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Combining Ability for Seed and Fruit Quality Traits using Line x Tester Analysis in Muskmelon (*Cucumis melo* L.)

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Abstract

Muskmelon (*Cucumis melo* L.) five female lines and twelve testers were used to produce sixty F_1 hybrids using line x tester design. Four economic characters fruit weight, fruit diameter, cavity size and total soluble solids were analysed along with seed quality traits. The analysis of variance indicated significant variability among all the genotypes for all the traits except for TSS. The combining ability analysis revealed that general combining ability effects and specific combining ability effects were significant for fruit weight and fruit diameter. Among cross combinations, L-3 x T-11, L-3 x T-12 and L-5 x T-1exhibited maximum specific combining ability for fruit weight and diameter traits and these hybrid combinations were also found statistically superior over commercial check.

Keywords : Muskmelon, Lines, Testers, Combining ability

Muskmelon, a member of genus *Cucumis* and family Cucurbitaceae is grown in temperate, sub-tropical and tropical regions of the world. It's short duration, high production potential and sweet taste provide a commercial and dessert fruit signature. It is a rich source of dietary fibre, vitamins and minerals like calcium, phosphrous and iron (Pitrat, 2008). It is enormously good for health as it is rich in ascorbic acid, carotene, folic acid and potassium as well as a number of other health bioactive compounds (Lester and Hodges, 2008). It is having magical health benefits therefore it is considered as a 'wholesome food'.

Muskmelon is cultivated on 1.2 million ha area with 29.5 million MT production with productivity of 24.9 tonnes ha^{-1}. China is being the largest producer with 50.04 per cent share followed by Turkey (5.76%), Iran (4.98%), Egypt (3.54%) and India (3.49%). In India, it is cultivated on 47,000 ha with 8,78,000 MT production with productivity of 20 tonnes ha^{-1} (Anonymous, 2017). It is extensively cultivated in hot and dry areas of Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh, Bihar and Karnataka.

The art of hybridisation came into existence along with heterosis. Hybrid vigour was first reported by Koelreuter (1763). In vegetables the phenomenon has been exploited in many crops and large number of hybrids has been released for commercial cultivation, along with improvement in yield, biotic and abiotic stress. Hybrid cultivation is increasing day by day because of hybrid development techniques. In muskmelon, hybrids are preferred over varieties due to their early maturity, high yield potential, superior quality and high input efficiency (Banga and Banga, 2000). Additionally, the development of F_1 hybrids in muskmelon is quite easy due to their andromonoecious nature. Therefore, selection of parents for the hybrids possessing desirable traits is most decisive and crucial step. Generally, parents are selected on basis of *per se* performance, but due to various gene combinations may does not stand true.

The extent of heterosis over mid parent, better parent and standard checks varies across the cross combinations for fruit and seed quality traits. Increased yield being the ultimate objective in any of crop breeding programme; hence positive and significant heterosis for fruit traits is always required.

Material and Methods

The present investigations were conducted during 2019- 2020 in the Research and Development station of Orbi Seeds International Pvt. Ltd., Bangalore. The experimental materials comprised five inbred lines, twelve testers and 1 standard check. The crosses were made during *rabi* season of 2019. The hermaphrodite flowers from the designated female lines were emasculated one day before opening of the flowers during evening hours, emasculated flowers were covered at bud stage with white parchment/ butter paper bags after removing anthers to avoid out-crossing. Male flower buds which were about to open the next day morning were removed and covered in a moist cloth and stored. The emasculated flowers were used for crossing in the next morning. The male flowers collected on the previous day evening were removed from moist cloth and emasculated flowers were pollinated with the pollens of the desired freshly opened male flowers. After pollination, each pollinated flower was tagged and again covered with parchment paper bag to prevent cross contamination.

Simultaneously each parent was selfed. Selfing was done by bagging the hermaphrodite flowers in the evening and these were pollinated by taking pollens from covered male flowers of the same plant and tagged with different colour thread to avoid confusion while harvesting.

F_1 seeds were collected from the female plants after the fruits reaches maturity. They were kept for overnight for fermentation, washed the next morning and dried to 8-10 per cent moisture levels.

Nursery was prepared by sowing the F_1 seeds of each entry in portrays and kept covered with polythene cover to protect the emerging seedlings from low temperatures. When the seedlings attained two to three leaf stage, irrigation was withheld for one day prior to transplanting to harden the seedlings. The seedlings were then transplanted in the evening hours in the experimental field after removing from portrays at Sira (Tumkur Dist.) location during Summer 2020 in RBD with two replications with the spacing of 45cm x 2m. Since the location is suitable for evaluating the hybrids. Twelve plants from each entry transplanted under each replication.

TABLE 1

List of lines and testers used for the study

Lines	Code	Testers	Code
ORBI-MG-1	L-1	ORBI-T1	T-1
ORBI-MG-2	L-2	ORBI-T2	T-2
ORBI-MG-3	L-3	ORBI-T3	T-3
ORBI-MG-4	L-4	ORBI-T4	T-4
ORBI-MG-5	L-5	ORBI-T5	T-5
		ORBI-T6	T-6
		ORBI-T7	T-7
		ORBI-T8	T-8
		ORBI-T9	T-9
		ORBI-T10	T-10
		ORBI-T11	T-11
		ORBI-T12	T-12

Data were recorded on five plants in each replication and analysed using line x tester analysis by Kempthorne (1957) using WINDOSTAT *ver* 9.1 at the Department of Genetics and Plant Breeding, UAS, GKVK, Bengaluru. Economic heterosis was estimated over a check Akany from Bhalsar Seeds International Pvt. Ltd. for fruit weight (g), fruit diameter (cm), cavity size (cm) and total soluble solids (TSS °Brix), Germination per cent, Shoot length (cm), Root Length (cm), Seedling vigour index-I and Seedling vigour index-II.

RESULTS AND DISCUSSION

Success of a breeding programme rests upon utilization of variability available among genotypes (parental lines) and its progeny for traits of importance. Variances due to genotypes (parents and hybrids) were significant for all the traits except total soluble solids. The mean sum of squares due to parents versus crosses was highly significant for yield attributes *viz.,* fruit diameter and average single fruit weight except for total soluble solids and cavity size (Table 2) Similar results were seen by Kamdi *et al.* (2011) in sorghum for grain yield. As evidenced by the significance of mean sum of squares due to crosses, the significant differences among the parental genotypes resulted in crosses that were also

TABLE 2

Analysis of variance for combining ability of seed and fruit quality traits

Source of variation	Degrees of freedom	Fruit weight (g)	Fruit cavity size (cm)	Fruit diameter (cm)	TSS (p Brix)	Germination (%)	Shoot Length (cm)	Root length (cm)	SVI-I	SVI-II
Replication	1	8483.43	3.24	7.70	20.36 *	3.14	0.001	0.02	2076.93	3507.00
Genotypes	76	364916.088 **	3.04 **	15.44 **	6.00	30.93 **	1.39 **	1.41 **	54196.65 **	32189.26 **
Lines (5) + Testers (12)	16	40779.466	0.66	0.21	0.75	7.61 **	0.33 **	0.34 **	10374.72 **	6698.22 **
Lines	4	59644.85	0.30	0.12	0.35	3.15	0.49 **	0.47 **	9156.22 **	2177.60 *
Testers	11	2721.37	0.65	0.25	0.95	9.92 **	0.18 **	0.20 **	8190.63 **	1296.04
Lines vs Testers	1	383956.94	2.18	0.24	0.14	0.03	1.28 **	1.43 **	39273.82 **	84202.77 **
Parents vs Crosses	1	7038007.89 **	2.67	321.21 **	1.24	186.80 **	32.95 **	33.23 **	1438302.59 **	1841805.50**
Crosses	59	339714.29 **	3.69 *	14.38 **	7.51	34.61 **	1.14 **	1.16 **	477937.7 **	28866.5 **
Line effect	4	2075815.44 **	23.49 **	78.33 **	5.67	208.40 **	15.87 **	16.11 **	8171.28	11983.26 *
Tester effect	11	101856.50	2.35	2.63	3.96	21.15	0.07	0.05	11659.37 **	5684.70 **
Line x Tester effect	44	241351.36	2.23	11.51 *	8.57 *	22.18 **	0.07 **	0.08 **	477937.7 **	28866.5 **
Error	76	131202.32	1.63	5.09	4.32	2.06	0.01	0.01	1218.29	717.79
Total	153	246493.35	2.34	10.24	5.26	16.41	0.70	0.71	27539.95	16368.91

*Significant at P=0.05; **Significant at P=0.01

significantly different from each other. This was reflected by the presence of average heterosis as evidenced by the significance of parents versus crosses with single degree of freedom. The findings are consistent with the findings of Gurav *et al*. (2000).

The variance due to lines and their interaction was significant for majority of the characters according to the analysis of variance for combining ability. Lines had significant effect on all the characters studied except for TSS and seedling dry weight. Kumar and Gowda (2016) recorded similar findings in tomato for fruit shelf life.

As such testers had no effect on the fruit quality traits studied but had significant effect on seed quality parameters except on seedling vigour-II. Mean sum of squares due to lines and lines x tester interaction were found significant for most of traits studied indicating both GCA and SCA variance to be equally cardinal in the inheritance of all the characters under investigation.

The general combining ability effects of lines and testers are presented in the Table 3. Identification of parents based on *per se* performance may not be reliable to make heterotic hybrids, GCA of parents for a particular trait would reflect in SCA of a specific cross combination due its interactive effect. Hence selection of line/ tester based on its GCA effect has greater importance in planning a breeding programme.

Fruit yield being a complex trait, expression of this depends upon number of other contributing characters like fruit weight and fruit diameter. For these traits line-4 exhibited significant effect on fruit weight and fruit diameter which in turn results in increased yield. Testers as such had no significant effect on the fruit yield characters. The findings are in agreement with Lal and Kaur (2002).

Line-1 had negative significant effect on cavity size which is important for smaller cavity in hybrid which is preferable by the consumers and also had significant effect on germination percentage of seed. Tester-1 had significant negative effect on cavity size (-1.38) which is preferable. Tester-1 and line-2 had

TABLE 3

General combining ability effects of lines and testers (parents) for seed and fruit quality traits in Muskmelon

Lines	Fruit weight (grams)	Cavity Size (cm)	Fruit Diameter (cm)	TSS (p Brix)	Germination (%)	Shoot Length (cm)	Root length (cm)	SVI-I	SVI-I
Line-1	-388.17 **	-1.57 **	-1.90 **	-0.20	4.86 **	-0.63 **	-0.63 **	-25.78 **	32.67 **
Line-2	249.65 **	-0.089 **	1.29 **	0.34	0.40	1.20 **	1.21 **	215.32 **	40.47 **
Line-3	-181.13 **	-0.33	-1.94 **	-0.40	-1.71 **	0.48 **	0.49 **	51.38 **	-38.15 **
Line-4	316.45 **	0.50	1.87 **	-0.40	-0.88 **	-0.49 **	-0.49 **	-98.48 **	-13.21 *
Line-5	3.2	0.51	0.67	0.67	-2.67 **	-0.56 **	-0.57 **	-142.44 **	-21.78 **
SEm ±	82.43	0.28	0.52	0.46	0.29	0.02	0.02	7.12	5.46
CD at 95%	164.95	0.57	1.04	0.93	0.58	0.04	0.05	14.25	10.94
Testers									
Tester-1	-18.68	-1.38 **	-1.08	-1.28	0.59	0.10 **	0.08 *	23.72 *	32.73 **
Tester-2	-84.98	-0.14	0.49	0.11	1.89 **	0.06	0.08	48.43 **	9.09
Tester-3	-114.98	-0.11	0.16	-0.38	-0.008	0.05	0.05	9.92	-32.54 **
Tester-4	125.41	0.12	0.37	-0.28	-0.30	0.06	0.05	4.99	48.95 **
Tester-5	179.41	-0.04	0.72	-0.08	-0.04	-0.02	-0.01	-10.21	2.77
Tester-6	-111.48	-0.08	-0.03	-0.38	-1.70 **	0.02	0.002	-29.69 **	-19.14 *
Tester-7	-130.38	0.02	-0.42	-0.08	-1.90 **	0.05	0.03	-25.63 *	-59.29 **
Tester-8	-2.7	0.41	0.22	-0.28	-1.60 **	-0.11 **	-0.08 *	-44.02 **	-32.53 **
Tester-9	40.71	0.17	0.34	0.21	-0.05	0.04	0.04	-2.23	20.29 *
Tester-10	109.21	0.34	-0.16	0.51	2.59 **	-0.006	-0.02	42.84 **	25.90 **
Tester-11	15.91	0.50	-0.63	0.81	-0.30	-0.10 **	-0.09 *	-22.65 *	-33.69 **
Tester-12	-7.38	0.18	0.06	1.11	1.69 **	-0.15 **	-0.13 **	4.52	37.48 **
SEm ±	127.71	0.44	0.80	0.72	0.45	0.03	0.04	11.03	8.47
CD at 95%	255.15	0.89	1.61	1.44	0.90	0.07	0.08	22.08	16.95

*Significant at P=0.05; **Significant at P=0.01

significant effect on all the seed quality parameters studied except for germination percentage. Tester-10 and Tester-12 had significant effect on germination percentage trait. This indicates that though some parents are inferior, interaction among the lines and testers has contributing for the crosses to perform superiorly. It is appealing to note that line-2 is most promising for fruit weight and fruit diameter. The similar results were reported by Al-araby (2004) and Choudhary *et al*. (2006) in Muskmelon.

The specific combining ability effects of top performing crosses are presented in Table 4. Out of sixty crosses which five cross combinations found to be significant and exhibited significant SCA effects in the desirable direction. The cross 1L x 4T was the best specific combination for fruit cavity (negative effect) and positive SCA effect for seedling vigour index-I and seedling vigour index-II.

The crosses 5L x 1T and 3L x 12T found to be significant in desirable direction for fruit weight and fruit diameter. The cross combinations 1L x 5T and 2L x 1T was found significant for TSS.

Few hybrids were result of cross between either one prominent and one poor combiner or from two poor combiners. The high prevalence of non-additive gene action in these hybrids suggested that once the beneficial genes were to be identified, a hybrid development programme may improve even better. To take the advantage of this form of gene activity, the best breeding activity to accumulate favorable genes through reciprocal recurrent selection. These results are in comparison with findings of aravindakumar *et al.* (2005).

It was observed that the cross combination 3L x 11T, 3L x 12T and 5L x 1T had significantly higher SCA values for fruit weight and fruit diameter traits. Cross

TABLE 4

Estimates of specific combining ability effects in top performing hybrids for seed and fruit quality traits in muskmelon

Crosses	Fruit weight (g)	Fruit cavity size (cm)	Fruit diameter (cm)	TSS (° Brix)	Germination (%)	Shoot Length (cm)	Root length (cm)	SVI-I	SVI-I
1L x 4T	-390.52	-4.40 **	-7.01 **	-8.30 **	5.43 **	0.18 *	0.12	120.75 **	84.03 **
1L x 5T	56.37	0.25	1.98	3.00 *	-2.46 *	-0.02	0.04	-41.13	-30.29
2L x 1T	75.14	-0.12	-0.35	3.65 *	-7.5	-0.30	-0.25	-197.48	-150.24
3L x 12T	1171.33 **	1.46	6.13 **	-1.19	-0.98	-0.21	-0.21	-52.34	-7.36
5L x 1T	745.13 **	0.53	4.34 **	-0.49	2.57 *	-0.02	-0.07	38.08	43.91 *
SEm ±	256.12	0.90	1.59	1.47	1.01	0.08	0.09	24.69	18.95
CD (0.05)	512.50	1.80	3.19	2.94	2.03	0.17	0.190	49.38	37.90

*Significant at P=0.05; **Significant at P=0.01

combination of 3L x 1T had higher sca value for fruit cavity size trait, similar studies have been reported by Munshi and Verma (1997) and Gurav *et al.,* (2000). Total soluble solids trait was significant for crosses 1L x 4T, 1L x 5T and 2L x 1T, similar effects were reported by Liou *et al.,* (1995).

Heterosis is the manifestation of hybrid vigour. The heterotic effect of hybrids is due to cumulative effect of divergent alleles from two contrasting parents. The present investigation involving seventeen parents (five lines and twelve testers) and their sixty hybrids were evaluated to determine the magnitude of heterosis over parental mean, better parent and standard check hybrid (Akany). Inclusion of a commercial hybrid as a standard check is desirable over a variety, as increase in yield over a prevailing hybrid that would enable detecting hybrids for large scale cultivation aiming at increased productivity.

Fruit weight and fruit diameter are important traits having a positive association with fruit yield. The highest significant positive heterosis for fruit weight and fruit diameter was recorded by 4L X 4T (182.13%), 5L X 1T (93.38%) for mid-parent heterosis, respectively.

Highest significant positive heterosis for fruit weight and fruit diameter was recorded by 5L X 1T (148.58%) and 4L X 8T (86.96%) for better parent heterosis. A large number of crosses showed the significant

TABLE 5

Estimates heterosis for fruit and seed quality traits in muskmelon

Characters	Mid parent heterosis		Better parent heterosis		Standard heterosis	
Fruit weight (g)	4L X 4T	182.13 **	5L X 1T	148.58 **	3L X 11T	121.15 **
Fruit cavity size (cm)	1L X 1T	-151.58 *	1L X 1T	-149.00 *	1L X 1T	-157.51 *
Fruit diameter (cm)	5L X 1T	93.38 **	4L X 8T	86.96 **	4L X 8T	72.00 **
TSS (p Brix)	5L X 12T	42.86 *	5L X 12T	38.89	4L X 11T	27.75
Germination (%)	1L X 1T	13.33 **	1L X 12T	11.90 **	1L X 4T	3.24 *
Shoot Length (cm)	2L X 11T	29.78 **	3L X 11T	23.18 **	2L X 11T	2.99 *
Root Length (cm)	2L X 11T	29.03 **	2L X 12T	37.37 **	2L X 11T	2.94 *
Seedling vigour index-I	2L X 12T	36.40 **	2L X 2T	33.07 **	2L X 2T	-2.59
Seedling vigour index-II	1L X 4T	42.24 **	1L X 4T	34.61 **	1L X 4T	6.81 **

*Significant at P=0.05; **Significant at P=0.01

heterosis in desirable direction for the traits attributing to fruit yield. The highest standard heterosis was exhibited by 3L X 11T (121.55%) for fruit weight and 4L X 8T (72%) for fruit diameter.

The highest negative heterosis was exhibited by 1L X 1T for fruit cavity trait which contributes to smaller seed cavity in hybrid. It's important to note that line-1 was used in most of the crosses which exhibited significant heterosis, which is a good combiner for seed cavity size. Germination per cent, 1L X 1T (13.33%), 1L X 12T (11.90%) and 1L X 4T (3.24%) exhibited significant mid-parent, better-parent and standard heterosis, respectively. Shoot length an d root length hybrid 2L X 11T exhibited significantly higher mid-parent (29.78%, 29.03%), Standard heterosis (2.99%, 2.94%) and significantly higher better-parent heterosis was reported in 3L X 11T (23.18%) for shoot length and 2L X 12T reported higher better parent heterosis (37.37%).

Highest significant mid-parent (36.40%) heterosis for seedling vigour index-I was recorded by 2L X 12T and 2L X 2T recorded higher better parent and standard heterosis. 1L X 4T recorded significantly higher mid-parent (42.24 %), better-parent (34.61 %) and standard heterosis (6.81 %). Munshi and Verma (1997) and Mohanty and Mishra (1999) reported similar findings in muskmelon.

The present investigation revealed that three hybrids *viz*., 3L x 12T, 5L x 1T and 1L x 4T were found promising and they were significantly better with the commercial check for fruit weight and fruit diameter along with other important attributes. The results of the present investigation were based on single location evaluation. Thus, the above three F_1 hybrids could be tested over multi-locations to make the results more reliable and to identify stable hybrids.

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