The Pharma Innovation Journal 2020; 9(5): 186-194

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2020; 9(5): 186-194

www.thepharmajournal.com
Received: 13-03-2020
Accepted: 15-04-2020

MK Patel
Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, India

NN Prajapati
Centre for Crop Improvement, SDAU, Sardarkrushinagar, Gujarat, India

BA Chaudhari
(1). Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, India
(2) Cotton Research Sub-Station, Navsari Agricultural University, Achhalia, Gujarat, India

AB Patel
Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, India

Corresponding Author:
MK Patel
Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, India

Heterosis analysis for seed yield and quality traits in karingada [*Citrullus lanatus* (Thumb) Mansf.]

MK Patel, NN Prajapati, BA Chaudhari and AB Patel

DOI: https://doi.org/10.22271/tpi.2020.v9.i5d.4651

Abstract
An experiment was conducted to study the heterosis analysis for seed yield and quality traits in karinagda [*Citrullus lanatus* (Thumb) Mansf.]. Experimental material consisting of 35 entries comprised of eight diverse genotypes (used as females) and three diverse genotypes (used as males) and their 24 crosses developed through line × tester mating design along with standard check (GK-1) were evaluated in a randomized block design with three replications. The analysis of variance revealed that mean squares due to genotypes were significant for all yield and yield attributes characters indicate the presence of considerable genetic variability among the material under studied. Heterosis analysis revealed that among all crosses, significantly positive heterosis over check GK-1 with regards to seed yield per plant were recorded by the top performing crosses *viz.,* MGPK 11 × SKNK 1102 (81.13 %), CAZJK 14-1 × MGPK 1 (67.38 %), SKNK 679 × SKNK 1102 (55.12 %), CAZJK 14-1 × CAZJK 13-2 (48.54 %) and SKNK 679 × CAZJK 13-2 (44.83 %). The cross CAZJK 14-1 × MGPK 1 recorded significant and positive for all three heterosis *viz.,* over mid parent heterosis, over better parent and standard heterosis (over check GK-1) for fruit yield per plant among the crosses evaluated. For quality traits cross combinations SKNK 138 × SKNK 1102 (4.98 % oil and 8.12 % protein) was recorded significant and positive standard heterosis over check GK-1.Where ever cross combinations involving either CAZJK 14-1 as female parent recorded significant positive heterosis for most of the yield and yield contributing characters. Thus, the female parent CAZJK 14-1 can be used within breeding programmes aimed for heterosis breeding after proper evaluation within multi-location trials.

Keywords: Karinagda, *Citrullus lanatus* (Thumb) Mansf., heterosis, yield, yield components

Introduction

Citrullus lanatus (Thumb) Mansf. (watermelon) locally known as a 'karingada'. It is an unconventional source of edible oil; it is also used as vegetable and animal food. It is a native crop of tropical and subtropical parts of Africa, which was introduced in to India during tenth or eleventh century (Tindall, 1983) [26]. It has 2n = 22 chromosomes and belong to family *Cucurbitaceae*. It can be grown during summer as well as in *Kharif* season. It is particularly grown in hot and dry situation on any ordinary soil. It is extremely drought hardy cucurbitaceous creeper. Sex expression in watermelon is highly influenced by environmental factors. Monoecious (staminate and pistillate flowers on the same plant) sex expression promotes allogamy, while andromonoecious (staminate and perfect flowers on same plant) sex expression favors autogamy (Martin *et al.*, 2009) [10]. Das *et al.* (2002) [6] reported 28 % crude fat and 23 % crude protein in karingada seeds while, in kernel corresponding values observed were 49 % and 40 %, respectively. The kernels contain 35-50 % crude protein, 28-40 % oil and minerals in appreciable quantity.

Nature and magnitude of heterosis is one of the important aspects for selection of the right parents for crosses and also help in identification of superior cross combinations that may produce desirable transgressive segregants in advanced generations (Pagi *et al.*, 2016; Makwana *et al.*, 2018) [15, 9]. The choice of parents to be incorporated in hybridization programme is a crucial step for breeders, particularly if the aim is to improve the complex quantitative characters such as yield and its components. Watermelon highly cross pollinated crop offers good potentialities for exploitation of hybrid vigor in improving yield and other quality attributes. In watermelon, total and early yield are important but quality attributes like total soluble solid content should also be considered, if hybrids were to prove superior over purebred varieties. The present study is an attempt to evaluate the prospects of heterosis breeding in watermelon.

Materials and Methods

Eight diverse genotypes (used as females) *viz.*, SKNK 138, SKNK 679, SKNK 903, SKNK 1302, SKNK 1407, SKNK 1502, MGPK 11 and CAZJK 14-1 and three diverse genotypes (used as males) *viz.*, SKNK 1102, MGPK 1 and CAZJK 13-2 with diverse origin, were developed through line × tester mating design to generate 24 hybrids during summer 2017. These hybrids along with one standard check GK-1 were grown in randomized block design with 3 replications at All India Coordinated Research Network on Potential Crop, Centre for Crop Improvement (CCI), Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India. All the seeds were sown in the crossing block with spacing of 3 m × 1 m. The recommended package of practices was followed as per the recommendation to raise a healthy crop. Observations were recorded on five randomly selected plants from each replication for each genotypes and the average value per plot was computed for recording observations on days to flowering (DF), node number to first female flower (NFF), number of primary branches per plant (NPB), leaf area (cm^2) (LA), main vine length (m) (MVL), days to fruit maturity (DFM), number of fruits per plant (NFP), fruit yield per plant (kg) (FYP), fruit diameter (cm) (FD), average fruit weight (g) (TW), seed yield per fruit (g) (SYF), seed yield per plant (g) (SYP), test weight (g) (TW), cotyledon ratio (%) (CR), oil content (%) (OC), protein content (%) (PC). Heterosis was estimated in terms of three parameters, *i.e.* relative heterosis (Turner, 1953) [28], heterobeltiosis (Fonseca and Patterson, 1968) [7] and standard heterosis (Meredith and Bridge, 1972) [11] were estimated as per standard method.

Results and Discussion

The phenomenon of heterosis has proved to be the most important genetic tool in boosting the yield of self as well as cross pollinated crops and is considered as the most important breakthrough in the field of crop improvement. Heterosis may be positive or negative, depending on the magnitude of the hybrid mean value. The primary objective of heterosis breeding is to achieve a quantum jump in yield of crop plants. The data collected from the experimental material was subjected to analysis of variance and results obtained had been presented in Table 1. The results revealed that the mean squares due to genotypes were significant for all the characters under study indicate that sufficient amount of genetic variability was present in the experimental material for all the character under study. The mean squares due to genotypes were further partitioned into parents, hybrids and parents *vs.* hybrids. The parents significant for all the characters except days to fruit maturity, number of fruits per plant and test weight. Whereas, hybrids were significant for all the characters except number of fruits per plant and test weight which indicated the existence of considerable genetic variability among these characters under study. Finally, parents *vs.* hybrids were significant for main vine length, days to fruit maturity, number of fruits per plant, seed yield per fruit, seed yield per plant, test weight, cotyledon ratio, oil content and protein content which suggested the presence of substantial amount of heterosis in crosses for most of the characters.

An examination of *per se* performance of hybrids revealed that MGPK 11 × SKNK 1102 (283.73 g), CAZJK 14-1 × MGPK 1 (262.20 g), SKNK 679 × SKNK 1102 (242.99 g), CAZJK 14-1 × CAZJK 13-2 (232.70 g) and SKNK 679 × CAZJK 13-2 (226.87 g) among hybrids exhibited higher mean performance for seed yield per plant and its attributing characters (Table 4). Seed yield is the economic important trait and breeders attempt to evolve varieties/hybrids with high seed yield. The perusal of the results revealed that heterosis over mid parent ranged from -5.20 (CAZJK 14-1 × SKNK 1102) to 78.34 (MGPK 11 × SKNK 1102) percent; better parent varied from -19.87 (CAZJK 14-1 × SKNK 1102) to 74.19 (MGPK 11 × SKNK 1102) percent and standard parent ranged from -1.97 (SKNK 903 × CAZJK 13-2) to 81.13 (MGPK 11 × SKNK 1102) per cent (Table 3).

Among 24 hybrids studied (Table-2), 10 hybrids exhibited significantly positive heterosis over check GK-1 for seed yield per plant and yield attributing traits. For seed yield per plant five best significant positive standard heterotic crosses arranged in descending order were MGPK 11 × SKNK 1102 (81.13 %), CAZJK 14-1 × MGPK 1 (67.38 %), SKNK 679 × SKNK 1102 (55.12 %), CAZJK 14-1 × CAZJK 13-2 (48.54 %) and SKNK 679 × CAZJK 13-2 (44.83 %) over GK-1. These results were akin to the result of Rajan *et al.* (2002) [18], Tarsem and Reetinder (2002) [25], Choudhary *et al.* (2003) [4], Moon *et al.* (2003) [12], Tomar and Bhalala (2006) [27], Pichaimuthu and Swamy (2009) [16], Singh *et al.* (2009) [23] and Singh *et al.* (2017) [22]. The hybrid SKNK 1502 × CAZJK 13-2 exhibited significant positive relative heterosis (28.24 %, 42.85 % and 19.50 %), heterobeltiosis (24.16 %, 32.54 % and 15.14 %) and standard heterosis over check GK-1 (14.53 %,25.48 % and 18.79 %) for numbers of primary branches per plant, seed yield per fruit and test weight, respectively (Table-2). Significant heterosis for the trait was also reported by Sindhu and Brar (1977) [2], Brar and Sindhu (1977) [2], Choudhary *et al*. (2003) [4], Pichaimuthu and Swamy (2009) [16], Singh *et al.* (2009) [23] and Sapovadiya *et al.* (2013) [19].

For earliness, heterotic effects in negative direction are desirable. With regard to days to maturity hybrids SKNK 903 × MGPK 1 (-4.62 % to -6.47 %) followed by SKNK 1302 × SKNK 1102 (-4.44 % to -7.33 %) showed significant negative relative heterosis and standard heterosis (over check GK-1), respectively for earliness with higher estimates (Table-2). The result obtained are in accordance with Nath and Dutta (1970) [14], Brar and Sindhu (1977) [2], Crall *et al.* (1987) [5], Sharma and Choudhary (1988), Rajan *et al.* (2002) [18], Choudhary (2003) [4], Moon *et al.* (2003) [12], Aravindakumar *et al.* (2005) [1] and Singh *et al.* (2017) [22]. For days to flowering top two hybrids *viz.*, SKNK 1407 × MGPK 1 (-10.34 %) and SKNK 679 × CAZJK 13-2 (-9.71 %) were registered significant heterosis in desirable direction over mid parent (Table-2). Negative estimation of heterosis for days to flowering was also reported by Nandpuri *et al.* (1974) [13], Choudhary *et al*. (2003) [4], Moon *et al*. (2003) [12], Aravindakumar *et al*. (2005) [1] and Singh *et al.* (2009) [23]. Node number to first female flower is an indication of earliness. For these trait, hybrid SKNK 1407 × MGPK 1 (-35.24 %, -38.18 % and -20.93 %) showed significantly negative relative heterosis, heterobeltiosis and standard heterosis (over check GK-1), respectively for earliness with higher estimates (Table-2). Similar results were achieved by Brar and Sukhija (1977) [3], Moon *et al*. (2003) [12], Aravindakumar *et al*. (2005) [1], Tomar and Bhalala (2006) [27] and Singh *et al*. (2009) [23]. The hybrid SKNK 1302 × SKNK 1102 (16.13 %, 14.34 % and 12.66 %) exhibited maximum significant positive relative heterosis, heterobeltiosis and standard heterosis in desirable direction over GK-1 for leaf area, respectively.

For biochemical traits, cross combinations SKNK 138 × SKNK 1102 (4.98 % and 8.12 %), SKNK 679 × SKNK 1102 (4.01 % and 7.40 %) and SKNK 679 × CAZJK 13-2 (5.54 % and 6.88 %) were recorded significant and positive standard heterosis over check GK-1 for oil content and protein content, respectively (Table-2). The result was in accordance to the result of Das *et al.* (2002) [6], Jerret and Levy (2012) [8], Prothro *et al.* (2012) [17], Tak and Jain (2016) [24] and Singh *et al.* (2017) [22]. The best heterotic crosses and their performance for seed yield per plant and related parameters are presented in Table 4.

Conclusion

Thus, the finding from the present study indicated that the higher and desirable magnitude of all yield and yield attributing traits not expressed in single hybrid combination, which varied from cross to cross due to diverse genetic background of their parents. Sufficient high magnitude of relative heterosis, heterobeltiosis and standard heterosis in desired direction was observed for all the characters. On the basis of crosses namely, MGPK 11 × SKNK 1102 (81.13 %), CAZJK 14-1 × MGPK 1 (67.38 %), SKNK 679 × SKNK 1102 (55.12 %), CAZJK 14-1 × CAZJK 13-2 (48.54 %) and SKNK 679 × CAZJK 13-2 (44.83 %) were identified as superior for seed yield per plant and yield attributing traits and cross combinations SKNK 138 × SKNK 1102 (4.98 % oil and 8.12 % protein) was recorded significant and positive standard heterosis over check GK-1 for biochemical traits. Therefore, these crosses could be exploited for heterosis breeding programme to boost the seed yield and quality parameters in karingada.

Table 1: Analysis of variance (mean sum of square) for experimental design for yield and its component traits in Karingada

Source	DF	DF	NFF	NPB	LA	MVL	DFM	NFP	FYP
Replication	2	1.04	11.01*	0.25*	24862.90	0.13*	7.74	4.48	0.17
Genotype	34	8.28**	13.43**	0.79**	132296.15**	0.94**	7.53**	12.42**	2.31**
Parents	10	7.09*	8.63*	0.75**	83434.95**	0.79**	2.82	1.63	2.37*
Lines	7	4.76	9.41*	0.86**	102668.19**	0.74**	2.71	2.24	2.87
Testers	2	17.33*	6.78	0.01	26972.44	0.67**	3.44	0.04	0.93
Lines *vs* Testers	1	2.91	6.91	1.39**	61727.35*	1.46**	2.34	0.48	1.71
Parents vs Hybrids	1	6.01	2.69	0.01	3433.61	6.01**	20.95*	371.09**	0.31
Hybrids	23	8.90**	15.98**	0.85**	159142.87**	0.78**	8.99*	1.52	2.36*
Error	68	2.57	3.00	0.07	10988.34	0.04	3.64	1.62	1.09
Source	**DF**	**FD**	**AFW**	**SYF**	**SYP**	**TW**	**CR**	**OC**	**PC**
Replication	2	0.495	14829.33	0.14	53.30	0.45	7.59	0.98	0.04
Genotype	34	1.310**	21718.37**	23.55**	3341.06**	0.56*	23.96**	14.44**	7.71**
Parents	10	1.579**	34277.04**	4.94**	2604.06**	0.28	10.08*	13.81**	5.58**
Lines	7	1.589**	25897.27*	6.13**	2959.66**	0.38	11.01*	12.35**	5.51**
Testers	2	2.064**	79958.75**	3.04	578.21	0.03	7.82	25.05**	4.07*
Lines *vs* Testers	1	0.537	1571.98	0.43	4166.58**	0.04	8.07	1.58	9.12**
Parents vs Hybrids	1	0.018	6216.67	267.49**	16045.17**	5.57**	82.43**	13.12**	15.80**
Hybrids	23	1.249**	16932.07*	21.04**	3109.15**	0.47	27.45**	14.76**	8.28**
Error	68	0.170	8360.94	1.11	540.72	0.34	3.79	0.78	0.62

*, ** Significant at 5 per cent and 1 per cent levels, respectively. Where, DF- days to flowering, NFF- node number to first female flower, NPB- number of primary branches per plant, LA- leaf area (cm^2), MVL- main vine length (m), DFM- days to fruit maturity, NFP- number of fruits per plant, FYP- fruit yield per plant (kg), FD- fruit diameter (cm), TW- average fruit weight (g), SYF- seed yield per fruit (g), SYP- seed yield per plant (g), TW- test weight (g), CR-cotyledon ratio (%), OC- oil content (%), PC- protein content (%).

Table 2a: Heterosis (%), heterobeltiosis (%) and standard heterosis (%) for days to flowering, node number to first female flower, number of primary branches per plant and leaf area (cm^2)

Sr. No.	Crosses	Days to flowering			Node number to first female flower			Number of primary branches per plant			Leaf area (cm^2)		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	SKNK 138 × SKNK 1102	-0.51	3.16	-2.00	32.50**	29.27**	23.26*	3.71	-4.42	-4.29	4.29	2.87	1.36
2	SKNK 138 × MGPK 1	0.48	1.96	4.00	23.60**	10.00	27.91**	18.43**	9.68*	9.83*	-9.89**	-12.40**	-11.08**
3	SKNK 138 × CAZJK 13-2	-5.21	-1.96	0.00	20.00*	10.87	18.60	-6.12	-12.58**	-12.46**	-3.79	-7.53**	-3.88
4	SKNK 679 × SKNK 1102	4.17	5.26	0.00	13.33	4.08	18.60	-7.81	-11.94*	-18.34**	8.55**	5.15*	10.53**
5	SKNK 679 × MGPK 1	-6.93*	-3.09	-6.00	-1.01	-2.00	13.95	6.88	2.61	-4.84	-7.47**	-9.06**	-4.40
6	SKNK 679 × CAZJK 13-2	-9.71**	-4.12	-7.00	-26.32**	-28.57**	-18.60	-18.62**	-21.42**	-27.13**	-3.45	-3.99	0.92
7	SKNK 903 × SKNK 1102	-1.05	-1.05	-6.00	24.44**	14.29	30.23**	3.02	-8.37	-0.69	-5.96**	-9.77**	-3.26
8	SKNK 903 × MGPK 1	-6.00	-1.05	-6.00	-5.05	-6.00	9.30	-22.33**	-30.59**	-24.78**	-16.07**	-18.31**	-12.41**

9	SKNK 903 × CAZJK 13-2	-7.84*	-1.05	-6.00	-26.32**	-28.57**	-18.60	10.87*	-0.38	7.96	-2.85	-4.33	2.57
10	SKNK 1302 × SKNK 1102	4.52	9.47*	4.00	9.89	0.00	16.28	0.19	-8.47	-6.57	16.13**	14.34**	12.66**
11	SKNK 1302 × MGPK 1	0.48	0.96	5.00	4.00	4.00	20.93*	-8.94*	-16.41**	-14.67**	9.77**	6.52**	8.12**
12	SKNK 1302 × CAZJK 13-2	0.47	2.88	7.00	-6.25	-10.00	4.65	4.81	-3.25	-1.25	-8.23**	-11.96**	-8.49**
13	SKNK 1407 × SKNK 1102	-1.55	0.00	-5.00	-8.33	-20.00*	2.33	-20.23**	-25.36**	-27.68**	-2.16	-4.23	-5.63*
14	SKNK 1407 × MGPK 1	-10.34**	-7.14	-9.00	-35.24**	-38.18**	-20.93*	-0.49	-6.43	-9.34*	-8.05**	-11.28**	-9.94**
15	SKNK 1407 × CAZJK 13-2	-7.25*	-2.04	-4.00	2.97	-5.45	20.93*	-17.67**	-22.14**	-24.57**	0.76	-3.88	-0.09
16	SKNK 1502 × SKNK 1102	8.54*	13.68**	8.00*	12.77	0.00	23.26*	12.03*	7.28	-1.04	6.02**	4.56	5.95*
17	SKNK 1502 × MGPK 1	-4.31	-3.85	0.00	-4.85	-7.55	13.95	2.10	-1.73	-9.34*	-1.77	-1.86	-0.38
18	SKNK 1502 × CAZJK 13-2	-8.92**	-6.73	-3.00	-3.03	-9.43	11.63	28.24**	24.16**	14.53**	4.28*	2.96	7.03**
19	MGPK 11 × SKNK 1102	4.00	9.47*	4.00	-5.38	-15.38	2.33	3.48	-2.94	-6.44	0.66	-0.75	-2.20
20	MGPK 11 × MGPK 1	-0.95	-0.95	4.00	-17.65*	-19.23*	-2.33	0.76	-5.03	-8.44	-2.79	-5.53*	-4.11
21	MGPK 11 × CAZJK 13-2	-0.93	0.95	6.00	14.29	7.69	30.23**	4.13	-1.29	-4.84	-0.97	-4.86*	-1.11
22	CAZJK 14-1 × SKNK 1102	5.05	9.47*	4.00	-21.43*	-23.26*	-23.26*	12.50*	3.28	-12.80**	1.30	-1.43	-2.88
23	CAZJK 14-1 × MGPK 1	0.00	0.97	4.00	-1.08	-8.00	6.98	23.12**	12.49*	-4.01	-3.33	-7.28**	-5.88*
24	CAZJK 14-1 × CAZJK 13-2	-1.89	0.97	4.00	1.12	-2.17	4.65	20.81**	9.78	-5.19	2.99	-2.32	1.53
S.Em.±		1.13	1.31	1.31	1.22	1.41	1.41	0.19	0.22	0.22	74.12	85.59	85.59
Range		-10.34 to 8.54	-7.14 to 13.68	-9 to 8	-35.24 to 32.50	-38.18 to 29.27	-23.26 to 30.23	-22.33 to 28.24	-30.59 to 24.16	-27.68 to 14.53	-16.07 to 16.13	-18.31 to 14.34	-12.41 to 12.66
Number of +ve significant		1	4	1	4	1	7	7	3	2	5	3	5
Number of –ve significant		6	0	0	5	6	2	5	7	10	6	10	6
*,** Significant at 5 and 1 per cent levels, respectively.													

Table 2b: Heterosis (%), heterobeltiosis (%) and standard heterosis (%) for main vine length (m), days to fruit maturity, number of fruit per plant and fruit yield per plant (kg)

Sr. No.	Crosses	Main vine length (m)			Days to fruit maturity			Number of fruits per plant			Fruit yield per plant (kg)		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	SKNK 138 × SKNK 1102	-21.83**	-27.37**	-23.97**	2.43	4.04	0.00	-35.59**	-37.70**	-36.71**	-1.78	-6.89	19.57
2	SKNK 138 × MGPK 1	-20.03**	-20.20**	-16.12**	0.65	0.87	-0.43	-48.06**	-49.81**	-49.02**	11.57	2.86	18.34
3	SKNK 138 × CAZJK 13-2	-15.57**	-15.69**	-11.74**	0.44	1.79	-1.72	-37.32**	-38.85**	-37.88**	1.77	1.23	16.46
4	SKNK 679 × SKNK 1102	7.81*	7.04*	-3.83	-0.45	-0.45	-4.31*	-43.20**	-44.38**	-44.92**	-5.19	-15.68	8.28
5	SKNK 679 × MGPK 1	-26.26**	-32.06**	-28.59**	-2.21	-0.90	-4.74*	-40.93**	-42.22**	-42.78**	23.25	21.45	21.45
6	SKNK 679 × CAZJK 13-2	-8.13**	-15.09**	-11.37**	-2.91	-2.69	-6.47**	-46.09**	-46.75**	-47.26**	-21.78	-26.53	-16.37
7	SKNK 903 × SKNK 1102	-15.27**	-17.73**	-21.53**	-2.00	-1.35	-5.17*	-23.63**	-26.85**	-30.56**	-38.69**	-47.43**	-5.55
8	SKNK 903 × MGPK 1	-30.40**	-33.62**	-30.23**	-4.62*	-3.98	-6.47**	-18.71*	-22.05*	-26.16**	-12.58	-32.67*	20.98
9	SKNK 903 × CAZJK 13-2	-4.63	-8.74**	-4.74	-1.78	-1.34	-4.74*	-31.05**	-34.51**	-36.71**	0.19	-18.17	47.04
10	SKNK 1302 × SKNK 1102	6.03*	-1.17	2.74	-4.44*	-3.59	-7.33**	-32.15**	-32.72**	-35.04**	-14.35	-15.16	8.94
11	SKNK 1302 × MGPK 1	-11.43**	-11.92**	-7.42*	-1.32	-0.88	-3.02	-26.47**	-27.16**	-29.68**	9.24	-3.29	21.83
12	SKNK 1302 × CAZJK 13-2	-14.39**	-14.57**	-10.83**	-2.88	-2.23	-5.60**	-32.90**	-32.93**	-35.19**	7.26	2.09	28.60
13	SKNK 1407 × SKNK 1102	-20.18**	-23.56**	-31.33**	-3.33	-2.24	-6.03**	-44.28**	-48.47**	-42.43**	-9.03	-12.16	12.79

14	SKNK 1407 × MGPK 1	-22.99**	-31.37**	-27.86**	-1.97	-1.75	-3.45	-40.96**	-45.45**	-39.06**	-19.67	-27.22	-12.98
15	SKNK 1407 × CAZJK 13-2	-11.80**	-21.15**	-17.70**	-3.10	-2.23	-5.60**	-44.87**	-48.60**	-42.57**	-30.51	-32.18	-18.91
16	SKNK 1502 × SKNK 1102	0.73	-2.44	-12.35**	0.67	1.35	-2.59	-33.73**	-35.84**	-34.95**	16.84	14.36	46.85
17	SKNK 1502 × MGPK 1	-9.45**	-18.46**	-14.29**	-0.66	0.00	-2.59	-45.91**	-47.69**	-46.97**	18.00	5.59	29.82
18	SKNK 1502 × CAZJK 13-2	0.77	-8.97**	-4.99	-0.44	0.00	-3.45	-40.51**	-41.91**	-41.11**	38.82*	33.66	64.35*
19	MGPK 11 × SKNK 1102	1.25	-1.22	-11.25**	-0.45	0.00	-3.88	-38.07**	-39.51**	-42.57**	-9.99	-18.17	28.41
20	MGPK 11 × MGPK 1	-10.37**	-18.75**	-14.60**	2.20	3.11	0.00	-27.25**	-28.86**	-32.61**	-10.89	-27.88	13.17
21	MGPK 11 × CAZJK 13-2	-14.77**	-22.49**	-19.10**	1.11	1.34	-2.16	-26.42**	-28.74**	-31.15**	33.56*	15.23	80.81**
22	CAZJK 14-1 × SKNK 1102	-15.21**	-17.54**	-25.91**	1.54	3.59	-0.43	-35.73**	-35.80**	-39.06**	5.52	-6.15	20.51
23	CAZJK 14-1 × MGPK 1	-20.68**	-28.30**	-24.64**	-4.12*	-3.49	-4.74*	-28.24**	-28.24**	-32.02**	50.84*	48.64*	48.64*
24	CAZJK 14-1 × CAZJK 13-2	-4.50	-13.40**	-9.61**	1.32	3.13	-0.43	-43.65**	-44.21**	-46.09**	-21.51	-26.28	-16.09
S.Em.±		0.15	0.17	0.17	0.90	1.04	1.04	0.90	1.04	1.04	0.74	0.85	0.85
Range		-30.40 to 7.81	-33.62 to 7.04	-31.33 to 2.74	-4.62 to 2.43	-3.98 to 4.04	-7.33 to 0.00	-48.06 to -18.71	-49.81 to -22.05	-49.02 to -26.16	-38.69 to 50.84	-47.43 to 48.64	-18.91 to 80.81
Number of +ve significant		2	1	0	0	0	0	0	0	0	3	1	3
Number of –ve significant		17	20	20	3	0	11	24	24	24	1	2	0

*,** Significant at 5 and 1 per cent levels, respectively.

Table 2c: Heterosis (%), heterobeltiosis (%) and standard heterosis (%) for fruit diameter (cm), average fruit weight (g), seed yield per fruit (g) and seed yield per plant (g)

Sr. No.	Crosses	Fruit diameter (cm)			Average fruit weight (g)			Seed yield per fruit (g)			Seed yield per plant (g)		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	SKNK 138 × SKNK 1102	4.19	-0.87	-2.61	-12.20	-21.54	6.94	32.49**	25.78**	21.77**	4.78	3.69	10.11
2	SKNK 138 × MGPK 1	8.43**	-1.03	6.33	-10.36	-19.77	9.36	2.61	0.65	-2.55	-2.48	-4.25	1.67
3	SKNK 138 × CAZJK 13-2	6.73*	4.90	-3.65	-16.88	-27.03*	31.58	2.25	1.13	-2.10	29.27**	18.13	25.44*
4	SKNK 679 × SKNK 1102	-2.88	-3.98	-3.49	9.05	-2.56	32.83	13.06**	9.52*	1.65	27.03**	10.61	55.12**
5	SKNK 679 × MGPK 1	-6.33*	-9.35**	-2.61	2.70	-8.09	25.29	-4.08	-4.23	-10.82**	1.62	-12.11	23.24
6	SKNK 679 × CAZJK 13-2	1.06	-3.29	-2.80	-11.65	-22.43*	39.87*	31.43**	30.14**	23.21**	26.98**	3.28	44.83**
7	SKNK 903 × SKNK 1102	-2.46	-2.71	-3.93	-1.35	-4.40	9.33	15.18**	13.97**	1.28	12.72	12.24	16.71
8	SKNK 903 × MGPK 1	4.12	-0.09	7.33*	13.16	9.86	25.64	-2.35	-4.58	-11.15**	21.89*	21.44	25.19*
9	SKNK 903 × CAZJK 13-2	2.36	-1.21	-2.46	-9.99	-26.45*	32.62	14.65**	11.13**	5.22	2.67	-4.91	-1.97
10	SKNK 1302 × SKNK 1102	-2.58	-4.33	-6.01	26.73	26.56	35.78	22.74**	16.38**	12.95**	11.51	7.60	11.89
11	SKNK 1302 × MGPK 1	4.17	-1.99	5.29	8.16	7.81	16.10	10.42**	8.17*	4.99	11.07	8.01	10.53
12	SKNK 1302 × CAZJK 13-2	1.33	-0.20	-5.48	-0.72	-20.91	42.62*	-5.49	-6.65	-9.40**	50.26**	43.42**	38.66**
13	SKNK 1407 × SKNK 1102	-0.97	-2.34	-4.06	16.18	4.00	41.18*	25.25**	20.06**	13.89**	13.94	13.52	18.92
14	SKNK 1407 × MGPK 1	3.78	-1.96	5.32	10.42	-0.99	34.40	24.65**	23.50**	17.16**	11.88	10.58	15.85
15	SKNK 1407 × CAZJK 13-2	-9.09**	-10.84**	-14.83**	-10.63	-21.67*	41.23*	10.84**	10.73**	5.04	44.37**	32.73**	39.05**
16	SKNK 1502 × SKNK 1102	-3.61	-4.26	-5.95	20.16	19.62	28.34	20.28**	16.14**	1.04	20.15*	15.51	30.16*
17	SKNK 1502 × MGPK 1	1.85	-3.14	4.06	-4.42	-5.02	2.28	28.49**	20.13**	11.86**	1.08	-3.56	8.67
18	SKNK 1502 × CAZJK 13-2	1.35	-1.30	-4.34	3.93	-17.39	48.95*	42.85**	32.54**	25.48**	13.76	1.24	14.08
19	MGPK 11 ×	-6.42*	-11.12**	-2.93	28.14	26.88	38.86*	19.41**	16.87**	6.19	78.34**	74.19**	81.13**

	SKNK 1102												
20	MGPK 11 × MGPK 1	-2.08	-2.88	6.07	0.85	0.04	9.48	9.87**	8.53*	1.06	14.56	12.78	15.41
21	MGPK 11 × CAZJK 13-2	-3.54	-11.21**	-3.02	-8.59	-26.56*	32.43	0.12	-1.90	-7.13*	29.80*	22.42	21.38
22	CAZJK 14-1 × SKNK 1102	-7.15*	-12.27**	-13.82**	28.01*	2.88	81.76**	15.47**	8.57*	7.26*	-5.20	-19.87*	20.66
23	CAZJK 14-1 × MGPK 1	2.62	-6.94*	-0.03	14.29	-8.03	62.49**	19.44**	16.01**	14.60**	32.36**	11.15	67.38**
24	CAZJK 14-1 × CAZJK 13-2	-2.97	-5.31	-13.03**	-7.14	-8.08	65.75**	21.75**	19.22**	17.78**	24.58**	-1.36	48.54**
S.Em.±		0.29	0.34	0.34	64.66	74.66	74.66	0.74	0.86	0.86	16.44	18.99	18.99
Range		-9.09 to 8.43	-12.27 to 4.90	-14.83 to 7.33	-16.88 to 28.14	-27.03 to 26.88	2.28 to 81.76	-5.49 to 42.85	-6.65 to 32.54	-11.15 to 25.48	-5.20 to 78.34	-19.87 to 74.19	-1.97 to 81.13
Number of +ve significant		2	0	1	1	0	9	18	18	10	11	3	10
Number of –ve significant		4	6	3	0	5	0	0	0	4	0	1	0
*,** Significant at 5 and 1 per cent levels, respectively.													

Table 2d: Heterosis (%), heterobeltiosis (%) and standard heterosis (%) for test weight (g), cotyledon ratio (%), oil content (%) and protein content (%)

Sr. No.	Crosses	Test weight (g)			Cotyledon ratio (%)			Oil content (%)			Protein content (%)		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	SKNK 138 × SKNK 1102	4.40	-0.30	10.13	-1.96	-4.31	-11.29**	1.41	0.99	4.98*	0.98	0.87	8.12**
2	SKNK 138 × MGPK 1	7.62	4.03	14.91*	-0.49	-5.17*	-7.60**	-0.60	-7.34**	-4.47*	-0.03	-2.88	3.87*
3	SKNK 138 × CAZJK 13-2	-0.58	-3.86	6.20	-2.07	-4.96	-10.85**	-1.02	-2.25	0.77	-1.21	-2.20	4.60*
4	SKNK 679 × SKNK 1102	7.71	7.50	8.47	-3.62	-4.15	-11.13**	1.05	0.06	4.01*	0.77	0.20	7.40**
5	SKNK 679 × MGPK 1	0.28	-0.78	2.27	-2.72	-5.59*	-8.01**	-1.16	-7.37**	-5.60**	-0.26	-2.66	3.14
6	SKNK 679 × CAZJK 13-2	15.49**	14.22*	17.84*	-0.35	-1.47	-7.58**	4.27*	3.56	5.54**	1.42	0.87	6.88**
7	SKNK 903 × SKNK 1102	5.57	5.27	5.82	2.69	2.13	-4.26	-1.22	-6.34**	-2.63	-1.72	-5.30**	1.51
8	SKNK 903 × MGPK 1	-0.51	-2.02	0.99	2.38	0.44	-2.14	4.72*	2.43	-4.54*	0.12	-0.61	0.24
9	SKNK 903 × CAZJK 13-2	7.55	5.87	9.23	0.01	-0.02	-6.22*	-2.76	-6.30**	-5.82**	-9.50**	-11.84**	-7.60**
10	SKNK 1302 × SKNK 1102	12.47*	10.72	14.86*	-10.08**	-10.63**	-16.11**	4.62**	0.16	4.12*	-5.17**	-8.82**	-2.27
11	SKNK 1302 × MGPK 1	2.97	2.65	6.48	-11.25**	-12.88**	-15.11**	2.00	-1.21	-6.06**	-7.95**	-8.83**	-8.06**
12	SKNK 1302 × CAZJK 13-2	-2.15	-2.42	1.23	-9.36**	-9.39**	-14.95**	-2.46	-5.09*	-4.60*	-7.85**	-10.44**	-6.13**
13	SKNK 1407 × SKNK 1102	11.61	11.16	12.64	-12.28**	-12.62**	-18.37**	-7.46**	-10.45**	-6.91**	-3.84*	-8.57**	-2.00
14	SKNK 1407 × MGPK 1	12.80*	11.85	15.29*	-6.28**	-8.21**	-10.56**	7.47**	2.98	0.13	-3.63*	-5.64**	-4.83**
15	SKNK 1407 × CAZJK 13-2	5.07	4.13	7.43	-12.53**	-12.71**	-18.12**	-6.31**	-7.84**	-7.36**	-1.30	-5.14**	-0.58
16	SKNK 1502 × SKNK 1102	7.99	5.37	5.92	-4.07	-5.62*	-12.50**	-8.26**	-9.12**	-5.53**	0.22	-4.21*	2.67
17	SKNK 1502 × MGPK 1	9.17	5.23	8.47	-4.62*	-8.40**	-10.74**	-5.48**	-11.45**	-9.68**	-2.30	-3.82*	-3.00
18	SKNK 1502 × CAZJK 13-2	19.50**	15.14*	18.79**	3.64	1.39	-4.89	-6.92**	-7.59**	-5.74**	1.11	-2.31	2.38
19	MGPK 11 × SKNK 1102	14.47*	12.09	17.56*	-1.87	-3.51	-7.45**	-7.61**	-14.54**	-11.17**	-5.69**	-8.26**	-1.67
20	MGPK 11 × MGPK 1	1.18	0.32	5.21	1.69	0.90	-1.69	-4.04*	-4.45*	-14.86**	-2.25	-2.48	-1.18
21	MGPK 11 × CAZJK 13-2	7.46	6.59	11.78	0.30	-0.80	-4.86	-6.67**	-12.32**	-11.86**	-4.14**	-5.73**	-1.20
22	CAZJK 14-1 × SKNK 1102	4.36	-0.21	9.94	-3.24	-5.36*	-8.24**	-9.29**	-14.74**	-11.37**	-6.38**	-8.92**	-2.37
23	CAZJK 14-1 × MGPK 1	3.42	0.09	10.27	-5.75*	-5.98*	-8.39**	-5.49**	-6.70**	-14.67**	-5.82**	-6.07**	-4.77**
24	CAZJK 14-1 × CAZJK 13-2	13.62*	10.01	21.20**	-2.79	-4.37	-7.28**	-6.45**	-10.66**	-10.20**	-6.97**	-8.49**	-4.09*
S.Em.±		0.41	0.48	0.48	1.38	1.59	1.59	0.62	0.72	0.72	0.56	0.64	0.64
Range		-2.15 to 19.50	-3.86 to 15.14	0.99 to 21.20	-12.53 to 3.64	-12.88 to 2.13	-18.37 to	-9.29 to 7.47	-14.74 to 3.56	-14.86 to 5.54	-9.50 to	-11.84 to 0.87	-8.06 to 8.12

						-1.69				1.42		
Number of +ve significant	6	2	7	0	0	0	4	0	4	0	0	5
Number of –ve significant	0	0	0	8	12	19	11	16	17	11	15	6
*,** Significant at 5 and 1 per cent levels, respectively.												

Table 3: Number of hybrids showing significant heterosis and range of heterosis for various characters

Sr. No.	Characters	Number of hybrids showing heterosis over						Range of heterosis (per cent) over		
		MP		BP		SH		MP	BP	SH
		P (+)	N(-)	P(+)	N (-)	P(+)	N(-)			
1	Days to flowering	01	06	04	00	01	00	-10.34 to 08.54	-07.14 to 13.68	-09 to 08
2	Node number to first female flower	04	05	01	06	07	02	-35.24 to 32.50	-38.18 to 29.27	-23.36 to 30.23
3	Number of primary branches per plant	07	05	03	07	02	10	-22.33 to 28.24	-30.59 to 24.16	-27.68 to 14.53
4	Leaf area (cm^2)	05	06	03	10	05	06	-16.07 to 16.13	-18.31 to 14.34	-12.41 to 12.66
5	Main vine length (m)	02	17	01	20	00	20	-30.40 to 07.81	-33.62 to 07.04	-31.33 to 02.74
6	Days to fruit maturity	00	03	00	00	00	11	-04.62 to 02.43	-03.98 to 04.04	-07.33 to 0.00
7	Number of fruits per plant	00	24	00	24	00	24	-48.06 to -18.71	-49.81 to -22.05	-49.02 to -26.16
8	Fruit yield per plant (kg)	03	01	01	02	03	00	-38.69 to 50.84	-47.43 to 48.64	-18.91 to 80.81
9	Fruit diameter (cm)	02	04	00	06	01	03	-09.09 to 08.43	-12.27 to 04.90	-14.83 to 07.33
10	Average fruit weight (g)	01	00	00	05	09	00	-16.88 to 28.14	-27.03 to 26.88	02.28 to 81.76
11	Seed yield per fruit (g)	18	00	18	00	10	04	-05.49 to 42.85	-06.65 to 32.54	-11.15 to 25.48
12	Seed yield per plant (g)	11	00	03	01	10	00	-05.20 to 78.34	-19.87 to 74.19	-01.97 to 81.13
13	Test weight (g)	06	00	02	00	07	00	-02.15 to 19.50	-03.86 to 15.14	0.99 to 21.20
14	Cotyledon ratio (%)	00	08	00	12	00	19	-12.53 to 03.64	-12.88 to 02.13	-18.37 to -01.69
15	Oil content (%)	04	11	00	16	04	17	-09.29 to 07.47	-14.74 to 03.56	-14.86 to 05.54
16	Protein content	00	11	00	15	05	06	-09.50 to 01.42	-11.84 to 0.87	-08.06 to 08.12

Table 4: Best heterotic crosses and their performance for seed yield per plant and related parameters

Best crosses (P_1 x P_2)	Mean yield (g)	Heterosis (%) over			Significant standard heterosis in other traits in desired direction
		MP	BP	SC	
MGPK 11 × SKNK 1102	283.75	78.34**	74.19**	81.13**	Average fruit weight, test weight.
CAZJK 14-1 × MGPK 1	262.20	32.36**	11.15	67.38**	Days to maturity, fruit yield per plant, average fruit weight, seed yield per fruit.
SKNK 679 × SKNK 1102	242.99	27.03**	10.61	55.12**	Days to maturity, oil content, protein content.
CAZJK 14-1 × CAZJK 13-2	232.70	24.58**	-1.36	48.54**	Average fruit weight, seed yield per fruit, test weight, leaf area.
SKNK 679 × CAZJK 13-2	226.87	26.98**	3.28	44.83**	Days to fruit maturity, average fruit weight, seed yield per fruit, test weight, oil content, protein content.
*, ** Significant at 5 per cent and 1 per cent levels, respectively.					

Acknowledgement
Authors are thankful to the authorities of S. D. Agricultural University for providing materials and resources to conduct the research.

References

1. Aravindakumar JS, Prabhakar M, Pitchaimuthu M, Gowda NCN. Heterosis and combining ability studies in muskmelon (*Cucumis melo* L.) for earliness and growth parameters. Karnataka Journal of Horticulture. 2005; 1(4):12-19.
2. Brar JS, Sindhu AS. Heterosis and combining ability of earliness and quality characteristics in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. Journal of Research. 1977; 14:272-278.
3. Brar JS, Sukhija BS. Line × Tester analysis of combining ability in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. Indian Journal of Horticulture. 1977; 34:410-414.
4. Choudhary BR, Dhaka RS, Fageria MS. Heterosis for yield and yield related attributes in muskmelon (*Cucumis melo* L.). Indian Journal of Genetics and Plant Breeding. 2003; 63(1):91-92.
5. Crall JM, Brar YV. The potential for F_1 hybrid icebox watermelon cultivars. Proceeding of the Florida State Horticulture Society. 1987; 100:251-253.
6. Das M, Das SK, Suthar SH. Composition of seed and characteristics of oil from karingada [*Citrullus lanatus* (Thumb) Mansf.]. International Journal of Food Science and Technology. 2002; 37:893-896.
7. Fonseca S, Patterson FC. Hybrid vigour in a seven parent diallel cross in common winter wheat. Crop Science. 1968; 8:85-88.
8. Jarret RL, Levy IJ. Oil and fatty acid contents in seed of *Citrullus lanatus* Schrad. Journal of Agricultural and Food Chemistry. 2012; 60(20):5199-5204.
9. Makwana RR, Patel VP, Pandya MM, Chaudhary BA. Heterosis and inbreeding depression for morpho-physiological traits in rice [*Oryza sativa* L.]. International Journal of Pure and Applied Bioscience, 2018; 6(2):1477-1482.
10. Martin A, Troadec C, Boualem A, Rajab M, Fernandez R, Morin H *et al*. A transposon induced epigenetic change leads to sex determination in melon. Nature. 2009; 461:1135-1138.
11. Meredith WR, Bridge RR. Heterosis and gene action in cotton (*G. hirsutum* L.). Crop Science. 1972; 12:304-310.

12. Moon SS, Verma VK, Munshi AD. Heterosis for yield and its components in muskmelon (*Cucumis melo* L.). Annals of Agricultural Research. 2003; 24(4):750-754.
13. Nandpuri KS, Kumar JC, Dhillon GS. Heterosis in watermelon. Punjab Horticultural Journal. 1974; 14:75-83.
14. Nath P, Dutta OP. Heterosis in watermelon. Indian Journal Horticulture Science. 1970; 27(3, 4):176-177.
15. Pagi NK, Ravindrababu Y, Dharajiya DT, Patel JM, Patel MP. Heterosis for Seed Yield and Its Component Characters in Pigeonpea [*Cajanus cajan* L. Millsp.]. International Journal of Agriculture Sciences. 2016; 8(60):3392-3395.
16. Pichaimuthu M, Swamy KRM. Development of F_1 hybrids for high yield and good qualities in watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai]. In: Intl. Conf. on Hort. 'Horticulture for Livelihood Security and Economic Growth' held at Bangalore from, 2009, 56.
17. Prothro J, Sandlin K, Gill R, Bachlava E, White V, Knapp SJ *et al*. Mapping of the Egusi seed trait locus and quantitative trait Loci associated with seed oil percentage in watermelon. Journal of the American Society for Horticultural Science. 2012; 137(5):311-315.
18. Rajan B, Sooch BS, Dhall RK. Heterosis in watermelon [*Citrullus lanatus* (Thunb.) Mansf.]. Environment and Ecology. 2002; 20(4):976-979.
19. Sapovadiya MH, Dhaduk HL, Mehta DR, Patel NB. Heterosis in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. Progressive Research. 2013; 8(2):217-220.
20. Sharma RR, Choudhury B. Studies on some quantitative characters in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. II Inheritance of total soluble solids and rind thickness. Indian Journal of Horticulture. 1988; 45(3, 4): 283-287.
21. Sidhu AS, Brar JS. Heterosis and combining ability of yield and its components in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. Journal of Research Punjab Agricultural University. 1977; 14:52-58.
22. Singh S, Solanki SD, Prajapati NN, Chaudhary B. Combining ability and heterosis analysis for seed yield and it's contributing traits in karingada [*Citrullus lanatus* (Thumb) Mansf.]. The Bioscan. 2017; 12(2):1253-1256.
23. Singh SP, Dadwadia G, Annapurna. Analysis of heterosis and combining ability status among diallel set of hybrid for yield and quality traits in watermelon [*Citrullus lanatus* (Thumb) Mansf.]. Vegetable Science. 2009; 36(3):323-326.
24. Tak J, Jain S. Nutrient potential of watermelon (*Citrullus lanatus*) seeds and its incorporation in product preparation. Food Science Research Journal. 2016; 7(2):202-206.
25. Tarsem L, Reetinder K. Heterosis and combining ability analysis for important horticultural traits and reaction to downy mildew in muskmelon (*Cucumis melo* L.). Journal of Research Punjab Agricultural University. 2002; 39(4):482-490.
26. Tindal HD. "Vegetables in the tropics." McMillan press, London, 1983, 150-152.
27. Tomar RS, Bhalala MK. Heterosis studies in muskmelon (*Cucumis melo* L.). Journal of Horticultural Sciences. 2006; 1(2):144-147.
28. Turner JH. A study of heterosis in upland cotton, combining ability and inbreeding effects. Agronomy Journal. 1953; 45:487-490.