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RESEARCH ARTICLE

Genetic studies for hybrid development in Indian muskmelon (*Cucumis melo* L.)

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Abstract

The analysis of general and specific combining ability with the estimation of heterosis was carried out under this study to select suitable parents and their hybrids for commercial use in muskmelon. 28 F_1 hybrids were developed from 8 parents by advocating a diallel mating strategy excluding reciprocals. The hybrids, along with parents, were evaluated for two consecutive years to assess general and specific combining ability with heterosis over better and check parent for eleven quantitative traits. The study revealed the effect of both additive and non-additive genetic control over the expression of the traits. Genotypes PMM-13, PMM-16 and PMM-18 were observed as excellent general combiners for yield and also found admirable for earliness, plant architecture and fruit quality. Among 28 F_1 hybrids, PMM-32 × PMM-16, PMM-4A × PMM-13 and PMM-18 × Hara Madhu exhibited higher sca effects for fruit yield. Outside yield, these hybrids showed appreciable sca effects in desirable direction for earliness, less seed cavity, fruit mesocarp thickness and total soluble solids. It has been observed in this study that one of the parents of a particular cross having a good GCA resulted higher sca effect. Among all the hybrids, PMM 13 × PMM 18, PMM 18 × Hara Madhu and PMM 13 × PMM 16 were the top three as per heterotic value regarding yield. These crosses also found great in earliness, vegetative and fruit quality traits.

Keywords: Heterosis, Combining ability, Muskmelon, GCA, SCA, Diallel analysis.

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Introduction

One of the main warm-season vegetables of the Cucurbitaceae family, muskmelon (*Cucumis melo* L.; 2n=2x=24) is grown throughout the world's tropical and subtropical regions for its ripe fruit and treated as a dessert cucurbit (Pandey et al., 2008). It is of Asian origin (Sebastian et al., 2010), with a core of diversity spanning from the Mediterranean Sea to East Asia. Melon fruits are consumed fresh. Their unique, gratifying flavor, sweetness, texture, and nutritional value make them prized commercially (Weng et al., 2021). The pulp is an invaluable source of antioxidants having low calorific value with significant amounts of potassium, folic acid, ascorbic acid, flavonoids, tochopherols and phenolics (Lohani et al., 2023). The cultivars with orange flesh are high in beta-carotene. The vast range of heterogeneity in morphological traits, particularly in fruit attributes like shape, size, firmness, rind pattern, pulp colour, texture, aroma and sugar content (Fergany et al., 2011; Pitrat, 2016), makes the crop one of the most diversified species within the genus *Cucumis*. The primary breeding objectives in this crop are increased productivity, consistent fruit size and shape, and excellent quality. Genetic recombination and subsequent selection of plants expressing valuable traits lead to the recognition of superior genotypes and breeding of new cultivars. Proper insight into genetic variability with the exploitation of heterosis is necessary for crop improvement in a quick manner (Sarkar and Singh, 2017). Analysis of combining ability is an efficient technique to select the desirable parents for hybridization and specific crosses for further exploitation (Tomar and Bhalala, 2009) by knowing the information of the genetic architecture of the parental materials. Hybrid vigour, both in terms of higher biomass and economic yield, could be achieved through heterosis by crossing diverse genotypes (Saha et al., 2022). Diallele mating design (Griffin, 1956) is an efficient aid to identify the potential parents having a higher frequency of favourable alleles and the most promising hybrid combinations by providing genuine information regarding the general combining ability (GCA) and specific combining ability (SCA) effect of the parents and their F_1 hybrids, respectively (Valerio et al., 2009). It also provides an estimation of heterosis as well as the knowledge of gene action involved in the expression of the quantitative traits (Costa et al., 2019). The nutrient potentiality of this vegetable results in an increasing demand for superior melon seed having good fruit quality and higher productivity among Indian farmers. However, the present varieties that are derived from landraces are incapable of meeting the needs. Therefore, a great scope exists in muskmelon to develop locally adopted hybrids by finding the best combiners and exploiting heterosis through crossing among diverse genotypes, as this crop exhibits considerable heterozygosity having minimum inbreeding depression. To date, in India, very few works have been carried out in this aspect of muskmelon. Hence, our study is an attempt to provide absolute genetic information for searching for novel genotypes and to find out the heterotic potential of their crosses, ultimately to develop suitable hybrids and further improvement in Indian muskmelon.

Materials and Methods

The investigational resources consisted of eight muskmelon inbreed lines (PMM-4A, PMM-1, PMM-32, PMM-13, PMM-16, PMM-18, PMM-37 and Hara Madhu) having an andromonoecious sex form of diverse morphological backgrounds (Table 1). The eight lines were crossed in a diallel mating design without reciprocals and 28 F_1s were developed. The developed hybrids with all their parents were evaluated for two years, both in the summer season to estimate heterosis and combining ability under open field situation at Vegetable Research Centre, Govind Ballav Pant University of Agriculture and Technology, Pantnagar, located at an elevation of 243.83 m above MSL, 29^0 North latitude and 79.3^0 East longitude under Tarai belt of Shiwalik ranges of Himalayas. The experiment was laid out in a Randomized Block Design with three replications. A healthy crop stand was maintained following the recommended agronomic practices. The quantitative observations were taken from 10 plants for each parent and 20 plants for F_1. The traits under observation were days taken to first male and female flowering, node number to first fruit set, vine length (cm), number of branches per plant, seed cavity diameter (cm), fruit flesh thickness (cm), total soluble solid (^{0}Brix), average fruit weight (g), number of fruits per plant and total fruit yield (q/ha). Days to first male and female flowering were recorded by counting the number of days from sowing of the seed to anthesis of the first male and female flowers. The number of nodes to which the first fruit appeared was counted from the base of the plant. Vine length was taken by measuring the distance from the soil surface to the

Table 1: Morphological features of inbreed lines

S. No.	*Parent*	*Morphological trait*
1	PMM-4A	Andromonoecious, intermediate growth, elongated globe shaped fruit with pointed peduncle end, yellowish green rind colour and creamy white flesh with high TSS content
2	PMM-1	Andromonoecious, determinate type, round shaped fruit with yellow rind colour and creamy white medium flesh thickness with moderate TSS content
3	PMM-32	Andromonoecious, long vine, oval shaped fruit with yellowish green rind and greenish white thick mesocarp and high TSS content
4	PMM-13	Andromonoecious, long vine, ovate shaped fruit with prominent suture and truncated peduncle end, creamy white rind and light yellow thick mesocarp and high TSS content
5	PMM-16	Andromonoecious, long vine, round shaped fruit with yellow rind and creamy white thick mesocarp and high TSS content
6	PMM-18	Andromonoecious, intermediate growth, oval shaped fruit with yellowish green rind and green thick mesocarp and high TSS content
7	PMM-37	Andromonoecious, bushy growth habit, ovate shaped fruit with tapering peduncle end, creamy white rind colour and yellowish green thin flesh with low TSS content
8	Hara Madhu	Andromonoecious, viny growth, round shaped large fruit with prominent green suture, light yellow rind colour and light green crispy flesh with high TSS content

apical tip of the main vine at final harvesting. The number of lateral branches that were emerging from the main vine was counted at the final harvesting stage. The fruit seed cavity diameter was measured by a vernier caliper and the average was estimated in cm. Fruit flesh thickness was measured at the third harvesting by a vernier caliper after peeling the rind from selected fruits of tagged plants and the average was calculated in cm. Total soluble solids were measured by a digital refractometer (Atago Digital Refractometer by ATAGO Co. Ltd, Tokyo, Japan). Average fruit weight was recorded by weighing five fruits from tagged plants in each harvesting and finally mean value from all the pickings was computed in grams. The number of fruits per plant was calculated by adding the marketable fruit number in each picking from tagged plants and depicting the mean value. Yield per plant was calculated by weighing the total fruits harvested each time from tagged plants and the average value was computed in kilograms. Analysis of combining ability was done using Griffing's (1956) method II model I. The percentage change in F_1s compared to better and check parents was taken into account to estimate heterosis. INDOSTAT software (version 8.1) and Microsoft Excel (2007) were used for statistical analysis.

Results and Discussion

All the traits under investigation significantly differed among all the parents and hybrids as revealed through the result of analysis of variance (Table 2), which represents the existence of adequate genetic variability in yield and its attributing characters in muskmelon. Therefore, plenty of scope for feasible crop improvement prevails for these genetic resources by the incorporation of desirable genes (Kitroongruang et al., 1992). The variances attributed to both GCA and SCA were also noticed to be highly significant (Table 3) for all the characters, denoting the influence of both the additive and dominant gene action governing these traits as earlier reported by Randhwa and Singh, 1990, in muskmelon, Sarkar and Singh, 2017, in ridge gourd and Munshi et al., 2006, in cucumber.

Table 2: Analysis of variance for various quantitative traits in muskmelon

Sources of variation		*Replication*	*Genotypes*	*Error*
Degrees of freedom		*2*	*35*	*70*
Days to first male flower	2022	1.40	21.20**	1.34
	2023	0.34	16.82**	0.86
Days to first female flower	2022	0.62	18.08**	1.11
	2023	0.23	32.17**	1.00
Node to first fruit set	2022	0.03	8.20	0.61
	2023	0.07	8.11*	0.69
Vine length (m)	2022	0.08	2.16**	0.03
	2023	0.01	2.43**	0.02
Number of branches per plant	2022	0.11	1.25**	0.30
	2023	0.15	1.24**	0.29
Seed cavity diameter (cm)	2022	0.04	10.92**	0.63
	2023	1.45	9.20**	0.68
Flesh thickness (cm)	2022	0.00	0.98**	0.01
	2023	0.01	0.85**	0.03
Total soluble solid (%)	2022	0.04	10.92**	0.63
	2023	1.45	9.20**	0.68
Average fruit weight (g)	2022	2638.92	142136.25**	7795.46
	2023	4971.86	140854.38**	5415.02
Number of fruits per plant	2022	0.45	24.92**	0.31
	2023	0.15	24.00**	0.21
Total fruit yield (q/ha)	2022	7.86	6221.25**	18.13
	2023	10.27	6113.94**	12.28

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

Combining Ability

General combining ability

The estimates of general combining ability (gca) for both seasons were analyzed (Table 4a and b) in order to assess the performance of each breeding line to combine in a succession of crosses. The parents PMM-1, PMM-37 and Hara Madhu showed excellent GCA effects in the required direction for earliness traits like days to male and female flowering. Results also revealed that genotype PMM-16 was consistently admirable for the same traits for both seasons. Regarding the node number to first fruit set, PMM-13 was reported to be best, followed by PMM-4A for both years. Therefore, these genotypes can be utilized for intermating to get good segregates having all the earliness traits. In this experiment, we have found a good influence of additive genetic variance in earliness traits rather than other quantitative ones, but the value of effects in sca is greater than the gca for the same characters, revealing the control of non-additive genes for earliness. Our findings are in conformity with those of Handayani et al. (2022 and Akrami & Arzani (2019) in muskmelon. PMM-13 was found worthy combiner regarding vine length and number of branches for both seasons. These vegetative traits are highly correlated to the number of fruits per plant and ultimately yield in muskmelon. PMM-13, PMM-16, and PMM-18 were observed to be good combiners for fruit flesh thickness, whereas PMM-32 was found outstanding for both seed cavity diameter and fruit flesh thickness for both seasons in the desirable direction. PMM-13 and PMM-18 were excellent for both flesh thick ness and total soluble solid content. These identified lines could be explored in a further breeding programme for quality improvement in muskmelon. Our results are supported by the findings of Luan et al. (2010 in muskmelon. Regarding economic traits like average fruit weight, fruit number and fruit yield, the parents PMM-13

Table 3: Analysis of variance for combining ability for various quantitative traits in muskmelon

Sources of variation		*GCA*	*SCA*	*Error*
Degrees of freedom		*7*	*28*	*70*
Days to first male flower	2022	15.63**	4.60**	0.41
	2023	15.22**	3.11**	0.35
Days to first female flower	2022	11.88**	4.66**	0.35
	2023	32.11**	5.18**	0.33
Node to first fruit set	2022	1.16**	1.67**	0.13
	2023	2.21**	1.72**	0.10
Vine length (m)	2022	1.72**	0.55**	0.01
	2023	2.38**	0.57**	0.01
Number of branches per plant	2022	0.28*	0.55**	0.10
	2023	0.35**	0.51**	0.10
Seed cavity diameter (cm)	2022	3.94**	3.56**	0.21
	2023	2.56**	3.19**	0.23
Flesh thickness (cm)	2022	1.04**	0.15**	0.00
	2023	0.84**	0.14**	0.01
Total soluble solid (%)	2022	3.94**	3.56**	0.21
	2023	2.56**	3.19**	0.23
Average fruit weight (g)	2022	158768.38**	192029.11**	2498.49
	2023	158735.88**	187838.25**	1705.01
Number of fruits per plant	2022	23.27**	4.57**	0.10
	2023	24.06**	3.99**	0.07
Total fruit yield (q/ha)	2022	36120.84**	4306.95**	56.78
	2023	36184.64**	4126.15**	42.19

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

performed best, followed by PMM-16 and PMM-18. These genotypes are of immense breeding utility since they are also found to be exceptional combiners for earliness, vegetative and quality characters. Hence, these combiners should be used in future breeding programmes for the exploitation of heterosis and concurrent improvement in yield as well as quality traits in muskmelon (Feyzian et al., 2009).

Specific combining ability

Among 28 F_1 hybrids, only the cross PMM-32 × PMM-18 showed a significant specific combining ability (sca) effect (Table 5a and b) in a negative direction for days to male and female flowers over the years. Other crosses like PMM-32 × PMM-16, PMM-13 × PMM-18, PMM-1 × Hara Madhu and PMM-4A × PMM-1 were found superior regarding days to female flower for both years. PMM-4A × PMM-1 was also found having significant negative effect for node number to first fruit set with the cross PMM-1 × PMM-13. Concerning vine length and number of branches, only the cross PMM-4A × PMM-1 and PMM-18 × PMM-37 showed positive sca effect over the years. Besides, some crosses like PMM-4A × PMM-32, PMM-4A × PMM-13, PMM-4A × PMM-18, PMM-1 × PMM-16, PMM-1 × PMM-37, PMM-32 × Hara Madhu, PMM-13 × PMM-16, PMM-13 × PMM-18 and PMM-16 × Hara Madhu had an admirable effect over both years for either trait. The significant effect in a desirable direction regarding sca for the traits related to earliness and vegetation was shown by less number of crosses in this experiment, revealing the lower effect of dominance and epistatic genetic variance in controlling these characters in muskmelon. Our results are in line with the findings of Feyzian et al. (2009) and Randhwa and Singh (1990) in muskmelon. Crosses like PMM-4A × PMM-32, PMM-4A × PMM-18, PMM-1 × PMM-13, PMM-1 × PMM-16, PMM-32 × PMM-16 and PMM-13 × PMM-18 reported significant effect in desirable direction for seed cavity diameter and for fruit flesh thickness PMM-4A × PMM-13, PMM-4A × PMM-18, PMM-4A × PMM-37, PMM-4A × Hara Madhu, PMM-1 × PMM-16, PMM-1 × PMM-18, PMM-1 × PMM-37, PMM-32 × PMM-18, PMM-32 × PMM-37 and PMM-13 × PMM-16 showed positive and significant sca effects over the years. The crosses like PMM-4A × PMM-18 and PMM-1 × PMM-16 were observed with significant sca for both of these traits over the years. Thus, these crosses are sources of hybrid vigour as well as can generate suitable segregates for thick-fleshed fruit and thereby higher yield as reported by Valerio et al., 2009 and Tomar and Bhalala, 2006 in muskmelon. The economic characters like average fruit weight, fruit number and yield are observed to be controlled by non-additive genetic variance since most of the crosses possessed significant and positive sca effects. F_1s like PMM-4A × PMM-13, PMM-1 × PMM-13, PMM-1 × PMM-37, PMM-1 × Hara Madhu, PMM-32 × PMM-13, PMM-32 × PMM-16, PMM-32 × Hara Madhu, PMM-13 × PMM-16, PMM-13 × PMM-18, PMM-13 × PMM-37, PMM-16 × PMM-37 and PMM-18 × Hara Madhu had a significant positive sca effect over the two years for all three economic traits. Among those hybrids, PMM-32 × PMM-16, PMM-4A × PMM-13 and PMM-18 × Hara Madhu were on top three for fruit yield. Outside yield, these hybrids showed appreciable sca effects in desirable direction for earliness, less seed cavity, fruit mesocarp thickness and total soluble solids. Hence, these F_1s could be of good heterotic potential for further commercial utility. It has been observed in this study that one of the parents of a particular cross having a good GCA resulted higher sca effect (Saha et el., 2022 and Shashikumar et al., 2011). These crosses would be of great use to get desirable transgressive segregants in further generations if multiple favourable alleles, as well as epistasis, work in the same direction to enhance the desirable traits and could be employed to develop improved cultivars in muskmelon. Both good GCA parents involved in a cross exhibiting significant sca effects confirm the prime role of additive gene effects that are fixable in nature. In contrast, some crosses reported little sca effect, even having good general combiners as parents. Therefore,

Table 4a: Estimates of general combining ability effects of parents for earliness and vegetative traits in muskmelon

Parents	*Days to first male flower*		*Days to first female flower*		*Node to first fruit set*		*Vine length (m)*		*Number of branches per plant*	
	2022	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*
PMM-4A	2.61**	1.60**	1.19**	2.80**	-0.36**	-0.30**	-0.11**	-0.16**	-0.48	-0.12
PMM-1	-1.78**	0.74**	-1.43**	0.38	0.52**	0.42*	-0.14**	0.14**	0.28*	0.48
PMM-32	-0.53**	1.14**	-0.44	0.81**	0.24	0.13	-0.42**	-0.40**	-0.44	0.42
PMM-13	0.31	-0.38*	0.42	-1.20**	-0.54**	-0.48**	0.82**	0.91**	0.26**	0.22*
PMM-16	-0.75**	-0.82**	-0.71**	-1.13**	0.28*	0.19	-0.09**	-0.14**	-0.24	-0.15
PMM-18	0.53**	0.73**	0.63**	0.51**	-0.18	-0.21**	0.39**	0.44**	0.09	0.08
PMM-37	-0.32*	-1.62**	-0.51**	-1.40**	-0.23	-0.22	-0.21**	-0.29**	-0.14	-0.48
Hara Madhu	-0.15	-1.39**	0.08	-1.35**	0.33*	0.15**	-0.27**	-0.34**	-0.08	-0.35**
SE (gi)	0.69	0.55	0.63	0.60	0.17	0.21	0.10	0.09	0.33	0.32

Table 4b: Estimates of general combining ability effects of parents for fruit characters and yield in muskmelon

Parents	*Seed cavity diameter (cm)*		*Flesh thickness (cm)*		*Total soluble solid (%)*		*Average fruit weight (g)*		*Number of fruits per plant*		*Fruit yield (q/ha)*	
	2022	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*
PMM-4A	-0.24	-0.35*	-0.50**	-0.42**	-0.26	-0.36*	-504.11**	-503.04**	-0.08	-0.06	-244.98**	-224.81**
PMM-1	0.34**	0.24	-0.36**	-0.20**	0.54**	0.24	-413.07**	-389.61**	-1.23**	-0.99**	-189.12**	-178.46**
PMM-32	-1.23**	-1.06**	0.19**	0.18**	-1.13**	-0.96**	-280.66**	-283.56**	-0.68**	-0.68**	-123.76**	-121.98**
PMM-13	0.71**	0.62**	0.23**	0.34**	0.77**	0.68**	617.01**	614.66**	2.50**	2.61**	270.98**	280.27**
PMM-16	-0.48**	0.20	0.37**	0.30**	-0.49**	0.21	157.41**	152.10**	1.50**	1.45**	57.18**	57.24**
PMM-18	0.41**	-0.19	0.31**	0.24**	0.41**	-0.09	350.61**	353.60**	-1.28**	-1.23**	210.44**	209.61**
PMM-37	-0.16	0.41**	-0.15**	-0.16**	-0.16	0.41**	101.15	-110.74	-0.61**	-0.81**	107.23	-113.82
Hara Madhu	0.31*	-0.13	-0.13**	-0.12**	0.31*	-0.13	-114.23	-106.42	-0.33*	-0.44**	-63.11	-58.73
SE (gi)	0.47	0.49	0.07	0.11	0.47	0.49	52.77	43.98	0.33	0.28	23.42	25.61

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

parents with higher gca may not produce crosses having high sca invariably (Saha et al., 2022; Glala et al., 2010). The greater sca effect of a particular cross having both poor gca parents, perhaps on account of overdominance as well as epistatic gene action and thus drives the progress away towards heterotic fixation, resulting in very little attainment from the segregating progenies (Tomar and Bhalala, 2006 and Kalb and Davis, 1984). The bi-parental mating design would be a good choice to obtain desirable segregates in early generations through the accumulation of favourable genes for several traits by involving the suitable general combiners in the crossing programme.

Analysis of Heterosis

The heterotic value of 28 F_1 hybrids was estimated in a desirable direction over the better parent (heterobeltiosis) as well as the standard check variety (standard or economic heterosis) and depicted in Tables 6a and b. The traits related to earliness (days to male and female flowering and node number to first fruit set) showed low to medium heterosis. Very few crosses resulted in desirable heterosis for node number to first fruit set, revealing a dominance of additive gene action for earliness in muskmelon. Our findings revealed the crosses like PMM 32 × PMM 13, PMM 32 × PMM 16, PMM 13 × PMM 18, PMM 32 × PMM 37, PMM 32 × PMM 13, PMM 13 × Hara Madhu, PMM 1 × Hara Madhu to have appreciable heterotic values for characters regarding earliness over the better parent and check variety for both the years. Medium range of heterobeltiosis and standard heterosis were observed for vine length and number of branches per plant. Very less number of crosses showed heterosis for the later vegetative trait. Crosses like PMM 4A × PMM 1, PMM 13 × PMM 18, PMM 18 × PMM 37 and PMM 18 × PMM 37 resulted in noticeable heterobeltiosis and standard heterosis over both years for these vegetative characters. Our study concludes that the average dominance of the alleles is low to medium in earliness and vegetative characters. The findings of our research are in line with the works done by

Table 5a: Estimates of specific combining ability effects of crosses for different quantitative traits of muskmelon

Crosses	*Days to first male flower*		*Days to first female flower*		*Node to first fruit set*		*Vine length (m)*		*Number of branches per plant*		*Seed cavity diameter (cm)*	
	2022	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*
PMM-4A X PMM-1	2.51**	-0.80	2.27**	-2.06**	-1.53**	-1.91**	0.52**	0.61**	0.75*	0.63*	2.07**	1.83**
PMM-4A X PMM-32	5.80**	-0.54	6.34**	2.97**	-1.10**	-0.24	-0.41**	-0.43**	1.12**	1.03**	-2.16**	-3.31**
PMM-4A X PMM-13	-2.17**	-1.28*	-0.16	-0.21	0.77**	-1.38**	0.93**	0.84**	-0.63*	-0.42	0.81*	0.40
PMM-4A X PMM-16	-1.20*	-2.86**	-1.40	1.70**	-0.16	-0.67	-0.51**	-0.60**	-0.88**	-0.14	3.54**	3.52**
PMM-4A X PMM-18	-1.64*	-0.69	-1.13*	0.72	-0.45	-1.92**	0.72**	0.90**	0.22	0.42	-1.70**	-1.17*
PMM-4A X PMM-37	0.03	-1.74**	1.08	3.64**	-0.95**	0.02	-0.11	0.01	-0.24	0.00	0.20	-0.67
PMM-4A X Hara Madhu	-0.91	-2.08**	-0.23	2.34**	-1.42**	-0.57	0.12	0.09	0.06	-0.50	-1.28**	-0.81
PMM-1 X PMM-32	-1.75**	-0.14	-0.63	-0.56	-0.49	-1.07*	-0.54**	-0.15	0.61*	0.50	0.04	-0.24
PMM-1 X PMM-13	-1.30*	0.15	-0.33	-0.06	-2.31**	-1.47**	-0.56**	0.45**	0.32	0.16	-3.20**	-2.50**
PMM-1 X PMM-16	-0.61	0.25	0.07	0.81	-0.05	-0.63	0.18	0.10	0.71*	0.66*	-2.61**	-2.74**
PMM-1 X PMM-18	-1.88**	-0.61	-2.31**	-0.40	0.15	0.77	0.17	0.60**	-0.84**	-0.14	-1.16**	-0.77
PMM-1 X PMM-37	-0.56	-0.61	-1.46*	-0.85	-0.32	0.50	0.79**	0.44**	-0.20	-0.28	0.27	-0.94*
PMM-1 X Hara Madhu	-0.56	-1.30*	-1.78**	-1.83**	-0.42	0.14	-0.13	-0.20**	-0.68*	-0.37	-0.06	0.25
PMM-32 X PMM-13	-1.71**	-0.24	-2.50**	-0.70	0.09	-0.09	-0.47**	-0.21*	-0.74*	-0.55	0.82	1.31**
PMM-32 X PMM-16	-0.71	-2.11**	-1.40*	-2.41**	0.73**	0.95*	0.15	0.11	0.30	0.42	-1.26**	-1.87**
PMM-32 X PMM-18	-1.98**	-1.05*	-2.45**	-1.77**	0.20*	0.44	-0.25*	-0.50**	-0.24	-0.74*	0.82	1.10*
PMM-32 X PMM-37	-0.34	-0.60	-0.96	-2.16**	-0.68	-0.39	-0.48**	-0.43**	-0.01	0.28	-0.26	-0.54
PMM-32 X Hara Madhu	0.00	-1.01*	-0.58	-2.43**	1.64**	0.63	0.32**	0.37**	-0.08	0.03	-0.16	0.46
PMM-13 X PMM-16	-0.62	-0.54	-0.70	-1.30*	-0.87	-0.60	0.55**	0.37**	0.04	-0.37	-0.83	-1.53**
PMM-13 X PMM-18	-3.20**	-0.45	-3.86**	-1.23*	0.07	0.61	0.52**	0.47**	0.79*	0.51	-1.46**	-1.50**
PMM-13 X PMM-37	0.41	0.60	0.77	-0.08	1.30**	1.10*	-0.98**	-1.15**	-0.31	-0.24	-0.16	-0.70
PMM-13 X Hara Madhu	-0.20	-0.41	0.81	-1.32*	0.64*	0.50	0.44**	0.04	0.64*	0.26	0.14	-0.84
PMM-16 X PMM-18	2.80**	-0.36	3.67**	-1.30*	0.32	0.16	-0.63**	-0.78**	-0.14	-0.50	1.20**	1.26**
PMM-16 X PMM-37	1.80**	0.05	0.64	-1.43*	0.72*	0.66*	-0.63**	-0.54**	-0.91**	-1.30**	-0.56	-1.90**
PMM-16 X Hara Madhu	-0.81	1.69**	-0.78	0.24	-0.84**	-0.14	1.08**	1.28**	0.05	0.24	1.64**	0.68
PMM-18 X PMM-37	-0.74	-0.24	-0.20	-2.03**	0.62	0.77	0.29**	0.30**	1.86**	1.90**	-0.80	-0.60
PMM-18 X Hara Madhu	1.23	-0.58	0.87	-1.00	-0.41	0.84	-0.62**	-0.71**	-0.21	0.06	0.07	0.56
PMM-37 X Hara Madhu	0.26	0.15	0.70	-1.46**	0.62*	0.26	-0.74**	-0.70**	0.30	0.00	1.30**	1.10*
SE (Sij)	1.68	1.34	1.53	1.45	0.84	0.67	0.23	0.21	0.80	0.78	1.15	1.20

Table 5b: Estimates of specific combining ability effects of crosses for different quantitative traits of muskmelon

Crosses	*Flesh thickness (cm)*		*Total soluble solid (%)*		*Average fruit weight (g)*		*Number of fruits per plant*		*Fruit yield (q/ha)*	
	2022	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*	*2022*	*2023*
PMM-4A X PMM-1	-0.30**	-0.43**	2.17**	1.63**	-78.60	-103.41*	0.47*	0.38*	-103.24	-114.91*
PMM-4A X PMM-32	-0.48**	-0.47**	-4.16**	-3.30**	-4.30	-5.38	0.42	0.34	-114.19	-103.25
PMM-4A X PMM-13	0.90**	0.68**	0.94*	0.46	458.49**	424.97**	0.91**	0.88**	215.12**	217.19**
PMM-4A X PMM-16	-0.14*	-0.19*	4.54**	3.53**	-168.37**	-156.86**	0.92**	1.01**	-68.10**	-71.45**
PMM-4A X PMM-18	0.15*	0.39**	-1.60**	-1.47*	53.63	7.89	0.01	-0.09	52.62	41.37
PMM-4A X PMM-37	0.46**	0.40**	0.28	-0.63	63.09	160.51**	1.35**	1.26**	32.95	37.64**
PMM-4A X Hara Madhu	0.52**	0.41**	-1.26**	-0.80	116.62*	109.12**	-1.49**	-1.45**	51.58*	50.19**
PMM-1 X PMM-32	-0.29**	-0.32**	0.14	-0.24	-161.09**	-162.15**	-1.21**	-1.30**	-24.65**	-24.70**
PMM-1 X PMM-13	-0.25**	-0.33**	-3.20**	-2.44**	308.37**	315.53**	1.64**	1.28**	26.61**	25.02**
PMM-1 X PMM-16	0.55**	0.48**	-2.62**	-2.54**	-14.89	-18.09	1.22**	1.30**	-36.78	-38.80
PMM-1 X PMM-18	0.63**	0.71**	-1.16**	-0.77	-34.49	-31.35	-0.24	-0.24	-71.63	-75.49
PMM-1 X PMM-37	0.29**	0.31**	0.07	-0.94*	362.50**	301.90**	0.95**	0.63*	111.24**	105.30**
PMM-1 X Hara Madhu	0.03	-0.05	-0.08	0.26	237.43**	239.24**	0.94**	1.19**	37.05**	39.39**
PMM-32 X PMM-13	0.19**	0.09	0.80	1.30**	216.83**	257.70**	1.06**	0.86**	121.72**	120.27**
PMM-32 X PMM-16	0.08	0.01	-1.26**	-1.87**	505.17**	524.46**	2.17**	2.01**	218.84**	215.59**
PMM-32 X PMM-18	0.20**	0.22**	0.84	1.10*	-178.29**	-183.34**	0.15	0.38	-63.44**	-65.51**
PMM-32 X PMM-37	0.35**	0.44**	-0.26	-0.74	181.43**	185.24**	0.37	0.41	82.10**	85.12**
PMM-32 X Hara Madhu	0.06	0.08	-0.06	0.46	123.83*	111.24*	1.46**	1.34**	75.26*	74.81*
PMM-13 X PMM-16	0.26*	0.29**	-0.82	-1.50**	214.17**	276.14**	2.10**	2.18**	100.35**	103.19**
PMM-13 X PMM-18	0.07	0.00	-1.40**	-1.54**	940.77**	924.71**	3.72**	3.40**	125.01**	123.94**
PMM-13 X PMM-37	-0.22**	-0.34**	-0.19	-0.70	106.83*	96.41*	1.84**	1.82**	115.51*	14.59*
PMM-13 X Hara Madhu	-0.19	0.01	0.24	-0.80	-195.63**	-207.05**	0.15	0.14	-28.90**	-29.86**
PMM-16 X PMM-18	-0.04	0.04	2.20**	1.26**	-282.36**	-287.80**	-2.94**	-2.79**	-213.90**	-212.75**
PMM-16 X PMM-37	-0.30**	-0.24*	-0.46	-0.90**	264.90**	285.94**	1.42**	1.50**	102.08**	103.61**
PMM-16 X Hara Madhu	-0.30**	-0.44**	1.64**	0.63	101.49*	103.65*	0.32	0.45	134.54*	139.94*
PMM-18 X PMM-37	-0.44**	-0.29**	-1.80	-1.62	-82.90	-63.50	-1.63**	-1.69**	-17.19	-17.17
PMM-18 X Hara Madhu	-0.34**	-0.38**	0.17	0.60	603.49**	619.04**	2.05**	2.07**	139.63**	140.00**
PMM-37 X Hara Madhu	-0.06	-0.16	1.39**	1.40*	-332.38**	-270.38**	-1.78**	-1.42**	-115.24**	-112.87**
SE (Sij)	0.18	0.25	1.15	1.20	128.07	106.74	0.81	0.67	106.09	105.08

* Significant at 0.05 levels of probability; ** Significant at 0.01 levels of probability

Table 6a: Heterosis in muskmelon for earliness and vegetative traits

Cross combinations		*Days to first male flower*		*Days to first female flower*		*Node to first fruit set*		*Vine length (m)*		*Number of branches per plant*	
		BP	*CP*	*BP*	*CP*	*BP*	*CP*	*BP*	*CP*	*BP*	*CP*
PMM-4A X PMM-1	2022	-2.19	7.17**	5.13**	6.43**	10.49*	-0.05	54.09**	38.10**	16.60	27.27*
	2023	-11.53**	9.00**	-1.46	3.98**	23.08**	-17.95**	42.18**	45.06**	23.32*	38.16**
PMM-4A X PMM-32	2022	9.43**	20.18**	13.83**	13.83**	18.79*	7.45	-10.31**	-3.39*	32.18**	27.27*
	2023	-10.15**	10.13**	5.26**	19.66**	11.54	25.64**	-15.55**	-6.43	26.31**	45.11**
PMM-4A X PMM-13	2022	-7.32**	2.70	-1.40	3.10	71.27**	54.92**	5.91**	51.60**	-20.08*	-9.09
	2023	-19.38**	4.18	-1.57	7.84**	42.31**	-5.13	2.56	53.12**	-21.43*	10.00
PMM-4A X PMM-16	2022	-8.11**	0.80	-0.77	-0.78	49.17**	34.93**	-14.80**	-3.80	-33.03**	-27.27*
	2023	-23.16**	-3.00	3.13	10.91**	32.69**	-11.54*	-20.14**	-9.41*	-15.36	11.00
PMM-4A X PMM-18	2022	-6.35**	4.51	-3.35*	3.33	10.49	-0.05	5.16	29.90**	20.00	9.09
	2023	-15.50**	8.16**	4.53	13.68**	11.54	25.64**	7.65**	37.11**	28.02*	31.10*
PMM-4A X PMM-37	2022	-3.76*	5.26*	4.60*	4.65*	28.18**	15.94*	-15.15**	4.72	0.00	-9.09
	2023	-23.16**	-1.18	7.09**	16.24**	5.39	-29.74**	-16.31**	3.49	10.00	10.00
PMM-4A X Hara Madhu	2022	-6.18**	3.51	3.11	4.10	-4.97	-14.04*	9.80**	10.87**	0.00	0.00
	2023	-22.03**	-4.13	3.90	12.82**	-5.77	-37.18**	4.62	6.68	-14.12	-7.02
PMM-1 X PMM-32	2022	-9.11**	-10.41**	-6.88**	-6.88**	19.89**	8.45	-23.44**	-15.02**	16.63**	27.27*
	2023	-8.33**	10.00**	-11.62**	11.71	15.39*	-23.08**	-1.44	11.61**	27.27*	40.00**
PMM-1 X PMM-13	2022	-17.97**	-7.89**	-9.03**	-5.13**	59.38**	27.44**	-21.26**	17.60**	7.69	27.27*
	2023	-7.14**	6.00*	-9.40**	-3.71	28.43**	3.85	3.04	47.14**	-7.14	30.00*
PMM-1 X PMM-16	2022	-4.59	-8.65**	-3.26	-6.20**	44.38**	15.44**	5.30	10.51**	15.63	27.27*
	2023	-7.89**	5.00*	-7.09**	0.85	0.00	20.51**	5.19	18.19**	7.69	40.00**
PMM-1 X PMM-18	2022	-15.45**	-8.77**	-13.49**	-9.53**	36.88**	9.45	-9.13**	19.03**	-16.67	-9.09
	2023	-6.90**	9.11**	-9.16**	1.31	-5.84	25.64**	18.54**	42.73**	8.09	18.02
PMM-1 X PMM-37	2022	-4.62	-7.89**	-6.20**	-9.20**	81.25**	44.93**	3.95	14.46**	-8.33	0.00
	2023	-14.28**	6.14	-12.11**	-4.27	22.58**	2.56	1.78	14.45**	9.12	10.00
PMM-1 X Hara Madhu	2022	-7.12**	-7.02**	-8.53**	-8.53**	6.25	-15.04*	4.86	3.87	-16.67	-9.09
	2023	-14.04**	-2.00	-13.37**	-7.84**	-33.87**	-47.44**	6.99*	6.99*	-9.18	1.02

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PMM-32 X PMM-13	2022	-18.40**	-6.44*	-14.85**	-9.75**	25.63**	0.45	-25.00**	14.02**	-20.08*	-9.09
	2023	-10.17**	6.33**	-14.38**	-2.56	-30.32**	-44.62**	-18.12**	27.95**	-20.43*	10.00
PMM-32 X PMM-16	2022	-3.60	-4.14*	-6.18**	-6.38**	25.00**	-0.05	-4.17	2.80	0.00	9.09
	2023	-16.32**	-1.00	-20.30**	-9.40**	-25.48	-19.23**	-8.68**	6.78	3.18	29.16*
PMM-32 X PMM-18	2022	-13.11**	-6.14*	-12.32**	-6.20**	47.50**	17.94**	-19.35**	7.30*	10.00	0.00
	2023	-10.86**	6.00**	-11.78**	-1.85	1.61	-35.89**	-22.49**	8.99*	-10.09	9.83
PMM-32 X PMM-37	2022	-1.83	-4.34	-5.43**	-5.43**	-22.50**	-22.54**	-26.11**	-14.59**	10.00	0.00
	2023	-11.83**	1.03	-19.05**	-6.80**	-14.38	-15.39**	-23.24**	-6.14	9.09	21.00
PMM-32 X Hara Madhu	2022	-2.62	-2.68	-3.40	-3.40	22.50	22.44**	-2.80	7.44	3.98	4.62
	2023	-18.67**	1.00	-18.15**	-3.94**	0.79	-25.64**	1.34	11.66**	7.02	10.13
PMM-13 X PMM-16	2022	-12.01**	-3.54	-8.89**	-4.65*	25.00**	16.94**	-1.44	47.21**	-7.69	9.09
	2023	-4.73*	-1.02	-9.32**	-8.55**	-5.48	-26.96**	-4.33*	50.14**	-21.43*	10.00
PMM-13 X PMM-18	2022	-19.19**	-9.02**	-11.04**	-6.98**	20.73**	14.44**	8.32**	56.80**	15.38	26.16**
	2023	-9.50**	3.00	-15.50**	-4.27	-17.39**	-27.69**	5.21*	64.49**	0.00	40.00**
PMM-13 X PMM-37	2022	-10.94**	0.00	-7.19**	-0.78	15.00	-7.05**	-29.60**	5.15	-15.38	1.08
	2023	-4.77*	10.00	-6.78**	-4.98**	-13.76*	46.15**	-31.85**	8.17**	-21.43*	10.35
PMM-13 X Hara Madhu	2022	-14.72**	-0.82	-3.78	1.78	-7.00	8.15	-4.60	42.49**	7.69	27.20*
	2023	-7.62**	-3.00	-10.47**	-9.40**	-45.54**	-23.85**	-13.21**	36.37**	-14.28	20.00
PMM-16 X PMM-18	2022	0.80	9.17**	0.00	6.98**	8.20	-9.05**	-21.17**	6.10	-8.33	0.00
	2023	-11.40**	2.16	-13.10**	-4.27	-5.41	-3.85	-22.78**	6.55*	-23.08*	0.00
PMM-16 X PMM-37	2022	3.50*	0.83	2.43	-2.30	-9.00	14.94*	-26.46**	-15.19**	-33.33**	-27.27*
	2023	-7.62**	-3.00	-10.17**	-9.40**	-9.03	-35.13**	-24.60**	-3.86*	-46.15**	-30.00*
PMM-16 X Hara Madhu	2022	-5.26*	-5.20*	-4.05*	-4.05*	21.05**	-4.05	21.83**	32.91**	-8.33	0.00
	2023	-2.87	2.00	-5.93**	-5.13*	17.86*	17.95**	18.87**	31.55**	-16.30	12.00
PMM-18 X PMM-37	2022	-9.36*	-3.63	-9.97**	-4.55	1.05	29.94**	-7.18**	25.51**	68.12**	54.55**
	2023	-12.17**	1.01	-15.73**	-6.84**	-16.07	2.56**	-6.91**	31.69**	52.13**	50.11**
PMM-18 X Hara Madhu	2022	-4.06	3.54	-4.35*	2.31	36.84**	4.95	-22.20**	3.43	0.00	0.00
	2023	-13.14**	0.00	-14.50**	-4.27	14.29*	-17.95**	-25.13**	4.62	10.00	10.00
PMM-37 X Hara Madhu	2022	-1.35	-1.05	-0.78	-0.78	10.53	5.45	-29.75**	-15.88**	9.09	9.09
	2023	-4.02*	-3.14*	-8.20**	-9.16**	-10.71	27.69**	-32.80**	-19.10**	0.00	0.00

Table 6b: Heterosis in muskmelon for fruit characters and yield

Cross combinations		*Seed cavity diameter (cm)*		*Flesh thickness (cm)*		*TSS (%)*		*Average fruit weight (g)*		*Number of fruits/ plant*		*Total fruit yield (q/ha)*	
		BP	*CP*	*BP*	*CP*	*BP*	*CP*	*BP*	*CP*	*BP*	*CP*	*BP*	*CP*
PMM-4A X PMM-1	2022	-7.89	20.61**	-10.23**	-26.75**	-6.81	29.63**	31.40	-37.53**	8.67*	10.49*	22.64	-48.11**
	2023	-11.11	33.33**	-13.54**	-30.54**	-9.14	30.13**	26.44	-38.18**	9.12*	11.39**	36.46	-43.50**
PMM-4A X PMM-32	2022	-59.23**	-58.22**	-26.84**	-23.25**	-58.20**	-59.36**	22.15	-38.75**	10.54**	13.53**	16.96	-29.54**
	2023	-50.00**	-45.83**	-26.94**	-25.10**	-48.12**	-46.81**	16.35	-23.52**	9.61**	15.13**	25.01	-47.90**
PMM-4A X PMM-13	2022	-15.79**	18.52*	12.20**	21.05**	-19.78**	18.12*	18.44**	63.19**	18.30**	42.61**	23.20**	80.29**
	2023	-25.64**	20.83*	1.38	10.88**	-21.62**	18.81*	36.45**	76.49**	15.31**	42.18**	49.15**	82.38**
PMM-4A X PMM-16	2022	36.00**	44.48**	-22.70**	-4.39	46.13**	43.40**	-28.14**	-54.38	29.73**	26.47**	-33.72**	-6.95
	2023	15.62*	54.17**	-21.32**	-19.46**	14.60*	53.16**	-44.32**	-23.64	21.70**	32.44**	-25.01**	-14.02
PMM-4A X PMM-18	2022	-30.33**	-14.81*	-14.30**	2.63	-30.30**	-14.81*	-28.53**	29.66**	3.01	5.12	-15.51**	34.43**
	2023	-21.43**	-8.33	3.08	2.51	-20.42**	-9.36	-32.52**	38.29**	7.06	5.99	-39.01**	33.83**
PMM-4A X PMM-37	2022	0.00	0.00	6.24	-2.19	0.00	0.00	-24.24	-46.27	19.91**	18.11**	-19.85	-0.91
	2023	-30.56**	4.17	9.66*	-6.02	31.16**	3.19	31.99	16.99	14.14**	21.96**	44.98	19.33
PMM-4A X Hara Madhu	2022	-14.12	-14.1	7.08	7.08	-14.14	-14.14	18.16	38.77	-1.46	0.56	2.94	2.94
	2023	-8.00	-4.17	-5.44	-5.44	-8.18	-5.16	25.66	65.38	-3.05**	4.80**	13.97	23.97
PMM-1 X PMM-32	2022	-34.58**	-4.70	-14.23**	-7.46**	-31.08**	-9.73	27.11	-27.93**	3.86	-14.18**	12.48	-32.24**
	2023	-33.33**	0.00	-15.11**	-12.97**	-33.13**	8.12	28.28	-38.28**	1.38**	-7.16*	13.20	-29.64**
PMM-1 X PMM-13	2022	-40.12**	-19.51*	-9.12**	-2.60	41.40**	-19.52*	19.23**	56.38**	18.07**	51.16**	23.37**	80.54**
	2023	-43.59**	-8.33	-16.67**	-3.95*	-33.52**	-9.36	34.12**	78.28**	24.78**	50.19**	79.46**	82.85**
PMM-1 X PMM-16	2022	-43.33**	-26.91**	-2.13	23.05**	-47.36**	-25.83**	-16.18**	29.84*	19.42**	20.93**	-13.50**	15.22*
	2023	-44.44**	-16.67	-1.84	11.72**	40.14**	-19.63	-26.86*	23.42**	18.76**	25.15**	-8.49*	38.23**
PMM-1 X PMM-18	2022	-38.96**	10.98	3.33	21.37**	-28.95**	18.10	-25.79**	17.57**	11.56*	-17.65	-13.79**	37.16**
	2023	-30.56**	4.17	16.42**	15.98**	-31.16**	5.16	-33.59**	38.64**	11.59**	-3.60	-14.29**	41.63**
PMM-1 X PMM-37	2022	-23.68**	7.41	6.02*	0.44	-21.67**	7.41	17.14**	86.49**	11.12**	9.60	20.96**	32.95**
	2023	-27.78**	8.33	10.63*	-4.18	-27.08**	9.33	31.98**	28.33**	15.80**	3.18*	24.45**	33.42**
PMM-1 X Hara Madhu	2022	-21.05**	11.14	-5.26	-5.26	-25.05**	14.10	22.32**	36.28**	16.60**	19.05**	42.49**	22.49**
	2023	-22.22**	16.67	-11.88**	-10.88**	-22.22**	16.63	36.18**	19.48**	19.76**	15.76**	25.52**	25.52**

Cont...

PMM-32 X PMM-13	2022	-23.63**	8.41	9.18**	21.42**	-23.60**	3.41	19.31**	76.83**	18.69**	51.10**	25.06**	83.01**
	2023	-23.08**	25.00**	1.14	14.72**	-23.08**	26.00**	24.56**	75.47**	10.33**	50.61**	21.39**	85.81**
PMM-32 X PMM-16	2022	-39.63**	-30.63**	-10.22**	-26.75**	-29.63**	-29.63**	44.32**	65.38**	25.41**	36.35**	30.57**	73.93**
	2023	-40.63**	-20.83*	-4.40	9.79*	-41.63**	-24.80*	25.28**	82.12**	25.84**	31.73**	37.60**	77.78**
PMM-32 X PMM-18	2022	-15.45*	3.73	-28.86**	-23.25**	-15.15*	3.70	-18.11**	33.27**	11.06**	9.02	-20.41**	26.63**
	2023	-3.57	12.50	11.20**	16.01**	-3.57	10.54	-19.86**	36.82**	18.23**	5.70	-22.05**	48.81**
PMM-32 X PMM-37	2022	-13.83*	-14.81*	12.21**	20.15**	-14.81*	-14.81*	26.54**	37.87**	11.19**	9.02	16.75**	28.32**
	2023	-36.11**	-4.17	5.32	9.95*	-36.41**	-4.17	20.84**	33.28**	18.10**	14.98**	21.24**	29.97**
PMM-32 X Hara Madhu	2022	-7.44	-7.40	-22.70**	-4.39	-7.41	-7.41	16.72**	87.33**	18.19**	20.59**	21.59**	21.59**
	2023	-3.85	4.17	-1.04	1.42	-1.85	5.17	34.19**	40.28**	24.16**	20.56**	21.96**	24.96**
PMM-13 X PMM-16	2022	-32.58**	-3.72	-13.33**	2.63	-31.58**	-3.70	22.16**	98.32**	27.44**	61.18**	86.76**	114.77**
	2023	-35.90**	4.17	5.19*	11.86**	-36.91**	6.19	85.34**	133.47**	20.51**	56.13**	46.04**	123.55**
PMM-13 X PMM-18	2022	-28.15**	8.12	3.24	-2.19	28.95**	0.00	93.17**	153.72**	44.14**	73.06**	106.42**	196.61**
	2023	-38.46**	0.00	2.37	12.93**	-31.45**	4.02	94.29**	187.32**	32.32**	71.04**	101.81**	198.40**
PMM-13 X PMM-37	2022	-23.68**	7.41	0.00	0.00	23.68**	7.41	30.12**	86.35**	23.72**	50.47**	32.71**	94.22**
	2023	-28.21**	16.67	-14.12**	-5.12	-21.20**	17.18	37.29**	84.33**	17.62**	69.88**	28.36**	96.48**
PMM-13 X Hara Madhu	2022	-20.41**	24.81*	-14.23**	-7.46**	-18.42**	14.81*	28.66**	72.34**	24.42**	41.31**	15.85**	69.54**
	2023	-33.33**	8.33	-6.34	4.63	-33.13**	9.33	23.18**	58.27**	8.89**	41.90**	41.49**	70.66**
PMM-16 X PMM-18	2022	3.08	25.93**	-9.76**	-2.63	3.03	25.93**	22.17	57.34**	-20.79**	-17.06**	31.35	61.25**
	2023	-3.13	29.17**	-0.74	12.97**	-3.15	20.98**	48.22	87.29**	-18.18**	-14.71**	10.61	66.26**
PMM-16 X PMM-37	2022	-11.10	-11.14	-2.13	20.25**	-11.11	-11.11	21.21**	67.84**	20.79**	25.47**	26.93**	69.09**
	2023	-36.11**	-4.17	-15.44**	-3.77	-36.14**	-4.13	38.73**	68.29**	24.16**	31.74**	34.92**	74.32**
PMM-16 X Hara Madhu	2022	18.52*	18.52*	3.33	23.21**	18.52*	18.52*	17.54**	49.38**	15.17**	21.59**	31.07**	55.95**
	2023	-9.38	20.83**	-18.76**	-3.94*	-9.38	20.81**	19.38**	47.38**	17.04**	23.35**	22.55**	58.33**
PMM-18 X PMM-37	2022	-21.21**	-4.70	6.02*	0.44	-21.21**	-3.70	8.32*	54.39**	-9.49*	-16.88**	28.06*	71.93**
	2023	-27.78**	8.33	-6.67	-6.28	-27.78**	8.33	31.25*	66.75**	-7.15	-14.37**	6.08*	75.31**
PMM-18 X Hara Madhu	2022	-9.09	11.11	-5.26	-5.26	-9.09	11.11	49.37**	113.64**	22.31**	22.35**	91.92**	138.53**
	2023	0.00	16.67	-7.82*	-7.50*	7.10	15.07	78.43**	177.39**	24.55**	20.55**	95.07**	140.88**
PMM-37 X Hara Madhu	2022	12.50*	11.52	9.76**	15.42**	18.52*	18.52	-0.77	9.06	-8.20*	-8.20*	0.31	10.25
	2023	-13.89*	29.17**	-11.43**	-11.43**	-13.89*	21.17**	15.38	44.38**	-4.12	-5.79	7.80	15.56**

*Significant at 0.05 level of probability;** Significant at 0.01 level of probability; BP- heterosis over better parent/ heterobeltiosis; CP- heterosis over check parent/ standard heterosis

Shashikumar and Pitchaimuthu (2011) and Kalb and Davis (1984) on muskmelon. The fruit quality traits, like seed cavity diameter, showed a good amount of heterobeltiosis in the desirable direction, although the superiority was very low over the check variety. Flesh thickness and total soluble solids exhibited very little heterosis and thus discovered less importance of non-additive genetic variance to control over these traits. The F_1s like PMM 4A × PMM 32, PMM 32 × PMM16, PMM 1 × PMM 18, PMM 32 × PMM 18, and PMM 4A × PMM 16 stood out for the above fruit quality traits. Our observations are in conformity with those of Tomar and Bhalala (2006) and Chaudhary et al. (2003) in muskmelon. Economic traits like average fruit weight, fruit number and fruit yield resulted in medium to high levels of heterosis (Saha et al., 2022) for most of the hybrids, depicting the dominance effect of non-additive genetic variance in controlling these traits. The range of heterosis varied from 8.32 to 187.32% for average fruit weight. The same noted from 1.38 to 73.06% and 6.08 to 198.40% for the number of fruits per plant and total fruit yield, respectively. Hence, there will be a scope for selecting better-performing offspring. Our findings are in agreement with those of El-Sayed et al. (2019 and Iria et al. (2009) in muskmelon. Among all the hybrids, PMM 13 × PMM 18, PMM 18 × Hara Madhu and PMM 13 × PMM 16 were the top three regarding yield. These crosses also found great in earliness, vegetative and fruit quality traits. Therefore, these identified heterotic crosses should be taken under evaluation in multiple locations to assess their performance as commercial hybrids for the future.

Conclusion

This investigation aimed to select suitable genotypes to act as parents for hybrid development in muskmelon, having higher yield, good plant architecture and fruit quality. Analysis of variance revealed the existence of ample genetic variability among the parental genotypes used in this study. The results indicated that most of the traits are governed by both additive and non-additive types of genetic components, which is challenging to improve through direct selection. Therefore, recombination breeding followed by selection in later generations would be the way of achievement in this. Recurrent selection would be an option for population improvement by mitigating the exposure of deleterious recessive alleles from selected selfed progeny. In order to make use of non-additive gene effect and to tackle non-allelic interactions, breeding strategies like restricted recurrent selection through intermating carried among improved segregates, followed by selection or biparental or diallel selective mating or multiple crosses during the initial segregating generations would be effective to get a desirable genotype with improved trait. Genotypes PMM-13, PMM-16, Hara Madhu, PMM-1 and PMM-37 were found admirable for earliness. PMM-13, PMM-16, PMM-18 and PMM-32 stood out for vegetative as well as fruit quality characters. PMM-13, PMM-16 and PMM-18 were observed as outstanding general combiners for yield traits like average fruit weight, fruit number and total fruit yield. These genotypes are of immense breeding utility since they are also found to be exceptional combiners for earliness, plant architecture and fruit quality. Hence, these combiners should be used in future breeding programmes for the exploitation of heterosis and concurrent improvement in yield as well as quality traits in muskmelon. Among 28 F_1 hybrids, PMM-32 × PMM-16, PMM-4A × PMM-13 and PMM-18 × Hara Madhu exhibited higher sca effects for fruit yield. Outside yield, these hybrids showed appreciable sca effects in desirable direction for earliness, less seed cavity, fruit mesocarp thickness and total soluble solids. Hence, these F_1s could be of good heterotic potential for further commercial utility. It has been observed in this study that one of the parents of a particular cross having a good GCA resulted higher sca effect. These crosses would be of great use to get desirable transgressive segregants in further generations and could be employed to develop improved cultivars in muskmelon. The bi-parental mating design would be a good choice to obtain desirable segregates in early generations through the accumulation of favourable genes for several traits by involving the suitable general combiners in the crossing programme. Among all the hybrids, PMM 13 × PMM 18, PMM 18 × Hara Madhu and PMM 13 × PMM 16 were the top three as per heterotic value regarding yield. These crosses also found great in earliness, vegetative and fruit quality traits. Therefore, these identified heterotic crosses should be taken under evaluation in multiple locations to assess their performance as commercial hybrids for the future.

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सारांश

खरबूजे में व्यावसायिक उपयोग के लिए उपयुक्त जनक और उनके संकर का चयन करने हेतु इस अध्ययन के अंतर्गत हेटेरोसिस के अनुमान के साथ सामान्य और विशिष्ट संयोजन क्षमता का विश्लेषण किया गया था। पारस्परिक को छोड़कर द्विगुणित संभोग रणनीति का पालन करके 8 जनक से 28 F_1 संकर विकसित किए गए थे। बेहतर पर हेटेरोसिस के साथ सामान्य और विशिष्ट संयोजन क्षमता का आकलन करने और ग्यारह मात्रात्मक लक्षणों के लिए जनक की जांच करने के लिए माता-पिता के साथ संकर का दो लगातार वर्षों तक मूल्यांकन किया गया था। अध्ययन से लक्षणों की अभिव्यक्ति पर योगात्मक और गैर-योगात्मक दोनों आनुवंशिक नियंत्रण के प्रभाव का पता चला। जीनोटाइप पीएमएम-13, पीएमएम-16 और पीएमएम-18 को उपज के लिए उत्कृष्ट सामान्य संयोजक के रूप में देखा गया और अगेती होने, पौधे की संरचना और फल की गुणवत्ता के लिए भी सराहनीय पाया गया। उपज के मामले में इन संकरों ने शीघ्रता, कम बीज गुहा, फल मेसोकार्प मोटाई और कुल घुलनशील ठोस पदार्थों के लिए वांछनीय दिशा में सराहनीय विशिष्ट संयोजन क्षमता काप्रभाव दिखाया। इस अध्ययन में यह देखा गया है कि एक विशेष क्रॉस के माता-पिता में से एक का अच्छा सामान्यसंयोजन क्षमता होने के कारण उच्च विशिष्ट संयोजन क्षमता काप्रभाव हुआ। सभी संकरों में से पीएमएम 13 x पीएमएम 18, पीएमएम 18 x हरा मधु और पीएमएम 13 x पीएमएम 16 उपज के संबंध में विषम मूल्य के अनुसार शीर्ष तीन थे। इन क्रॉस में शीघ्रता, वनस्पति और फल गुणवत्ता लक्षण भी बहुत अच्छे पाए गए।