruit maturity, number of fruits per plant, average fruit weight and fruit yield per vine in PS × P-1343, for earliest node to male flower and number of fruits per vine in P-41212 × P-6242, for vine length, earliest node to male and female flower, days to 50% female flowering, days to fruit maturity, number of fruits per vine and fruit yield per vine in P-41212 × P-2211, for days to 50% male and female flowering in P-10224× P-6242 and for days to 50% male flowering, number of fruits per vine, and average fruit weight in P-3621×P-2211 disclosed the preponderance of both additive and non-additive gene effects for the inheritance of these traits in mentioned crosses and suggested the exploitation of these gene effects through heterosis breeding and recurrent selection for high SCA, especially, in these crosses for improvement in bush growth, earliness and high yield in pumpkin.

The union of both good combiners for average fruit weight in PS × P-364 and PS × P-1343, for days to 50% male flowering, fruit yield per vine in P-41212 × P-10224 and P-41212 × P-6242, for days to 50% male flowering in P-41212 × P-2211, for earliest node to male flower and fruit yield per vine in P-10224× P-6242 and short vine, early node to male and female flower, days to 50% male and female flowering, node to first fruit, and days to fruit maturity in P-3621×P-2211 revealed the prevalence of additive and additive × additive gene effects for the inheritance of these traits in discussed crosses and favoured the utilization of these gene effects through hybridization followed by selection for short vine, earliness and yield traits in pumpkin. High additive genetic variance for more vine growth, earliness higher fruit weight and high yield potential has been earlier reported in pumpkin (Hussien and Hamed 2015, El-Tahawey et al. 2015).

Economic heterosis (%): Among 36 crosses, the magnitude of economic heterosis for short vine length, earliest node to male and female flower, days to 50% male and female flowering, node to first fruit, days to fruit maturity, number of fruits per plant, average fruit weight and fruit yield per vine over PPH-1 and PPH-2 ranged from -62.42 to 342.62%, 0 to 58.0 %, -31.5 to 420 %, -3.66 to 161.64%, -52.32 to 107.67%, -20.44 to 237.33%, -0.85 to 49.13%, -17.60 to 81.69%, -58.11 to 228.87% and 42.68 to 347.72, respectively (Table 4). Emphasizing the objective of present investigation, the maximum economic heterosis over both checks for short vines was observed in P-364× P-6711 (-62.42 and -51.54%, respectively), followed by P-364× P-2211 (-60.82 and -49.48%, respectively) and P-6711× P-3621 (-54.05 and -40.76%, respectively), P-41212 × P-3621 (-53.38 and -39.89 respectively), P-6711× P-2211 (-51.79 and -37.84 respectively), P-364× P-3621 (-51.79 and -37.84, respectively), P-6711×P-6242 (-50.73 and -36.47, respectively) and P-3621 × P-2211 (-47.28 and -32.02, respectively). Most of these hybrids had significant heterosis for earlier flowering and P-364× P-6711, P-6711× P-3621, P-41212 × P-3621, P-6711× P-2211, P-364× P-3621 and P-6711×P-6242 had significant heterosis for lower fruit weight and more number of fruits per vine.

The *per se* performance of best hybrid combinations selected on the basis of short vines and earliness as well as their yield performance (q/ha) are presented in Table 5. Among 36 crosses, P-3621 × P-10224(533.3q/ha), PS × P-364 (401.3 q/ha), P-6711 × P-2211(397.4q/ha), P-364 × P-1343 (395.0 q/ha), P-364 × P-10224 (360.2 q/ha), P-6711× P-10224 (357.1q/ha), P-3621× P-6242 (347.6 q/ha), P-3621 × P-2211 (330.2 q/ha), P-364 × P-3621 (320.7 q/ha), P-6711× P-3621 (308.1 q/ha), and P-41212 × P-3621 (304.1q/ha) were some crosses with good yield potential. Both the parents of these hybrids were either poor combiners or combination of one poor and the other good or average combiner for yield per hectare indicating the presence of non additive genetic variances that suggested the exploitation of heterosis. However, among these hybrids, P-3621 × P-10224 (70.05%), PS × P-364 (27.96%), P-6711 × P-2211(26.71%), P-364 × P-1343 (25.96%) represented significant and desirable economic heterosis for yield per hectare over PPH-2 and were at par with PPH-1. Other six hybrids were at par with PPH-2. All these hybrids being short vine could fit into intensive cultivation and start early bearing within 46 days of sowing. The hybrid P-3621 × P-10224 had butternut fruits, while PS × P-364, P-6711 × P-2211, P-364 × P-1343 were round fruited.

The heterosis for earliest node to male and female flower, less number of days to 50% male and female flowering as well as days to fruit maturity favoured a scope for development of short vine hybrids showing early bearing and fruit development. These results of heterosis for earliness could be substantiated with reports of Nisha and Veeraragavathatham 2014 and Hussien and Hamed 2015 in pumpkin. The number of fruits per vine, fruit weight and fruit yield per vine have been the important

Table 4: Economic heterosis of bushy hybrids for traits contributing in earliness and yield

F_1 Hybrid	VL (cm)		ENFF		DFFF		NFF		DFM		NFPV		AFW(kg)		FYPV (kg)	
	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2	PPH-1	PPH-2
P-41212× P-6711	-46.21**	-30.65**	13.2	-3.08**	-51.81**	-10.58**	-20.44**	-6.52**	12.71	14.63	76.05**	76.05**	-51.28	-38.70	7.92**	34.09**
P-41212 × P-3621	-53.38**	-39.89**	50.0	28.42	-50.25**	-7.7**	14.88	34.98	10.17	12.05	76.05**	76.05**	-55.55	-44.08	-21.34	-2.27
P-364× P-6711	-62.42**	-51.54**	-20.0**	-31.5**	-48.18**	-3.86*	-3.77**	13.05	5.94	7.75	52.81**	52.81**	-56.41	-45.16	-33.53	-17.42
P-364× P-3621	-51.79**	-37.84**	16.8	0.00	-48.7**	-4.81**	18.44	39.16	9.33	11.19	64.08**	64.08**	-45.29	-31.18	-17.68	2.27*
P-364× P-2211	-60.82**	-49.48**	-20.0**	-31.5**	-46.63**	-0.98	-12.88**	2.34	13.57	15.51	-6.33	-6.33	-35.89	-19.35	-38.41	-23.48
P-6711 × P-3621	-54.05**	-40.76*	-10.0**	-22.94**	-41.44**	8.65	1.77	19.58	9.33	11.19	46.47**	46.47**	-44.44	-30.10	-20.73	-1.51
P-6711× P-10224	-45.54**	-29.78**	86.8	59.93	-47.66**	-2.88	22.22	43.6	14.41	16.36	-6.33	-6.33	-3.41	21.5**	-8.53	13.63**
P-6711× P-6242	-50.73**	-36.47**	93.2	65.41	-45.08**	1.90	26	48.04	11.87	13.78	28.87**	28.87**	-41.02	-25.80	-23.17	-4.54
P-6711 × P-2211	-51.79**	-37.84**	56.8	34.24	-47.14**	-1.93	-18.44**	-4.17**	8.49	10.34	46.47**	46.47**	-29.91	-11.82	1.82**	26.51**
P-3621 × P-10224	-50.06**	-35.61**	116.8	85.61	-45.59**	0.95	40.66	65.27	16.95	18.95	17.60**	17.60**	14.52**	44.08**	37.19**	70.45**
P-3621× P-2211	-47.28**	-32.02**	116.8	85.61	-46.1**	0.00	14.88	34.98	9.33	11.19	-17.60	-17.60	3.41**	30.10**	-15.24	5.30**
CD at 5%	22.17		1.14		3.20		0.95		1.16		0.59		0.39		1.10	
CD at 1%	29.45		1.52		4.26		1.26		1.55		0.78		0.52		1.47	

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

Table 5: *Per se* performance of short vine and early hybrids under intensive cultivation in pumpkin

F_1 Hybrid	Fruit yield under intensive cultivation					*Per se* performance						
	Yield (q/ha)	GCA of parents	SCA of hybrids	Heterosis over checks (%)		VL (cm)	ENFF	DFFF	DFM	AFW (kg)	NFPV	FS*
				PPH-1	PPH-2							
P-3621 ×P-10224	533.3	P × G	-1.22	36.95**	70.05**	41.78	5.42	35.0	46.00	1.34	1.67	Butternut
PS × P-364	401.3	P × P	-7.26	3.05	27.96**	73.78	2.75	32.67	39.00	0.69	2.5	Round
P-6711 × P-2211	397.4	P × A	19.06**	2.05	26.71**	40.33	3.92	34.00	42.67	0.82	2.08	Flat round
P-364 × P-1343	395.0	P × P	1.17	1.43	25.95**	59.78	3.58	33.00	40.33	0.87	1.92	Round
P-364× P-10224	360.2	P × G	19.72**	-7.49	14.85	55.44	4.33	31.33	41.00	0.98	1.58	Round
P-6711× P-10224	357.1	P × G	-0.98	-8.30	13.86	45.56	4.67	33.67	45.00	1.13	1.33	Flat round
P-3621× P-6242	347.6	P × G	-20.49**	-10.73	10.84	53.22	4.25	30.67	43.00	0.60	2.42	Butternut
P-3621× P-2211	330.2	P × A	-3.65	-15.20	5.29	44.11	5.42	34.67	43.00	1.21	1.17	Butternut
P-364× P-3621	320.7	P × P	-3.70	-17.64	2.26	40.33	2.92	33.0	43.00	0.64	2.33	Butternut
P-6711 × P-3621	308.1	P × P	-3.20	-20.87*	-1.75	38.44	2.25	37.67	43.00	0.65	2.08	Butternut
P-41212 × P-3621	304.1	A× P	31.58**	-21.90*	-3.02	39.00	3.75	32.0	43.33	0.52	2.5	Butternut
P-6711×P-6242	298.6	P × G	-2.59	-23.33*	-4.79	41.22	4.83	35.33	44.00	0.69	1.83	Round
PPH-1	389.4	-	-	-	-	83.67	2.50	44.33	39.33	1.17	1.42	Round
PPH-2	313.6	-	-	-	-	64.89	2.92	34.67	38.67	0.93	1.42	Round
CD at 5%	20.43		13.22	20.40		22.17	1.16	3.20	1.18	0.40	0.60	-
CD at 1%	26.08		17.34	26.06		29.45	1.53	4.22	1.54	0.52	0.79	-

P = Poor GCA, G = Good GCA, A = Average GCA *FS- fruit shape traits for the assessment of yield potential of a cucurbitaceous crop. However, to get the economical fruit size in pumpkin, negative heterosis would be desirable. In contrast, the earlier studies accorded on positive heterosis for fruit weight in pumpkin (Hussien and Hamed 2015). High heterosis for number of fruits and fruit yield per vine were in accord with the studies of Hussien and Hamed (2015) in pumpkin. Among bushy hybrids, P-3621 × P-10224, P-3621 × P-2211, P-3621× P-6242, P-6711× P-10224 and P-6711× P-6242 after hybridization can be further used for the selection of transgressive segregates with bushy growth habit, early bearing and high yield potential. However, PS × P-364, and P-364 × P-1343 with high heterosis and involving non additive genetic variances for yield can be evaluated in multi-environments for their release.

It is concluded from the present investigation that the parents P-1343, P-3621, P-6711, P-364 and P-2211 had perspectives for creating the breeding materials for bushy growth and earliness. Similarly, the number of fruits can be increased by involving P-41212, P-364 and P-3621 and fruit yield per plant can be improved through using P-10224, P-6242 and P-41212 in the hybridization programme. The economical fruit size of the fruits can be brought with P-1343, P-3621 and P-364. These parents with above mentioned traits can be used in suitable combinations for developing bushy, extra early and high yielding hybrids for intensive cultivation. Among 36 crosses, P-41212 × P-6242, PS × P-364 and PS× P-1343 represented highly significant SCA effects for short vine growth and earliness. However, P-6711 × P-10224, PS × P-2211, and P-41212 × P-3621 had been better specific combiners for yield per plant, but poor combiners for short vine length. The SCA effects of crosses with short vine and early bearing can be used to improve yield through high density planting. Both additive and non-additive gene effects for these traits suggested further improvement through heterosis breeding and recurrent selection for high SCA. The significant economic heterosis over both checks for short vines was observed in ten hybrids. Most of these hybrids had significant heterosis for earlier flowering, lower fruit weight and more number of fruits per vine. However, PS × P-364 (27.96%), P-6711 × P-2211(26.71%), P-364 × P-1343 (25.96%) represented significant and desirable economic heterosis for yield per hectare over PPH-2 and were at par with PPH-1.

Ikjka'k

कद्दू की घनी खेती के लिये लघु बेल, अगेती और उच्च उपज के आनुवांशिक अध्ययन की जरूरत है। इसके लिये कद्दू की झाड़ीनुमा और बटरनट किस्मों को हाफ डाइएलिल में अध्ययन किया गया है। अध्ययन में, पी–1343 झाड़ी नुमा बेल, अगेतीपन और निचले गांठों पर बने फल के लिये, पी–41212, 50 प्रतिशत नर फूल (–1.72) और फलों की संख्या (–0.23) और पी–10224 प्रति पौध उपज (0.89) के लिये सबसे अच्छे सामान्य संयोजक थे। कुल 36 संकरण संयोजों में से पी–41212 × पी–6242, पीएस × पी–364 पीएस × पी–1343, पीएस × पी–10224 × पीएस × पी–6242, पी–41212 × पी–2211ए पी–41212 × पी–10224, पी–3621 × पी–2211 और पीएस × पी–6242 छोटी बेल और अगेती उपज के लिये, और पी–6711 × पी–10224, पीएस × पी–2211, पी–41212 × पी–3621, पी–41212 × पी–1343, पी–364 × पी–10224 प्रति बेल उपज के लिये सबसे अच्छे विशिष्ट संयोजक थे जिससे इन गुणों के लिये कद्दू में योज्य और अयोज्य प्रभाव का पता चलता है। इन गुणों के सुधार के लिये ओज प्रजनन और उच्च विशिष्ट संयोजन क्षमता का चयन जरूरी है। सभी संकरण में से पीएस × पी–364 छोटी बेल, अगेती और अधिकतम उपज के लिये सबसे अच्छा रहा। इसके बहुवातावरण परीक्षण के बाद यह घनी खेती में सुगमता से सम्मिलित हो सकता है।

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