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Heterosis and combining ability for fruit quality, mineral nutrients and post harvest traits of muskmelon

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ABSTRACT

Twenty-one F1 hybrids of muskmelon, along with seven parents from two horticultural groups, were evaluated for heterosis and combining ability for fruit quality, mineral nutrients, and post harvest traits, in a half diallel scheme, during the spring-summer and kharif seasons. For all fruit quality, mineral nutrient, and post harvest traits, SCA Component of variance (σ2s) was greater than the GCA component of variance (σ2g), indicating the importance of non-additive gene action for improvement. Kashi Madhu (P6) was the best general combiner for K, Zn, Cu, Ca and Mg content, whereas Pusa Madhuras (P5) was for ascorbic acid and Mn content. Besides, the parent DCM-31 (P4) was the best general combiner for TSS and Fe content; Hara Madhu (P7) for acidity and Na content; DHM-162 (P2) for respiration rate and ethylene emission rate. The hybrid, DCM-31 × Pusa Madhuras, was the best heterotic combination for ascorbic acid and Fe content. The cross DMM-159 × Pusa Madhuras was the best heterotic hybrid for TSS and Cu content. Similarly, the cross DHM-163 × DMM-159 was superior for respiration and ethylene emission rates. The cross-combinations, DCM-31 × Kashi Madhu, DHM-163 ×DCM-31, DMM-159 × Hara Madhu, DCM-31 × Hara Madhu, DMM-159 × DCM-31 and DHM-163 × Pusa Madhuras, exhibited highest heterosis for acidity, Na, K, Zn, Mn and Ca content. None of the hybrids excelled in fruit quality, mineral nutrients, and post harvest traits, indicating the importance and need for multiple crossing breeding approaches to improve muskmelon fruit quality, mineral concentration, and post harvest life.

Keywords: *Cucumis melo* L., GCA, SCA, Heterosis, Predictability ratio

INTRODUCTION

Muskmelon (*Cucumis melo* L., 2n=2x=24) is a nutritious and commercially important cucurbit known for its aromatic musky flavour, sweet taste, and richness of vitamins and minerals (Choudhary *et al*., 3). The yellow and orange fleshed melons contain 4200 IU β-carotene, 0.3 g protein, 32 mg calcium, 1.4 mg iron and 14 mg phosphorus and 26 mgascorbic acid per 100 g of edible portion (Lester, 6). Muskmelon genotypes classified as *inodorous* have a very long shelf life, excellent fruit quality, and do not dehisce from the stem after maturity. Sun melon, also known as sarda melon, belongs to *inodorous* group and has an orange or yellow rind and green, white, or orange flesh. It used to be imported into India but now it is being grown in some areas with mild climatic conditions. The high level of genetic diversity for fruit quality traits and mineral composition was reported among 65 melon genotypes from 3 different horticultural groups (Bhimappa *et al*., 2) which could be classified into 13 clusters. Many of these genotypes from *inodorous* group were not used for study of heterosis and combining ability in crosses with Indian muskmelon genotypes from *cantalupensis* or *reticulatus* group. Improvement of quality traits in melon has not received much attention in the earlier period, and the behaviour of genotypes and crosses from different horticultural groups for heterosis and combining ability with respect to minerals, acidity, ascorbic acid, TSS and traits related to post harvest life are less studied. To date, there is no information available on heterosis and combining ability for mineral nutrients and post harvest traits in Indian muskmelon. As a result, the current study was conducted to estimate combining ability and extent of heterosis for quality traits, mineral nutrients and post harvest traits in muskmelon for quality breeding programme.

MATERIALS AND METHODS

This study was conducted at ICAR- Indian Agricultural Research Institute, New Delhi (28°08'N, 77°12'E) during the *spring- summer* and *kharif* seasons of 2017. Seven diverse inbred lines, including three commercial varieties of muskmelon from 2 groups exhibiting the considerable amount of variation, *viz.,* DHM-163 (P_1), DHM-162 (P_2), DMM-159 (P_3) from *inodorous* group; DCM-31 (P_4), Pusa Madhuras (P_5), Kashi Madhu (P_6), and Hara Madhu (P_7) from *cantalupensis* were crossed in a half-diallel mating design during *spring-summer* season. The

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twenty-one F_1 hybrids derived from the crosses along with seven parents were grown under polyhouse in a RBD (randomized block design) with three replications during *kharif* season of 2017. The crop was sown on raised beds that were 1.2 m apart with 50 cm plant to plant spacing, and the recommended cultivation practices were followed. Five plants of melon were randomly selected in each treatment for recording fruit quality, mineral nutrients and post harvest traits.

Fruits were harvested at fresh marketable stage for recording of physico-chemical traits. Five fruits of each genotypes were used for the analysis and TSS was recorded using a digital refractometer. Ascorbic acid content was determined by direct colorimetric method (AOAC, 1). The total titratable acidity was estimated by the visual titration method (AOAC, 1). For estimation of mineral elements, 200 g of chopped fruits were dried at 50–55˚C in a hot air oven and ground in pestle-mortar. The ground material was sieved through a 1 mm sieve, and the sieved fruit powder was stored in an air-sealed plastic pouch. Mineral nutrients were determined by digesting oven dried samples (1 g) overnight in a diacid solution of perchloric acid and nitric acid (1:1) and then heating the solution to 200°C for 2-3 hours until it became colourless (Singh *et al.*, 9). The digested content was filtered using Whatman No. 42 filter paper and double distilled water was added to make 100 ml. The filtrate was used for estimating the concentrations of Zn, Mn, Cu, and Fe using an Atomic Absorption Spectrophotometer (AAS-4141) at wavelengths of 213.9 nm, 279.8 nm, 324.8 nm, and 248.3 nm, respectively. The contents of K and Na were estimated using a Flame photometer (ELICO CL-361) at 766.5 and 622 nm wavelengths, respectively. Ca and Mg contents were determined by EDTA titration method. A gas analyzer (Model: Checkmate 9900 O_2 / CO_2, PBI Dansensor, Denmark) was used for determining respiration rate of fruits. Ethylene emission rate of fruit was detected by using a Hewlett Packard gas chromatograph (model 5890 Series II), with minor modifications (Gaillard and Grey, 4).

INDOSTAT software package Version 8.1 was used for data analysis. The combining ability analysis for different fruit quality and mineral nutrients was performed using standard method which included parents and F1's but not the reciprocals. Relative importance of general combining ability and specific combining ability was calculated by the predictability ratio $2\sigma^2g/ 2\sigma^2g + \sigma^2s$ for fixed effect model where, σ^2g is the additive component of variance and σ^2s is the non-additive component of variance, respectively. Heterosis was calculated in the favorable direction over better parent (BP) and mid parent (MP).

RESULTS AND DISCUSSION

Significant general combining ability and specific combining ability effects on fruit quality, mineral nutrients, and post harvest traits were detected (Table 1). Thus, additive and non-additive gene actions are important in the expression of studied characters. SCA variance (σ^2s) was higher than GCA variance (σ^2g) for all the traits studied, which indicated the importance of non-additive gene action in expression of these characters. The predictability ratio and mean degree of dominance for all fruit quality, mineral nutrients, and post harvest traits were found to be less than 0.5 and more than one, respectively, confirming the dominant role of non-additive component of variance and the importance of heterosis breeding in improving these characters. Singh *et al.* (9) also reported the role of non-additive gene actions for mineral contents in cabbage.

The results of general combining ability (Table 2) showed that the parent, Kashi Madhu (P_6), was the best general combiner for K, Zn, Cu, Ca and Mg content. Pusa Madhuras (P_5) was the best general combiner for ascorbic acid and Mn content. Besides, it also showed good gca for K and Cu content. DCM-31 (P_4), besides being best general combiner for TSS and Fe content, was a good general combiner for ascorbic acid, Mg, Ca, Zn and Mn content, also. Hara Madhu (P_7) was the best general combiner for acidity and Na content, whereas DHM-162 (P_2) was the best general combiner for respiration rate and ethylene emission rate followed by DMM-163 (P_1). The estimate of gca of a line indicates its suitability to be used as parent in combination with other lines. The identified parental lines with superior performance can be crossed in suitable combinations to exploit heterosis. Crosses with high sca may be used in heterosis breeding for commercial use.

Significant sca effects were observed in 7 crosses for acidity and Cu; 3 crosses for ascorbic acid; 9 crosses for respiration rate and ethylene emission rate; 8 crosses for TSS, Na, K and Fe; 6 crosses for Zn; 5 crosses for Mn, Mg and Ca (Table 3). With regard to sca effects, the cross DMM-159 × Pusa Madhuras (good × good general combiner) was superior for TSS and K content. The cross DCM-31 × Pusa Madhuras (good × good general combiner) was superior for ascorbic acid and Cu content. Similarly, the cross DCM-31 × Kashi Madhu (good × good general combiner) exhibited superior sca effects for acidity and Zn content. The cross, DHM-163 × DMM-159 (good × good general combiner), was superior for respiration rate and ethylene emission rate.

Table 1. Analysis of variance for combining ability for fruit quality, mineral nutrients and post harvest traits in muskmelon.

Characters	Source of variation of gca		Source of variation of sca		Error		σ^2g	σ^2s	PR	MDD
	D.F.	M.S.S.	D.F.	M.S.S.	D.F.	M.S.S.				
TSS(°Brix)	6	1.60 **	21	1.63 **	54	0.06	0.006	0.050	0.05	2.04
Acidity (%)	6	0.00092**	21	0.00065**	54	0.00004	0.0001	0.0006	0.24	1.69
Ascorbic acid (mg/100g)	6	26.89 **	21	6.26 **	54	0.54	2.92	5.72	0.50	2.02
Na (mg/100g)	6	0.36**	21	0.77 **	54	0.06	0.03	0.71	0.08	2.02
K(mg/100g)	6	194.32 **	21	127.40 **	54	1.92	21.37	125.48	0.25	1.54
Zn(mg/100g)	6	1.48 **	21	0.65 **	54	0.02	0.16	0.62	0.33	2.20
Mn(mg/100g)	6	0.08 **	21	0.06 **	54	0.004	0.008	0.058	0.22	2.89
Cu(mg/100g)	6	0.009**	21	0.002**	54	0.0001	0.0011	0.0028	0.43	1.69
Fe(mg/100g)	6	0.19 **	21	0.21 **	54	0.0014	0.02	0.21	0.16	2.17
Mg(mg/100g)	6	6.32 **	21	7.98 **	54	1.17	0.57	6.81	0.14	3.34
Ca(mg/100g)	6	6.24 **	21	7.58 **	54	0.72	0.61	6.86	0.15	3.42
Respiration rate (ml.CO_2/kg/hr)	6	7.52**	21	6.74 **	54	0.05	0.82	6.68	0.19	1.63
Ethylene emission rate(µl/kg/hr)	6	4578.88**	21	1811.27**	54	0.27	508.73	1811.001	0.35	2.79

** Significant at 1% level

D.F = Degree of freedom; M.S.S = Mean sum of squares; σ^2 g = Variance of gca; PR =Predictability ratio; σ^2s = Variance of sca; MDD = Mean degree of dominance

Table 2. Estimate of gca effects of parents in muskmelon for fruit quality, mineral nutrients and post harvest traits.

Parents	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg /100g)	Na (mg /100g)	K (mg /100g)	Zn (mg /100g)	Mn (mg /100g)	Cu (mg /100g)	Fe (mg /100g)	Mg (mg /100g)	Ca (mg /100g)	Respiration rate (ml. CO_2 /kg /h)	Ethylene emission rate (µl/ kg/h)
P_1	-0.14	0.00	-1.37**	0.14	-6.52**	0.22**	-0.03	-0.04**	-0.22**	0.68*	0.405	-1.02**	-32.50**
P_2	-0.68**	-0.011**	-2.29**	-0.009	-3.15**	-0.56**	-0.12**	-0.03**	0.1**	-1.04*	-1.19**	-1.16**	-33.44**
P_3	0.37**	0.007**	-1.58**	0.08	-0.511	-0.31**	0.05**	-0.01**	0.05**	-0.21	-0.46	-0.90**	-22.94**
P_4	0.46**	0.011**	1.61**	0.012	-0.85	0.32**	0.09**	0.03**	0.19**	0.81*	0.96**	-0.92**	31.50**
P_5	0.34**	0.012**	1.79**	0.08	5.80**	-0.09	0.12**	0.01**	0.04**	-0.16	-0.23	1.16**	26.66**
P_6	0.01	-0.006**	1.52**	0.12	6.39**	0.60**	-0.009	0.04**	0.005	0.93*	1.05**	1.84**	16.53**
P_7	-0.35**	-0.013**	0.31	-0.44**	-1.15*	-0.18**	-0.10**	0.005	-0.16**	-1.01*	-0.52	1.01**	14.19**
S.E. (gi)	0.08	0.001	0.22	0.07	0.42	0.05	0.019	0.003	0.011	0.33	0.26	0.074	0.161
S.E. (gi - gj)	0.12	0.002	0.34	0.11	0.65	0.07	0.029	0.004	0.017	0.51	0.40	0.253	0.246
C.D. at 5%	0.17	0.004	0.55	0.18	1.04	0.12	0.047	0.007	0.028	0.81	0.64	0.166	0.361

* Significant at 5% level; ** Significant at 1 % level.

Besides, the crosses, DHM-163 × DCM-31 (poor × poor general combiner), DMM-159 × DCM-31 (Good × pood general combiner), Pusa Madhuras × Kashi Madhu (good × average general combiner), DHM-162 × DCM-31 (poor × good general combiner), DHM-163 × Pusa Madhuras (average × poor general combiner) were the superior crosses for Na, Mn, Fe, Mg and Ca, respectively. In most cases, high gca effects of parents resulted in high sca effects of the cross combinations. Generally, using at least one parent with high gca effect resulted in promising results in the concerned crosses, as reported by others (Jagtap and Musmade, 5; Ram *et al*., 8). On the other hand, some crosses had low sca effects despite having high gca effects in both their parents. Thus, high gca of parents may not always result in high sca of crosses (Singh *et al*., 9). Heterosis was calculated in the favorable direction over better parent (BP) and mid parent (MP). The range of mean values of parents, F_1 hybrids and heterosis percentage are presented in table 4. For

Table 3. Ranking of best crosses for significant sca effects and their *per-se* performance with respect to fruit quality, mineral nutrients and post harvest traits in muskmelon.

Characters	Crosses with significant sca effects	Crosses with *per-se* performance
TSS(°Brix)	DMM-159 × Pusa Madhuras (2.57) DCM-31 × Pusa Madhuras (1.58) DMM-159 × Kashi Madhu (1.04)	DMM-159 × Pusa Madhuras (14.33) DCM-31 × Pusa Madhuras (13.43) DMM-159 × Kashi Madhu (12.47)
Acidity (%)	DCM-31 × Kashi Madhu (-0.04) Pusa Madhuras × Kashi Madhu (-0.03) DHM-162 × DMM-159 (-0.02)	DCM-31 × Kashi Madhu (0.1) Pusa Madhuras × Kashi Madhu (0.11) DHM-162 × DMM-159 (0.11)
Ascorbic acid (mg/100g)	DCM-31 × Pusa Madhuras (5.80) DCM-31 × Kashi Madhu (3.67) DHM-163 × DMM-159 (3.11)	DCM-31 × Pusa Madhuras (22.67) DCM-31 × Kashi Madhu (20.27) DHM-163 × DMM-159 (13.6)
Na (mg/100g)	DHM-163 × DCM-31 (-1.16) DHM-163 × Kashi Madhu (-1.06) DHM-162 × DCM-31 (-0.94)	DHM-163 × DCM-31 (4.75) DHM-163 × Kashi Madhu (4.96) DHM-162 × DCM-31 (4.81)
K(mg/100g)	DMM-159 × Pusa Madhuras (18.00) DHM-163 × DHM-162 (14.05) DCM-31 × Kashi Madhu (13.44)	DMM-159 × Pusa Madhuras (95.47) DHM-163 × DHM-162 (76.54) DCM-31 × Kashi Madhu (91.15)
Zn(mg/100g)	DCM-31 × Kashi Madhu (2.01) DHM-163 × DMM-159 (1.16) Pusa Madhuras × Hara Madhu (1.12)	DCM-31 × Kashi Madhu (5.06) DHM-163 × DMM-159 (2.55) Pusa Madhuras × Hara Madhu (2.96)
Mn(mg/100g)	DMM-159 × DCM-31 (0.65) DHM-163 × Pusa Madhuras (0.41) DHM-163 × Kashi Madhu (0.21)	DMM-159 × DCM-31 (1.99) DHM-163 × Pusa Madhuras (1.7) DHM-163 × Kashi Madhu (1.36)
Cu(mg/100g)	DCM-31 × Pusa Madhuras (0.06) DMM-159 × Pusa Madhuras (0.05) DCM-31 × Kashi Madhu (0.05)	DCM-31 × Pusa Madhuras (0.31) DMM-159 × Pusa Madhuras (0.25) DCM-31 × Kashi Madhu (0.34)
Fe(mg/100g)	Pusa Madhuras × Kashi Madhu (0.54) DHM-162 × DCM-31 (0.44) DCM-31 × Pusa Madhuras (0.43)	Pusa Madhuras × Kashi Madhu (1.8) DHM-162 × DCM-31 (1.93) DCM-31 × Pusa Madhuras (1.87)
Mg(mg/100g)	DHM-162 × DCM-31 (3.83) DCM-31 × HaraMadhu (2.76) DHM-163 × Pusa Madhuras (2.40)	DHM-162 × DCM-31 (21.6) DCM-31 × HaraMadhu (20.57) DHM-163 × Pusa Madhuras (20.92)
Ca(mg/100g)	DHM-163 × Pusa Madhuras (3.97) DHM-162 × DCM-31 (3.72) DHM-163 × DMM-159 (3.45)	DHM-163 × Pusa Madhuras (17.76) DHM-162 × DCM-31 (17.1) DHM-163 × DMM-159 (17)
Respiration rate (ml.CO_2/kg/hr)	DHM-163 × DMM-159 (-3.28) DHM-163 × DHM-162 (-2.50) DCM-162 × Kashi Madhu (-1.96)	DHM-163 × DMM-159 (1.80) DHM-163 × DHM-162 (0.83) DCM-162 × Kashi Madhu (1.69)
Ethylene emission rate (µl/kg/hr)	DHM-163 × DMM-159 (-40.24) DHM-163 × DHM-162 (-39.83) DMM-159 × Kashi Madhu (-37.41)	DHM-163 × DMM-159 (1.46) DHM-163 × DHM-162 (1.74) DMM-159 × Kashi Madhu (10.66)

most of the characters studied, the range of mean values in F_1 hybrids was higher than that of parents, except for acidity, sodium content, respiration rate, and ethylene emission rate, where negative heterosis is desired. For all fruit quality, mineral nutrients, and post harvest traits, there was a significant amount of heterosis in either positive or negative direction. The best crosses for quality traits were DMM-159 × Pusa Madhuras (24.64%), Pusa Madhuras × Kashi Madhu (18.17%) and DCM-31 × Pusa Madhuras (11.33%) for TSS; DCM-31 × Kashi Madhu (-42.47%), Pusa Madhuras × Kashi Madhu (-36.6%) and DHM-162 × DCM-31 (-30.87%) for acidity. For ascorbic acid, DCM-31 × Pusa Madhuras (44.07%) and DCM-31

Table 4. Range of heterosis, number of heterotic hybrids and best heterotic combination for fruit quality, mineral nutrients and post harvest traits in muskmelon.

Parameters	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100g)	Na (mg/100g)	K (mg/100g)	Zn (mg/100g)	Mn (mg/100g)
1.Range of heterosis %							
M.P.	1.16 to 31.10	-11.92 to -31.91	14.29 to 47.83	-11.66 to -31.43	6.02 to 45.2	31.16 to 117.22	17.48 to 60.51
B.P.	3.00 to 24.64	-13.82 to -42.47	26.67 to 44.07	-12.83 to -34.32	7.54 to 30.55	34.68 to 104.85	17.37 to 43.08
2. Number of heterotic crosses over							
M.P.	11	5	4	8	10	8	4
B.P.	11	10	2	11	6	7	2
4. Three top F_1 with heterosis %							
M.P.	DMM-159 × PM (31.10)	DCM-31 xKM (-31.91)	DCM-31 × PM (47.83)	DHM-163 × DCM-31 (-31.4)	DMM-159 × HM (45.2)	DCM-31 × HM (117.22)	DMM-159 × DCM-31 (60.5)
	PM × KM (20.89)	PM xKM (-25.8)	DCM-31 xKM (31.03)	DHM-163 xKM (-26.91)	DHM-162xDMM-159 (38.36)	DCM-31 × KM (98.72)	DHM-163 × PM (36.74)
	DCM-31 × PM (19.76)	DHM-162x DCM-31 (-15.89)	DHM-163 xDMM-159 (17.04)	DCM-31 xKM (-20.77)	DMM-159 × PM (37.74)	PM xKM (96.16)	DCM-31 × PM (21.63)
B.P.	DMM-159 × PM (24.64)	DCM-31 × KM (-42.47)	DCM-31 × PM (44.07)	DHM-163 × DCM-31 (-34.32)	DHM-162xDMM-159 (30.55)	DCM-31 × HM (104.85)	DMM-159 × DCM-31 (43.08)
	PM × KM (18.17)	PM xKM (-36.6)	DCM-31 xKM (26.67)	DHM-163 xKM (-31.34)	DMM-159 × HM (29.9)	PM × KM (70.74)	DHM-163 × PM (17.37)
	DCM-31 × PM (11.33)	DHM-162x DCM-31 (-30.87)	–	DHM-163 × HM (-28..3)	DHM-163 × DHM-162 (22.06)	DHM-163 × DCM-31 (70.44)	–

Parameters	Cu (mg/100g)	Fe (mg/100g)	Mg (mg/100g)	Ca (mg/100g)	Respiration rate (ml.CO_2/kg/hr)	Ethylene emission rate (µl/kg/hr)
1. Range of heterosis %						
M.P.	13.64 to 42.99	8.06 to 67.00	-36.1 to -17.14	24.96 to 30.00	-36.93 to -72.2	-6.01 to 100
B.P.	20.98 to 34.63	12.6 to 39.79	-37.52 to -16.69	-18.55 to 20.45	-42.04 to	-7.13 to 85.09
2. Number of heterotic crosses over						
M.P.	4	8	0	2	5	12
B.P.	3	5	0	1	5	7

Contd...

Table 2 contd...

Parameters	Cu (mg/100g)	Fe (mg/100g)	Mg (mg/100g)	Ca (mg/100g)	Respiration rate (ml.CO_2/kg/hr)	Ethylene emission rate (µl/kg/hr)
4. Three top F_1 with heterosis %						
M.P.	DCM-31 × PM (42.99)	DCM-31 × PM (67.00)	–	DHM-163 × PM (30.00)	DHM-163 × DMM-159 (-72.2)	DHM-163 × DMM-159 (-100)
	DMM-159 × PM (36.19)	DHM-163 × DCM-31 (53.27)	–	DHM-163 × DMM-159 (24.96)	DHM-162 × KM (-71.63)	DHM-162 × DMM-159 (-98.11)
	DHM-163 × PM (30.41)	DHM-162 × DCM-31 (51.35)	–	–	DMM-159 × DCM-31 (-65.76)	DMM-159 × DCM-31 (-83.19)
B.P.	DMM-159 × PM (34.63)	DCM-31 × PM (39.79)	–	DHM-163 × PM (20.45)	DHM-163 × DMM-159 (-85.12)	DHM-163 × DMM-159 (-85.09)
	DCM-31 × PM (23.11)	DHM-163 × DCM-31 (38.53)	–	–	DHM-162 × KM (-80.46)	DHM-162 × DMM-159 (-72.08)
	DHM-163 × PM (20.98)	PM xKM (20.46)	–	–	DMM-159 × DCM-31 (-77.35)	DMM-159 × DCM-31 (-67.35)

× Kashi Madhu (26.67%) showed the highest better parent heterosis. The F_1 crosses showing the highest significant heterosis in desired direction over better parent for mineral content in order of merit were DHM-163 × DCM-31 (-34.32%), DHM-163 × Kashi Madhu (-31.34%) and DHM-163 × Hara Madhu (-28.3%) for Na content; DHM-162 × DMM-159 (30.55%), DMM-159 × Hara Madhu (29.9%) and DHM-163 × DHM-162 (22.06%) for K content; DCM-31 × Hara Madhu (104.85%), Pusa Madhuras × Hara Madhu (70.74%) and DHM-163 × DCM-31 (70.44%) for Zn content; DMM-159 × Pusa Madhuras (34.63%), DCM-31 × Pusa Madhuras (23.11%) and DHM-163 × Pusa Madhuras (20.98%) for Cu content; DCM-31 × Pusa Madhuras (39.79%), DHM-163 × DCM-31 (38.53%) and Pusa Madhuras × Kashi Madhu (20.46%) for Fe content. There was no positive heterotic combination over MP and BP for Mg content. Only one cross, DHM-163 × Pusa Madhuras (20.45%), exhibited significant positive heterosis over BP for Ca content. DMM-159 × DCM-31 (43.08%) and DHM-163 × Pusa Madhuras (17.37%) were the best heterotic combinations for Mn content. DHM-163 × DMM-159 (-85.12%), DHM-162 × KM (-80.46%) and DMM-159 × DCM-31 (-77.35%) showed better parent heterosis for respiration rate. For ethylene emission rate, DHM-163 × DMM-159 (-85.09%), DHM-162 × DMM-159 (-72.08%) and DMM-159 × DCM-31 (-67.35%) recorded higher heterosis over better parent.

Overall, the hybrid, DCM-31 × Pusa Madhuras, showed significant heterosis for ascorbic acid, Fe content, TSS, and Cu content. Hybrid DHM-163 × Pusa Madhuras, showed significant heterosis for Ca, Mn, and Cu contents. The hybrid DHM-163 × DCM-31 showed significant heterosis for Na, Zn, and Fe contents. The hybrid DMM-159 × Hara Madhu exhibited maximum significant amount of heterosis for K content. The hybrid DMM-159 × Pusa Madhuras recorded highest significant heterosis for TSS and Cu content. These heterotic combinations also showed high *per se* performance for their respective quality traits, mineral nutrients and post harvest traits. Previously, moderate to high heterosis for quality and nutrient traits in muskmelon were reported by Moon *et al.* (7), Jagpat and Musamade (5) and Ram *et al.* (8) in cauliflower. The promising heterotic hybrids identified in this study may be evaluated in multiple locations to assess their potential as hybrids for commercial use in future.

AUTHORS' CONTRIBUTION

Conceived and designed the experiments (HC, KS and RA); Carried out the experiment (KS); statistical analysis (HC, VKS); writing of manuscript (KS) made necessary corrections (HC, RA).

DECLARATION

The authors declare that they have no conflicts of interest.

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