

Original Research Article

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Combining ability analysis for yield and yield-related traits in Muskmelon (*Cucumis melo* L.)

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ABSTRACT

A combining ability analysis was carried out to assess the nature of gene action governing yield and its component traits in muskmelon using a half diallel mating design. The experimental material consisted of six parents and fifteen hybrids evaluated during late *kharif* 2021 and early summer 2022. The hybrids were evaluated in a Randomized Block Design with two replications to study their performance for various growth, earliness, and yield parameters. Analysis of variance revealed significant differences among parents and hybrids for most of the traits studied, indicating the presence of substantial genetic variability. The estimates of general combining ability (GCA) and specific combining ability (SCA) variances showed that non-additive gene action was predominant for the majority of traits, as evidenced by lower $\sigma^2\text{GCA}/\sigma^2\text{SCA}$ ratios. Among the parental lines, VRMM-310 exhibited significant positive GCA effects for yield and its contributing traits and were identified as good general combiners. Several cross combinations, notably VRMM-310×VRMM-37, recorded high and significant SCA effects along with superior mean performance for yield, suggesting their potential for hybrid development. The results indicated that both additive and non-additive gene actions played an important role in the inheritance of yield and related traits, and the identified parents and crosses could be effectively utilized in future breeding programmes aimed at yield improvement in muskmelon.

Keywords

GCA,
SCA,
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Introduction

Muskmelon (*Cucumis melo* L.) (2n = 24), a member of the family Cucurbitaceae, includes cultivated edible forms mainly belonging to *C. melo* var. *reticulatus* and *C. melo* var. *cantaloupensis*. The crop is an annual with monoecious or andromonoecious sex expression, long trailing vines and shallowly lobed leaves. Considerable

variation exists in fruit size, shape and external appearance, with fruits being smooth or netted and rind colour ranging from white and green to yellow, often with speckles. During ripening, fruits soften and develop a characteristic aroma.

Muskmelon is primarily consumed as a dessert fruit and its juice is valued for its cooling effect. Immature fruits

are also used as a vegetable. The fruit is nutritionally rich, containing vitamins and minerals, particularly β -carotene, provitamin A and vitamin C, while being relatively low in protein. The seeds are edible and rich in oil, and various plant parts possess medicinal properties (Chakrabarti, 2011).

In breeding programmes aimed at developing high-yielding hybrids, the selection of suitable parents and cross combinations is crucial. Combining ability analysis provides valuable information on the genetic potential of parents and hybrids and aids in the identification of superior combiners. Selection based solely on per se performance may not always be effective, emphasizing the need for genetic evaluation. Estimates of general and specific combining ability offer insights into the nature of gene action governing yield and its related traits.

With this background, the present investigation was undertaken to identify superior parental lines and cross combinations in muskmelon. A line \times tester mating design was employed to assess general and specific combining ability for yield, its component characters and quality traits, with the objective of facilitating the development of superior hybrids.

Materials and Methods

The present investigation was conducted at Dr. Y.S.R. Horticultural College, Venkataramannagudem, during 2021–2022. The study was carried out in two phases, namely generation of breeding material and evaluation of F_1 hybrids.

Six parental lines were raised in a polyhouse during October 2021 to develop F_1 hybrids using a partial diallel mating design excluding reciprocals, which resulted in fifteen hybrids. Hybridization was performed by selecting healthy male and female flower buds, which were bagged prior to anthesis to avoid contamination. Pollination was carried out the next morning between 5:30 and 8:00 a.m., followed by re-bagging and proper tagging. Self-pollination of parental lines was also carried out to maintain genetic purity.

The F_1 hybrids along with their parents were evaluated during the summer of 2022 in a Randomized Block Design with two replications. Data were recorded from five randomly selected vines per replication for growth, earliness and yield-related traits, including number of

branches per vine, days to first male and female flower appearance, number of male and female flowers per vine, sex ratio, average fruit weight and fruit yield per vine.

Results and Discussion

The combining ability analysis revealed significant variation among parents and hybrids for most of the growth, earliness, yield and quality traits studied, indicating the presence of substantial genetic diversity in the experimental material. Parents and hybrids showing desirable and significant general combining ability (GCA) and specific combining ability (SCA) effects were identified for different traits.

For growth and earliness traits such as days to first male and female flower appearance, node of first female and hermaphrodite flower appearance, and sex ratio, negative and significant GCA and SCA effects were considered desirable. Parents such as VRMM-310, VRMM-37, VRMM-29 and VRMM-7 consistently exhibited favourable GCA effects for one or more earliness traits, indicating their usefulness in developing early maturing hybrids. Several cross combinations including VRMM-35 \times VRMM-7, VRMM-310 \times VRMM-7, VRMM-37 \times VRMM-29 and VRMM-7 \times VRMM-29 showed significant and desirable SCA effects, suggesting the role of non-additive gene action in controlling these traits. These results are in same line with those obtained by Bayoumy et al. (2014) in melon. For yield and its component traits such as number of fruits per vine, average fruit weight and fruit yield per vine, positive and significant GCA and SCA effects were considered desirable.

The parent VRMM-310 emerged as the best general combiner for yield-related traits, consistently recording significant positive GCA effects. Hybrids such as VRMM-35 \times VRMM-29, VRMM-310 \times VRMM-37, VRMM-310 \times VRMM-29 and VRMM-35 \times VRMM-7 exhibited high and significant SCA effects along with superior mean performance, indicating their potential for exploitation in hybrid breeding programmes. Due to predominant role of non-additive gene action for yield and its components, it is difficult to bring together desirable genes by pedigree method. In this situation formation of central gene pool by bringing together the multiple parents having the good GCA effects suggested by Jensen (1970) might prove to be useful.

Table.1 Estimates of general combining ability effects for growth attributing characters in muskmelon parents

Sl. No.	Parent	Number of branches per vine	Days to first male flower appearance	Days to first female/ hermaphrodite appearance	Number of male flowers per vine	Number of female flowers per vine	Number of hermaphrodite flowers per vine	Node at which first female flower appeared	Node at which first hermaphrodite flower appeared	Sex ratio
1	VRMM-35	-0.27*	-0.04	0.35 *	0.48	-0.07*	-0.10 *	-0.46 ***	-0.47 ***	0.19 *
2	VRMM-310	0.47 **	0.09	0.03	-0.66*	-0.17	0.12 *	0.08	-0.83***	-0.47 ***
3	VRMM-37	-0.12	-0.10**	-0.05**	0.66**	0.10	-0.20***	-0.30 **	-0.64 ***	0.09
4	VRMM-7	-0.05*	0.09	-0.30*	0.06	0.20*	0.09	0.25 **	1.12 ***	-0.17
5	VRMM-29	0.11	-0.12**	0.14	-0.35*	0.04*	-0.08	-0.02	1.21***	-0.17
6	VRMM-14	-0.13	0.08	-0.17	-0.20	-0.09	0.10 *	0.53***	-0.39**	0.52 ***
	SE (gi) at 5%	0.42***	0.33 ***	0.37 ***	0.84 ***	0.43 ***	0.12***	0.21***	0.28 ***	0.23 ***
	SE (gi) at 1 %	0.65***	0.53***	0.58***	1.32 ***	0.68***	0.19 ***	0.33 ***	0.42 ***	0.37 ***
	SE (gi-gj) at 5 %	0.65 ***	0.52 ***	0.58 ***	1.30 ***	0.67 ***	0.18***	0.33 ***	0.43***	0.37 ***
	SE (gi-gj) at 1 %	1.02***	0.82 ***	0.91***	2.05 ***	1.05***	0.29 ***	0.52***	0.68 ***	0.58 ***

* and ** Significance at 5% and 1% level respectively.

Sl. No.	Parent	Number of fruits per vine	Weight of fruit (g)	Fruit yield per vine (kg)	Length of fruit (cm)	Diameter of fruit (cm)	Rind thickness (cm)	Pulp thickness (cm)
1	VRMM-35	0.008	-64.61 *	-0.13	-0.5 **	-0.87***	0.005	-0.07 **
2	VRMM-310	0.12*	98.21 **	0.32**	0.99***	1.05***	-0.023 *	0.02
3	VRMM-37	-0.05	71.58*	0.09	1.65 ***	0.69 ***	0.01	-0.17 ***
4	VRMM-7	-0.004	20.58	0.01	-1.25 ***	-0.35***	0.03 *	-0.01
5	VRMM-29	-0.01	-44.92	0.02	-0.60***	0.71***	-0.01	0.14 ***
6	VRMM-14	-0.05	-80.84	-0.32**	-0.26	-1.233 ***	-0.01*	0.11***
	SE (gi) at 5%	0.25***	74.61***	0.25***	0.36 ***	0.206 ***	0.03 ***	0.06***
	SE (gi) at 1 %	0.39***	117.04***	0.39***	0.57 ***	0.323 ***	0.05***	0.10 ***
	SE (gi-gj) at 5 %	0.38***	115.60***	0.39 ***	0.57***	0.319 ***	0.05***	0.10 ***
	SE (gi-gj) at 1 %	0.61 ***	181.32***	0.61 ***	0.89 ***	0.501 ***	0.08***	0.16***

* and ** Significance at 5% and 1% level respectively

Sl. No.	Parent	TSS (°B)	Acidity (%)	Reducing sugars (%)	Total sugars (%)	Non- reducing sugars (%)	Beta – carotenes (µg/100 g)
1	VRMM-35	-1.01 ***	0.19 ***	-0.31 ***	-0.62 ***	-0.36 **	-16.15***
2	VRMM-310	0.42***	-0.01	-0.003	-0.44 ***	-0.49***	13.54 ***
3	VRMM-37	1.28 ***	-0.13 ***	0.21 **	0.32***	0.22*	-2.17 ***
4	VRMM-7	0.04	-0.09 ***	0.49***	0.26***	-0.11	0.37 ***
5	VRMM-29	-0.10*	-0.05 **	-0.08	-0.07	-0.04	6.90***
6	VRMM-14	-0.63 ***	0.10 ***	-0.30 ***	0.54 ***	0.79 ***	-2.49***
	SE (gi) at 5%	0.12 ***	0.04***	0.18***	0.16***	0.25***	0.22 ***
	SE (gi) at 1 %	0.20***	0.07***	0.29 ***	0.25***	0.39***	0.35***
	SE (gi-gj) at 5 %	0.19 ***	0.07 ***	0.28***	0.24***	0.39 ***	0.34***
	SE (gi-gj) at 1 %	0.31***	0.12***	0.45 ***	0.38***	0.61***	0.54***

* and ** Significance at 5% and 1% level respectively

Table.2 Estimates of specific combining ability effects for growth attributing characters in muskmelon hybrids

Sl No.	Cross	Number of branches per vine	Days to first male flower appearance	Days to appearance of first female/hermaphrodite appearance	Number of male flowers	Number of female flowers	Number of hermaphrodite flowers	Node at which first female flower appeared
1	VRMM-35 × VRMM-310	0.90	0.22	-0.30	-1.06	0.36	-0.73***	-0.13
2	VRMM-35 × VRMM-37	1.10 *	0.42	-1.41 **	2.294*	-0.30	0.60 ***	0.48*
3	VRMM-35 × VRMM-7	0.42	-1.07 **	1.23**	-1.30	-0.008	-0.69 ***	0.01
4	VRMM-35 × VRMM-29	0.16	0.15	-0.16	0.36	-0.080	0.10	0.005
5	VRMM-35 × VRMM-14	0.11	-0.66	-0.09	0.56	0.49*	-0.70 ***	-0.45
6	VRMM-310×VRMM-37	-0.35	-0.01	0.40	0.15	0.48*	0.27	-0.39
7	VRMM-310×VRMM-7	1.37**	-0.81 *	-0.75*	-0.25	-0.51	0.17	0.04
8	VRMM-310×VRMM-29	-0.38*	-0.08	-0.39	-2.53*	0.34	-0.83***	0.13
9	VRMM-310×VRMM-14	-0.23*	0.90 *	0.22	3.12 **	0.18	-0.94***	-0.23
10	VRMM-37×VRMM-7	0.27	0.68*	0.83	-1.28	0.71**	0.10	-0.34
11	VRMM-37×VRMM-29	0.31	-0.68*	-0.40	1.13	0.66**	0.20	0.04
12	VRMM-37×VRMM-14	-0.83	-0.19	-0.18	-0.91	-0.787	-0.60***	-1.02 ***
13	VRMM-7×VRMM-29	0.13	0.31	-1.15 *	2.93**	-0.03	-0.79***	-0.82**
14	VRMM-7 × VRMM-14	-0.21	0.10	0.06	-0.51	-0.38	0.39**	-0.68**
15	VRMM-29×VRMM-14	0.82	0.22	1.11 *	-2.39 *	-0.3	0.09	-0.49*
	SE (sij) @ 5%	0.96	0.77	0.85	1.93	0.99	0.27	0.49
	SE (sij) @ 1%	1.33	1.07	1.19	2.68	1.38	0.38	0.68
	SE (sij-sik) @ 5%	1.43	1.15	1.28	2.89	1.48	0.41	0.73
	SE (sij-sik) @ 1%	1.99	1.60	1.77	4.01	2.06	0.57	1.02

* and ** Significance at 5% and 1% level respectively.

Sl No.	Cross	Node at which first hermaphrodite flower appeared	Sex ratio	Number of fruits per vine	Weight of fruit (g)	Fruit yield per vine (kg)	Length of fruit (cm)	Diameter of fruit (cm)	Rind thickness (cm)	Pulp thickness (cm)
1	VRMM-35 × VRMM-310	-7.40***	-0.17	-0.06	-106.06 **	-0.39	-1.11*	-1.89**	-0.003	-0.16*
2	VRMM-35 × VRMM-37	5.60 ***	-0.14	0.21*	-82.94*	-0.11	3.48**	0.67 **	0.04	0.01
3	VRMM-35 × VRMM-7	-9.36 ***	-0.82 **	-0.03	269.55**	0.63*	1.33 **	1.98***	0.03	-0.06
4	VRMM-35 × VRMM-29	3.94 ***	-0.07	-0.02	80.94	1.30 ***	1.33 **	-0.60 *	0.02	-0.17*
5	VRMM-35 × VRMM-14	-7.84***	0.20	0.61*	-37.00	0.18	-1.64***	0.21	0.01	0.08
6	VRMM-310×VRMM-37	6.47 ***	-1.42***	0.80 **	93.22*	1.07**	-2.28 ***	-0.05	-0.06*	0.48 ***
7	VRMM-310×VRMM-7	4.19 ***	0.55*	-0.15	139.72	0.27	-0.67	4.22***	0.03	-0.13
8	VRMM-310×VRMM-29	-9.09***	-0.50	0.36*	5.74	0.13	-0.67	2.16 ***	-0.02	-0.11
9	VRMM-310×VRMM-14	-7.48***	0.50	0.00	-73.83*	-0.11	-0.82	-0.77*	0.13**	-0.08
10	VRMM-37×VRMM-7	5.10***	0.16	0.32	-161.14**	-0.16	-0.02	-2.69***	0.01	-0.11
11	VRMM-37×VRMM-29	5.32***	0.45	-0.36	-163.13**	-0.85 **	0.42	0.81**	-0.01	0.18*
12	VRMM-37×VRMM-14	-7.66 ***	0.41	-0.12	153.29	0.34	3.01***	-0.28	-0.05*	0.15
13	VRMM-7×VRMM-29	-11.05 ***	-0.002	0.08	183.36*	0.53	2.35***	-1.94 ***	0.03	-0.07
14	VRMM-7 × VRMM-14	4.85***	-0.47	0.42	-80.21	0.10	-0.39	-0.27	0.07 *	-0.10
15	VRMM-29×VRMM-14	5.17 ***	1.235***	-0.06	-38.69	-0.31	-0.96*	-1.54***	0.01	-0.07
	SE (sij) @ 5%	0.64	0.54	0.57	170.98	0.58	0.84	0.47	0.08	0.15
	SE (sij) @ 1%	0.89	0.75	0.79	237.32	0.80	1.17	0.65	0.11	0.21
	SE (sij-sik) @ 5%	0.96	0.81	0.85	255.18	0.86	1.25	0.70	0.11	0.23
	SE (sij-sik) @ 1%	1.33	1.13	1.19	354.18	1.20	1.74	0.97	0.16	0.32

SI No.	Cross	Total soluble solids (^o B)	Acidity (%)	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)	Beta-carotene (µg/100 g)
1	VRMM-35 × VRMM-310	-1.68 ***	0.53***	0.40	0.50 *	0.14	-4.62***
2	VRMM-35 × VRMM-37	0.31 *	-0.19 **	-0.78 **	-1.30***	-0.62 *	2.32 ***
3	VRMM-35 × VRMM-7	1.22 ***	-0.20 **	-0.94 ***	-0.11	0.71*	-4.48 ***
4	VRMM-35 × VRMM-29	0.27	-0.15 **	0.01	-0.21	-0.17	-9.46 ***
5	VRMM-35 × VRMM-14	-0.25	0.37***	-0.006	0.57 **	0.62*	14.29 ***
6	VRMM-310×VRMM-37	3.18 ***	-0.43 ***	0.08	2.70***	2.50 ***	16.95 ***
7	VRMM-310×VRMM-7	-0.72 ***	-0.007	-0.69 **	-1.61***	-1.03 **	9.01***
8	VRMM-310×VRMM-29	1.23 ***	-0.23 ***	1.04 ***	0.92***	-0.07	-8.66***
9	VRMM-310×VRMM-14	-1.11***	0.41 ***	0.39	-1.45 ***	-1.80 ***	-12.00***
10	VRMM-37×VRMM-7	2.45***	-0.22 ***	2.07***	0.63**	-0.40	-12.51***
11	VRMM-37×VRMM-29	1.22 ***	-0.03	-0.16	-0.77***	-0.73 *	-14.02***
12	VRMM-37×VRMM-14	-1.63 ***	0.50***	-0.64 **	-0.54 **	-0.02	2.21***
13	VRMM-7×VRMM-29	-2.05 ***	0.72 ***	0.30	0.94 ***	0.52	-1.34***
14	VRMM-7 × VRMM-14	-0.57 ***	0.002	-0.79**	0.32	0.35	19.32***
15	VRMM-29×VRMM-14	-0.28	-0.40 ***	-1.10 ***	1.69***	2.85 ***	6.22 ***
	SE (sij) @ 5%	0.29	0.11	0.42	0.36	0.58	0.51
	SE (sij) @ 1%	0.407	0.157	0.59	0.50	0.80	0.71
	SE (sij-sik) @ 5%	0.438	0.168	0.63	0.54	0.86	0.76
	SE (sij-sik) @ 1%	0.608	0.23	0.88	0.75	1.20	1.06

* and ** Significance at 5% and 1% level respectively.

Quality traits including fruit length, fruit diameter, rind thickness, pulp thickness, total soluble solids, sugars, acidity and β -carotene content also exhibited significant GCA and SCA effects. Parents VRMM-310, VRMM-37, VRMM-7 and VRMM-14 were identified as good general combiners for several quality parameters. Cross combinations such as VRMM-310 \times VRMM-37, VRMM-37 \times VRMM-7, VRMM-35 \times VRMM-29 and VRMM-310 \times VRMM-7 showed desirable SCA effects for sweetness, sugars and β -carotene content, indicating improvement in fruit quality.

Overall, the predominance of significant SCA effects for most traits suggests the importance of non-additive gene action, highlighting the scope for heterosis breeding in muskmelon. The identified parents with good GCA and hybrids with high SCA effects can be effectively utilized in future breeding programmes for the development of high-yielding and quality muskmelon hybrids. The present findings are in agreement with earlier reports in muskmelon and other cucurbit crops.

In Conclusion, the study identified significant genetic variability for growth, earliness, yield, and quality traits in muskmelon. VRMM-310 emerged as the best general combiner for yield and quality traits, while VRMM-37, VRMM-7, and VRMM-29 were superior for earliness and quality. Hybrids such as VRMM-35 \times VRMM-29, VRMM-310 \times VRMM-37, and VRMM-35 \times VRMM-7 exhibited high specific combining ability, indicating the importance of non-additive gene action. These parents and hybrids can be effectively used in breeding programmes to develop high-yielding, early maturing, and quality-rich muskmelon hybrids.

Author Contributions

Akhila Srinidhi Pendyala: Investigation, formal analysis, writing—original draft, E. Padma: Validation, methodology, writing—reviewing, Neeraja: Formal analysis, writing—review and editing, Kousalya: Investigation, writing—reviewing. Sushmitha Talla: Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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