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MALE STERILITY IN MUSKMELON (*CUCUMIS MELO* L.). I. STUDIES ON COMBINING ABILITY

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ABSTRACT

Combining ability (gca and sca) was studied in muskmelon (*Cucumis melo* L.) involving a 2 × 32 line × tester cross. The variances due to males, females and their cross combinations were significant for all the characters of earliness, yield and quality. Additive genetic variances were more important for earliness while nonadditive for yield and quality. Of the two females, ms-1 was a good combiner for earliness, and ms-2 for yield and quality. Among male parents, 15 out of 32 combined significantly well for three or more characters, indicating their promise in heterosis breeding. Indian parents Harela, Hara Madhu, Lucknow Safeda, Arka Jeet, Pusa Madhuras, Allahabad Kajra, Punjab Sunehri and Kutana, and exotic parents Sweet Gold, Gold Silver, Edisto-47, R. L. Hales Best, Honey Dew, Rio Gold and Persiiskii-5 held promise. Among the crosses, six ms-1 combinations with Crenshaw, Sheep Head, Campo, Arka Jeet, Sweet Gold, Pusa Sharbati and five ms-2 combinations with PMR-6, Durgapura Madhu. PMR-45, Top Mark, and Jacumba exhibited significant sca effects for three or more characters.

Key words: Male sterility, combining ability, muskmelon.

Although the two male sterility genes, ms-1 and ms-2 in muskmelon were discovered as early as 1949 by Bohn and Whitaker [1] and in 1964 by Bohn and Principe [2], these have not been utilized for commercial production of hybrids. For commercial exploitation of heterosis, it is necessary to test the combining ability of these male sterile lines with commercial varieties of diverse origin as male parents under Indian conditions. Bhattacharya et al. [3] in Japan and Nandpuri et al. [4] in India tested the combining ability of these male sterile lines only against two and four male parents, respectively. The present study was undertaken making use of 2 male sterile lines and 32 testers of diverse origin at the Indian Agricultural Research Institute, New Delhi.

MATERIALS AND METHODS

The 2 female parents, viz. ms-1 (100) and ms-2 (200), 32 commercial varieties (males), viz., Lucknow Safeda (001), Arka Jeet (002), Kutana (003), Hara Madhu (004), Durgapura Madhu (005), Punjab Sunehri (006), Harela (007), Pusa Madhuras (008), Pusa Sharbati (009), Allahabad Kajra (010) from India; PMR-45 (011), Edisto-47 (013), Planter's Jumbo (014), Campo (016), Golden Perfection (017), Honey Dew (018), Top Mark (019), Crenshaw (020), Wescan (021), Gulf Stream (022), Heart of Gold (025), Rio Gold (026), Jacumba (027), Red Land's Hales Best (028), Casaba Golden Beauty (029), Perlita (030), PMR-6 (032), from U.S.A.; Sheep Head (015) from U.S.S.R.; Yanco Treat (012) from Australia, and Persiiskii-5 (031) from Bulgaria and their 64 cross combinations (101 to 132 and 201 to 232) were used as experimental material.

These male and female lines and their crosses were grown in randomised block design with three replications. Each plot was represented by a 4.5 m long channel spaced at 2.0 m. Six hills spaced at 0.75 m were prepared on one side of each channel and two plants were grown on each hill maintaining thereby 12 plants per plot. The crop was raised during February-June under irrigated conditions using 120 N:, 80 P: 60 K/ha.

Observations were recorded on all the twelve plants in a plot on eight economic characters, viz. days to first harvest, early yield (%), total yield per vine, number of fruits per vine, average fruit weight, early TSS (total soluble solids %), TSS and flesh proportion. Number of days from sowing to first fruit harvest were averaged from all the 12 plants to compute days to first harvest. Fruit number, fruit weight, total yield and TSS of the fruits were also averaged for all the 12 plants. The TSS of fruits was recorded using hand refractometer. The yield obtained within 80 days of sowing was taken into account for recording early TSS, and early yield which, again, was converted into percentage of total yield. Flesh proportion was depicted as ratio between (fruit diameter-cavity diameter) and cavity diameter, and averaged plant wise and plot wise as was also done for TSS. Variance, its components, and general and specific combining ability effects (gca and sca) were analysed following the line × tester model of Kempthorne [5].

RESULTS AND DISCUSSION

It can be seen from Table 1 that the variances due to male parents and hybrid combinations were highly significant for all the characters studied. Female parents showed significant variances only for days to first harvest, early yield (%) and TSS.

The observations on variance components and combining ability effects (Tables 1 and 2) are discussed for various characters grouped under earliness, yield and quality.

EARLINESS

High genetic diversity within the male and female parents was indicated through large and highly significant variances due to male as well as female parents for days to first harvest and early yield proportion. Highly significant gca for both male and female parents indicated preponderance of additive gene action for these two characters as also reported earlier [3, 6, 7, 9–13].

Among the female parents, ms-2 exhibited highly significant gca for both the earliness cnaracters. Eighteen hybrid combinations, viz, 102, 107, 115, 120, 122, 123, 124, 126, 128, 203, 205, 211, 213, 218, 219, 227, 229 and 232, showed significant

Table 1. Analysis of variance for combining ability effects and estimates of variance components

Source/ component	MSS for different characters							
	days to first harvest	ealry yield (% of total yield)	total yield per vine (kg)	No. of fruits per vine	average fruit weight (kg)	early TSS (%)	TSS (%)	flesh propor-tion
Source of variation:								
Females (lines)	803.60**	7982.84**	0.00	0.86	0.01	0.04	3.80*	0.01
Males (testers)	97.17**	726.23**	6.54**	8.50**	0.44**	24.74*	7.79**	0.09**
Female × male (Hybrids)	21.25**	269.50*	0.67**	0.69**	0.06**	13.00**	1.94**	0.01**
Error	4.46	164.64	0.39	0.31	0.03	6.55	0.59	0.00
Variance components								
σ^2 gca (females)	8.15	80.35**	−0.01	0.00	−0.00	−0.14	0.02	−0.00
σ^2 gca (males)	12.65**	76.12**	0.98**	1.30**	0.06**	1.96**	0.98**	0.01**
σ^2 gca (parents)	8.42**	80.10**	0.05**	0.08**	0.00**	−0.01**	0.08*	0.00**
σ^2 sca (hybrids)	5.60**	34.95**	0.09**	0.13**	0.01**	2.15	0.45**	0.00**
σ^2 gca/σ^2 sca	1.50	2.29	0.55	0.62	0.25	−0.01	0.17	0.33
σ^2 gca/(♀)σ^2 sca	1.46	2.30	−0.08	0.01	−0.05	−0.06	0.04	−0.02
σ^2 gca(♂)/σ^2 sca	2.26	2.18	10.62	10.38	5.41	0.91	2.17	4.81

*, ** Significant at 0.05 and 0.01 levels, respectively.

sca for days to first harvest and eight combinations, viz., 117, 120, 124, 128, 211, 216, 219 and 232 for early yield (%). As such hybrid combinations 120, 124, 128, 211, 219 and 232 showed significant sca for both the earliness characters studied. These observations are in conformity with earlier reports [3, 4]. Among the 32 male parents, 13 parents, viz., 001, 002, 004, 007 and 005, 009, 010, 016, 023, 024, 026, 028 and 031 showed significant gca for days to first harvest and 7 parents, viz., 016, 023, 024, 025, 027, 028 and 031 for early yield. As such five parents, viz.. 016, 023, 024, 028 and 031 exhibited significant gca for both the earliness characters.

A comparison of the ratios σ^2 gca (♂)/ r^2 sca and σ^2 gca (♀)/δ^2 sca (Table 1) indicates that in most of the hybrid combinations earliness was influenced to a greater extent by the behaviour of the male parent. Some of the varieties tested here have also been reported as good combiners against andromonoecious [9, 11, 13] and against monoecious [10, 14] female parents.

YIELD

Highly significant variances due to male parents (Table 1) are suggesfive of high genetic diversity among the male parents for the three yield characters studied. Higher estimates of σ^2 sca than σ^2 gca indicated that non-additive components contributed more than the additive components for the expression of total yield as

Table 2. Estimates of combining ability effects of promising parents (gca) and hybrids (sca)

Parent or hybrid		Days to first harvest	Early yield (% of total yield)	Total yield (kg)	Number of fruits per vine	Average fruit weight (kg)	Early TSS (%)	TSS (%)	Flesh proportion
1		2	3	4	5	6	7	8	9
Lines:									
Male sterile-1	100	—	—	0.00	0.07*	—	0.01	0.14**	0.01
Male sterile-2	200	2.05**	6.45**	—	—	0.01	—	—	—
S.E. ± (g_i)		0.123	0.748	0.036	0.033	0.010	0.149	0.045	0.003
S.E. ± ($g_i - g_j$)		0.303	1.852	0.090	0.081	0.024	0.370	0.111	0.008
Testers:									
Lucknow Safeda	001$	4.19**	0.52	1.32**	2.22**	—	1.24	0.74**	—
Arka Jeet	002$	6.01**	—	1.93**	2.61**	—	1.57	1.07**	—
Kutana	003$	—	—	0.63**	0.98**	—	—	0.90**	—
Hara Madhu	004$	1.42*	—	1.50**	1.61**	—	2.01*	1.30**	—
Durgapura Madhu	005	3.10**	7.49	—	—	—	1.32	0.37	—
Punjab Sunehri	006$	—	—	0.04	—	0.02	1.86*	1.04**	0.25**
Harela	007$	2.38**	—	0.54**	1.00**	—	2.56**	1.95**	—
Pusa Madhuras	008$	0.46	—	1.86**	1.27**	0.09	2.76**	1.58**	—
Pusa Sharbati	009	4.74**	3.28	—	—	—	—	—	0.09**
Allahabad Kajra	010$	1.93**	—	2.50**	1.47**	0.21**	0.69	—	—
PMR-45	011	—	—	—	—	0.03	—	—	0.12**
Yanco Treat	012	—	2.79	—	—	0.26**	—	—	0.12**
Edisto-47	013$	—	—	0.61**	0.67**	—	1.83*	0.93**	—
Planter's Jumbo	014	—	—	—	—	0.23**	—	—	0.12**
Sheep Head	015	—	—	—	—	0.52**	—	—	—
Campo	016	2.24**	14.24**	—	—	—	—	—	—
Golden Perfection	017	—	0.51	—	—	—	0.38	—	—
Honey Dew	018$	—	—	0.54**	—	0.69**	1.56	0.89**	—
Top Mark	019	—	—	—	—	0.17**	0.64	—	0.12**
Crenshaw	020	—	5.10	—	—	0.45**	—	0.14	0.06**
Wescan	021	—	—	—	—	—	—	—	0.02
Gulf Stream	022	—	2.99	—	—	—	0.71	—	0.12**
Gold Silver	023$	3.18**	11.11**	0.04	2.06**	—	2.02*	1.45**	—
Sweet Gold	024$	10.19**	24.60**	—	0.67**	—	3.67**	2.57**	—
Heart of Gold	025	0.78	10.06**	—	—	—	0.22	—	0.07**
Rio Gold	026$	2.23**	1.35	1.12**	0.79**	0.04	—	—	—
Jacumba	027	—	7.94*	—	—	—	—	—	0.16**
Red Land's Hales Best	028$	4.18**	10.61**	0.65**	0.59**	—	—	—	—
Casaba Golden Beauty	029	—	—	—	—	0.40**	—	—	0.01
Perlita	030	—	—	—	0.75**	—	0.25	—	—
Persiiskii-5	031$	3.64**	30.85**	—	—	0.02	—	0.06	0.15**
PMR-6	032	—	—	—	—	0.02	—	—	0.13**
SE ± (g_i)		0.685	4.167	0.203	0.182	0.053	0.831	0.045	0.018
SE ± ($g_i - g_j$)		1.214	7.408	0.361	0.323	0.095	1.478	0.111	0.033

Table 2 (contd.)

1	2	3	4	5	6	7	8	9
Hybrid combinations:								
102$	1.87**	0.86	0.30	0.44*	—	0.10	0.24	0.04*
107	1.41*	—	0.13	0.28	—	0.07	0.11	0.03
108	—	0.96	—	—	—	0.75	0.81**	0.04*
109$	1.18	4.70	0.52*	0.44*	0.04	2.05*	0.35	—
111	—	—	0.28	0.03	0.13*	—	—	—
113	—	1.39	—	—	0.04	—	—	0.07**
114	1.27	1.85	0.50*	0.09	0.16**	0.17	—	0.01
115$	1.74*	7.49	0.14	—	0.09	2.79**	1.12**	0.08**
116$	1.01	—	0.84**	0.85*	0.04	2.28**	1.62**	—
117	—	8.22*	—	—	—	0.39	0.03	0.01
119	—	—	—	—	0.14**	0.29	—	—
120$	3.84**	9.78*	—	0.11	—	2.65**	0.80**	0.06**
122	1.64*	—	0.22	—	0.09	0.19	0.10	—
123	2.41**	3.23	0.01	0.56**	—	0.29	0.20	0.03
124$	1.84**	11.97**	0.19	0.36*	—	0.63	—	—
125	1.18	—	—	0.06	0.01	0.16	0.27	0.01
126	1.73*	7.90	—	—	—	—	—	0.03
127	—	—	—	—	0.13*	—	—	—
128	2.72**	8.85*	0.07	—	0.03	—	—	0.03
130	0.28	5.79	—	—	—	0.07	0.15	—
203	3.20**	1.87	—	—	—	1.28	—	0.09**
204	0.86	0.25	—	—	—	0.07	0.65**	—
205$	2.06**	—	0.82**	0.96*	—	0.32	0.93**	—
208	0.75	—	0.43*	0.04	0.11*	—	—	—
211$	2.89**	15.73**	—	—	—	2.17**	0.73**	—
212	—	5.41	—	—	0.15**	—	0.22	0.06**
213	2.54**	—	0.16	0.40*	—	0.21	0.47	—
216	—	15.19**	—	—	—	—	—	0.15**
218	1.56*	—	—	0.02	—	—	—	—
219$	3.28**	8.29*	0.08	0.27	—	—	0.68**	0.02
220	—	—	0.35	—	0.39**	—	—	—
221	—	—	0.20	0.31	—	1.92*	0.28	0.02
227$	1.47*	5.66	0.04	0.26	—	1.37	0.79**	0.04*
229	1.82**	2.84	—	0.01	—	1.40	0.18	0.01
230	—	—	0.44*	0.08	0.10	—	—	0.01
232$	2.67**	9.82*	0.50	0.57**	—	5.09**	0.74**	0.01
SE ± (S_{ij})	0.685	4.17	0.20	0.18	0.053	0.831	0.249	0.018
SE ± $(S_{ij} - S_{kj})$	1.696	10.31	0.50	0.45	0.132	2.057	0.617	0.045
SE ± $(S_{ij} - S_{il})$	1.214	7.41	0.36	0.32	0.095	1.478	0.443	0.033

*, ** Significant at 0.05 and 0.01 levels, respectively.

$ indicate parents/hybrids having significant gca/sca for three or more characters.

well as number of fruits per plant and average fruit weight in the hybrids in the present studies. The significance of σ^2 gca (♂) as observed here has also been reported earlier [4].

Among females, significant gca effects were observed with ms-1 for number of fruits per vine and with ms-2 for individual fruit weight. For total yield, ms-1 exhibited positive but nonsignificant gca.

Among the cross combinations, seven hybrids exhibited significant sca for total yield per vine, an equal number for average fruit weight, and eight hybrids for number of fruits per vine. All the seven specific combiners for total yield were statistically at par. Of these combinations, crosses 109, 116, 205 and 232 combined well for number of fruits also while 114 and 208 were good combiners for total yield as well as individual fruit weight. Specific combinations which gave significant sca for individual yield characters were: 230 for total yield; 102, 123, 124 and 213 for number of fruits; and 111, 119, 127, 212 and 220 for average fruit weight. These observations are in agreement with those of [4] who also observed good specific combiners to have either or both parents with high gca for yield and fruit weight.

Among the male parents, 002, 001, 004, 010, 008, 007, 003, 026, 013 and 028 were good general combiners for fruit number and also for total yield, and 010 and 018 for total yield along with average fruit weight. The parents 015, 020, 029, 012, 014 and 019 exhibited good combining ability effects for average fruit weight but not for total yield. In total, 13 out of 32 male parents were good general combiners for fruit number, 8 for average fruit weight, and 12 for total yield. Some of these male parents have also been reported as good combiners for yield characters [4, 9, 10, 13].

QUALITY

Like yield characters, quality characters also exhibited higher magnitude of σ^2 sca than σ^2 gca indicating comparative importance of nonadditive components of variance even for quality attributes, viz., TSS and flesh proportion. The comparisons of σ^2 gca (♂) and σ^2 gca (♀) with σ^2 sca (hybrids) (Table 1) indicated that gca of male parent has contributed more to the hybrid performance than the gca of female parent or sca of the hybrid combination. In the earlier studies [3, 6, 8], the comparative importance of nonadditive genetic variances was not observed probably because their material comprised a close group of only a few varieties. Since we have tested varieties of diverse origin, these observations seem to be more representative of the crop behaviour.

Of the two female parents, ms-1 had highly significant gca for TSS while ms-2 registered positive but nonsignificant gca for early TSS and flesh proportion. Favourable gca in male sterile lines for quality characters were also reported earlier [3]. Among the 64 hybrid combinations, 9 hybrids exhibited significant sca for flesh proportion, 7 for early TSS, and 10 for TSS. Among these, cross combination 116 had highest sca effects for TSS, 232 for early TSS, and 216 for flesh proportion, and these were significantly different from other combinations for the respective characters. The cross combinations 115 and 120 had highly significant sca effects for all the three quality characters. Combinations 232, 211 and 116 showed high specific combining ability for the TSS of fruits of both early (80 days) and total harvests, while significant sca effects for TSS and flesh proportion were observed in crosses 108 and 227. The specific combiners for individual characters were 102, 203, 113 and 212 for flesh proportion, 205, 219 and 204 for TSS, and 109 and 221 for early TSS.

Out of the 32 male parents, 12, i.e., 006, 027, 031, 019, 011, 032, 014, 022, 009, 025 and 020, exhibited significant gca effects for flesh proportion. None of these except 006 also combined well for TSS and early TTS. Parents 004, 006, 007, 008, 013, 023 and 024, which combined significantly for TSS, also combined for early TSS. However, parents 001, 002, 003 and 018 were late ripening hence combined for TSS only. The earlier observations of Sharma [9] and Chadha and Nandpuri [13] against andromonoecious female parents and More [10] against monoecious female parents about the combining ability of such parents as 002, 004, 005, 009 and 030 are in conformity with the present observations.

To sum up, a perusal of Table 2 indicates that ms-2 was a good general combiner for earliness and ms-1 for the remaining characters. In the present experiment, 11 specific cross combinations utilizing the two male sterile females exhibited good combining ability for these or some more characters. All these combinations, except crosses 109 and 116, behaved similarly for days to first harvest but differed for the remaining characters. Hybrid combinations 120, 127 and 115 gave significant $\hat{s}_{ij}$ for flesh proportion along with earliness and TSS and in the former case for early yield also. Hybrid 232 combined well for all the characters except average fruit weight and flesh proportion; 211 for earliness, early yield, early TSS and TSS, 219 for earliness, early yield and TSS, and 124 for earliness, early yield and fruit number. Hybrid combination 109 combined well for number of fruits per vine and total yield along with early TSS.

A look at the important $\hat{g}_i$ values of the male parents for various characters indicated that 15 out of 32 male parents exhibited significant effects for three or more characters. Parents 023, 024, 007 and 004 showed high combining ability for days to first harvest, number of fruits and total yield per vine, TSS and early TSS, and the former two parents also contributed to higher proportions of early yield. Parents 008, 003 and 013 had high gca effects for these characters, except for days to first harvest, while 018 combined well for fruit weight rather than for fruit number, besides total yield, TSS and early TSS. Parent 010 combined well for early harvest and yield along with its component factors but not for quality while 006 combined well only for quality characters and 031 for earliness characters and flesh proportion. Significant gca effects for twin characters like average fruit weight and flesh proportion were exhibited by parents 012, 014, 019, 020; for days to first harvest and flesh proportion by 009; for early yield and flesh proportion by 025 and 027; and for the two characters of earliness by 016. Since the female parents used in these studies are purely genetic stocks, further improvement in yield and quality of these stocks and incorporation of these male sterility genes into well adapted commercial varieties having good gca should be a rewarding proposition.

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