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Heterosis in watermelon for yield and quality traits [C*itrulus lanatus* (Thunb.) Matsum. & Nakai]

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Abstract

Ten lines and four testers were crossed in line x tester fashion during 2018 and evaluated in 2019 to assess the heterotic potential of 40 hybrids of watermelon hybrid for various morphological and quality traits. Significant mean squares due to lines, testers, hybrids, line x tester and parents x hybrids were observed for most of the traits. The results indicated that significant negative heterosis for earliness was shown by EC829875 x Sugar Baby. Similarly, heterosis for number of fruits, total yield, lycopene and TSS were seen in WM-53 x Sugar Baby, EC 829875 x Arka Manik, WM-14 x EC-829827 and EC 829823 x Sugar baby respectively. The present investigation revealed that hybrids WM-14 x EC-829852, EC829870 x EC829827, KFF-1-1-2 x Arka Manik, and WM-14 x Sugar Baby had good heterotic potential for TSS, less seed number and total yield which can be exploited for their commercial values.

Key words: Water melon, heterosis, combining ability, TSS and lycopene

Introduction

Watermelon [*Citrullus lanatus* var. *lanatus* (Thunb.) Matsum. & Nakai, 2X=22] has been allocated to the member of Cucurbitaceae family and is native to Kalahari Desert of West Africa (Jeffrey 1990; Maynard 2001). These plants are relatively drought tolerant under sandy soils in hot, sunny and dry environments (Robinson and Decker-Walters, 1997). The large edible watermelon fruits have contributed to the diets of con-sumers throughout the world. Although consisted mainly of water (often over 90%), also contains significant nutritional compounds, including sugars, lycopene and cardiovascular health–promoting amino acids, such as citrulline, arginine and glutathione (Perkins-Veazie et al 2006). It is a good source of dietary fibres, vitamins and minerals (Pitrat 2008).

In 2018, the growing area of watermelon is 35.08 lakh ha with a production of 117.2 million tones in world. In India, it is being cultivated on an area of 1.01 Lakh ha with a production of 25 lakh tones (http://faostat.fao.org/). India accounts 10-____th position among the Asian countries. Watermelon is widely cultivated in Karnataka, Tamil Nadu, Odisha, West Bengal, Uttar Pradesh and Punjab. In Punjab area under watermelon cultivation is 1.47 thousand ha with production 26.22 thousand MT and with an average productivity of 17.8 MT ha^{-1} during 2018-19 (Anonymous 2019). Watermelon is also cultivated on the river bed areas (diara) of Yamuna, Ganga, Satluj, Narmada, Kaveri, Krishna and Godavari. There is wide range of variability that exists in terms of fruit size, shape, flesh colour, and stripes etc. that has not been utilized efficiently for watermelon improvement. Since watermelon is still under exploited crop in comparisons to other major vegetables in our conditions, heterosis breeding is an efficient tool to utilize the genetic diversity (Dadwadiya et al. 2009). In watermelon, total yield is not only sole intention for heterosis breeding, but resistance to insect pests, diseases and fruit quality is too a dominating factor. Hence strategy for developing F_1 hybrids in watermelon depends primarily on obtaining early yielding sweet firm fruited and disease resistant genotypes.

Lot of hybrids had been developed by private sector. However, most of the varieties and hybrids lack resistance to different diseases. Presently hybrids have been preferred over varieties by watermelon growers due to the better quality, uniformity and stability of performance. They also have an added advantage of early maturity, high yield, uniform fruit shape, fruit size and excellent quality characteristics (Zalapa et al. 2006). In order to develop hybrids, information about combining ability, *per se* performance and inbred lines is pre-requisite. There are several techniques for the evaluation

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of varieties or strains in terms of their combining ability and line × tester analysis is one of them. This technique had been developed by Kempthorne in 1957. This method also suggests, whether breeder has to go in for the production of commercial F_1 hybrids or the selection in the advanced generations to realize promising improved genotypes in homozygous condition.

Genetic analysis provides a guide line for the assessment of relative breeding potential of the parents (Weerasingh et al. 2004) which could be utilized either to exploit heterosis in F_1 or the accumulation of fixable genes to evolve a variety.--- Heterosis has been found in characters related to yield and adaptation to adverse conditions like, characteristics such as plant height, earliness, total yield, resistance attributes, uniformity and resistance to extreme environmental conditions. Heterosis has been also found for characteristics related to fruit quality, for instance pericarp thickness, total soluble solids content and ascorbic acid content (Tiwari and Lal 2004). Keeping these facts in view, the new lines of watermelon diverse in fruit size, shape, flesh colour, stripes, TSS *etc* collected from China, Japan, India, America were assessed for heterotic potential for yield and quality traits in different hybrids of watermelon following line × tester mating design.

Materials and Methods

The present investigation was carried out at the Department of Vegetable Science, Punjab Agricultural University Ludhiana, India, during 2017-2018 and 2018-2019. The experimental field is situated at 30° 55' north latitude, 75° 54' east longitude and at an altitude of 247 m above sea level. The soil was of the sandy loam class. The material for the present study was obtained from crossing 10 lines *viz*. EC-829823, WM-53, EC-829870, EC-829826, EC-829872, EC-829858, KFF 1-1-2, EC-829852, WM-14, and IC-611625, with each 4 testers *viz*. EC-829827, EC-829852, Sugar Baby, and Arka Manik.

The forty F_1 crosses were developed in a line × tester fashion by using 10 lines and 4 testers during February-May of 2018. The experimental material comprising 40 F_1 hybrids, 14 parental lines was sown on 18nd February, 2019. The transplanting was done on 3.0 meter wide beds with plant to plant distance of 60 cm in the field on 20th March 2019. Ten plants of each i.e. F_1 hybrids, parents and checks were transplanted in a randomized block design with three replications. All the horticultural practices were followed as per recommendation in the Package of Practice for Vegetable Crops, Punjab Agricultural University, Ludhaina (Anonymous 2019). The observations were recorded on days to anthesis, number of fruits per plant, fruit weight (kg), fruit length (cm), fruit width (cm), total yield (q/ha), seed number per fruit, 100 seed weight, TSS (°Brix), total carotenoids (µg/g), lycopene (µg/g), vitamin C (mg/100ml), total dry matter (%). Data on yield related traits were collected from 5 plants tagged in each replication of the genotype while yield was calculated on per plot basis and converted into ha. Total carotenoids were estimated using Ranganna (2001) method. Lycopene was estimated as per method suggested by Davis *et al* (2003). The ascorbic acid content in the sample was determined using the method of Hienze *et al* (1994). 50gm flesh of five fruits per replication was taken in a pre-weighted petri dish and kept in oven at a temperature 65°C until weight not become constant. Then petri dish was taken out for reweight. Heterosis was expressed as per cent deviation of F_1 hybrid performance from the better parent and standard check hybrid (MHW-4 of Mahyco).

Results and Discussion

The results of the analysis of variance for the experimental design have been presented in Table 1. The mean squares due to replications were significant for seed number per fruit, vitamin C (mg/100ml) at 1% level of significance where as non-significant for other characters. The mean squares due to parent were significant for days to anthesis, fruit length (cm), fruit width (cm), flesh colour, average fruit weight (kg), seed number per fruit, 100 seed weight (g), TSS° (brix), total carotenoids (µg/g), lycopene (µg/g), vitamin C (mg/100ml), total dry matter (%) and non-significance for total yield (q/acre) at 1% level of significance indicates significant variation among parents for heterosis. The mean squares due to lines were significant for days to anthesis, fruit length (cm), fruit width (cm), flesh colour, average fruit weight (kg), 100 seed weight (g), TSS (°Brix), total carotenoids (µg/g), lycopene (µg/g), vitamin C (mg/100ml), total dry matter (%) at 1% level of significance and non-significant for number of fruits plant^{-} total yield (q/acre) and seed number per fruit^{1}. The mean squares due to hybrids were significant for all the characters except, total yield/ plant (kg), lycopene (µg/g) at 1% level of significance. This indicates that enough genetic variation exists in the lines, testers and hybrids for majority of the traits and can be exploited through heterosis breeding. These results are in accordance with El-shimi et al (2003) in melon.

Now-a-days, lot of emphasis is being laid on the commercial exploitation of hybrids in various cross-pollinated crops. But in watermelon hybrid vigour is reported for various characters. The exploitation of this phenomenon can prove to be a potential tool in the hands of plant breeders for the improvement of this crop. The data pertaining to mean performance and percent heterosis over the better parent and standard check have been given in Table 2, 3 and 4. Earliness is an important parameter in watermelon as farmers tends to catch the early premium of the market. In case of days to anthesis negative heterosis is desirable. The best cross combinations with significant negative heterosis over better parent were EC-829875 x Sugar Baby (-11.29), EC-829826 x Sugar Baby (-10.26), EC-829858 × EC829827 (-9.52), EC-829826 × Arka Manik (-9.23), EC-829826 × Arka Manik (-9.23) and over standard check were EC-829875 x Sugar Baby (-11.29), EC-829858 × EC-829827 (-8.06), EC-829872 × Arka Manik (-8.06), EC-829872 × EC-829852 (-8.06). Number of fruits per plant is directly related to total yield and when compared to the standard check, six hybrids showed significantly positive maximum and best heterosis percent were 46.67 (WM-53 × Sugar Baby), 46.67 (EC-829826 × Sugar Baby), 46.67 (WM-14 × Sugar Baby) and 46.67 (EC-829870 × Arka Manik) for the number of fruits plant per plant. Lal and Kaur (2002) assessed forty crosses for heterosis which showed positive and significant heterosis for number of fruits per vine. Fruit weight has assumed great significance in watermelon as 2-4 kg watermelon fruit is considered ideal in present day nuclear families. Out of forty hybrids, eight hybrids exhibited significantly positive heterosis over the respective better parent and twenty-six hybrids over the standard check. Among F_1 cross combinations EC-829826 x Arka Manik (51.7), EC-829826 x Sugar Baby (34.15) and EC-829823 x Arka Manik (31.19) showed positive, significant and best heterosis over better parent and maximum 146.3% (EC-829826 × Arka Manik) to minimum 4.28 (WM-53× Sugar Baby) check hybrid, respectively and the best F_1 hybrids were EC-829826 × Arka Manik (146.03), EC-829823 x Arka Manik (113.4), EC-829875 x Arka Manik (88.1) and EC-829826 × Sugar Baby (85.7) over the standard check for average fruit weight (kg). Lal and Kaur (2002) also reported positive and significant heterosis for the trait average fruit weight in muskmelon. For fruit length, out of forty hybrids, three crosses exhibited significant positive heterosis over better parent and 35 crosses exhibited significant positive heterosis over the check. The range of positive significant heterosis over better parent was 38.9% (EC-829872 × EC-829827) to 50.4 percent (KFF 1-1-2 × Sugar Baby) and for check was from 15.24% (WM-53 x EC-829852) to 58.67% (EC-829870 × EC-829827) respectively. The cross combinations namely, KFF 1-1-2 × Sugar Baby (50.4% and 42.1%), KFF 1-1-2 × EC-829827 (42.17 and 41.91%) and EC-829872 × EC-829827 (38.9 and 45.52%), showed positive and significant heterosis percentage and best over better parent and check, respectively. Hybrid EC-829870 × EC-829827 had the longest fruit length (27.77 cm) followed by EC-829870 × Arka Manik (27.47). It indicated that the high percentage of heterosis over the standard check was derived from the hybrids involving parents with high average fruit length. In case of fruit width, the cross combinations viz. EC-829826 × Sugar Baby (27.7 and 91.07%), EC-829870 × Arka Manik (31.26 and 83.76%) and EC-829870 × EC-829827 (23.87 and 85.23%) exhibited positive best heterosis

Table 1: Analysis of variance for experimental design for different characters

Source of variation	d.f.	Days to anthesis	Number of fruits plant^{-1}	Average fruit weight (kg)	Fruit length (cm)	Fruit width (cm)	Total yield (q/acre)
Replications	2	1.241	0.5	0.235	14.7	0.147	4,661.30
Parents	13	8.441**	0.705*	0.788**	35.87**	21.477**	654.652
Testers	3	2.222	1.194*	1.112**	8.439	6.028**	662.667
Lines	9	11.07**	0.296	0.634**	29.956**	28.934**	702.163
Lines vs Testers	1	3.438	2.917**	1.205**	171.391**	0.714*	203.01
Hybrids	39	43.928**	0.824**	1.355**	23.093**	9.581**	9,553.84
Parents vs Hybrids	1	5.34**	23.819**	1.251**	190.403**	204.493**	11,521.20
Error	106	1.499	0.324	0.114	6.977	0.168	6,249.31

Table 1 contd.

Source of variation	d.f	Seed number per fruit	100 seed weight (g)	TSS (ºBrix)	Total carotenoids (µg/g)	Lycopene (µg/g)	Vitamin C (mg/100ml)	Total dry matter (%)
Replications	2	35,881.72**	0.439	0.022	2.05	1.42	54.04**	0.064
Parents	13	164,974.63**	3.161**	1.205**	1285.31**	1075.49**	16.64**	1.695**
Testers	3	9,613.86**	2.592**	1.107**	416.09**	356.86**	4.83**	1.221**
Lines	9	234,148.06	3.185**	1.333**	1713.59**	1433.30**	21.80**	1.981**
Lines vs Testers	1	8,496.00	4.643**	0.35*	38.53**	11.09**	5.73**	0.549**
Hybrids	39	101,025.87**	2.191**	2.43**	783.56**	630.69**	8.31**	1.206**
Parents vs Hybrids	1	1,300,801.79**	26.163**	72.614**	4530.54**	6494.22**	4.70**	5.819**
Error	106	5,553.96	0.295	0.074	0.15	0.26	0.56	0.044

*, ** significant at 5 per cent and 1 per cent level, respectively

Table 2. Morphological traits and mean values of lines and testers in watermelon

S. No.	Lines	Total yield (q/ha)	Seed number per fruit	100 seed weight (g)	TSS° (Brix)	Total carotenoids (µg/g)	Lycopene (µg/g)	Vitamin C (mg/100ml)	Total dry matter (%)
1	EC-829823	116.00	449.67	3.63	9.50	79.47	99.66	16.59	3.86
2	EC-829858	156.00	200.67	4.10	9.47	93.21	154.81	14.433	4.97
3	WM-53	113.33	298.67	4.88	9.60	48.03	103.25	13.433	3.79
4	EC-829826	116.00	216.33	4.35	9.47	58.42	40.79	8.733	4.46
5	WM-14	120.00	365.00	3.22	8.61	59.68	99.85	9.433	4.85
6	KFF 1-1-2	106.67	256.33	4.17	9.40	83.86	120.98	9.9	3.03
7	EC-829875	130.67	835.67	3.19	9.80	85.87	132.30	9.5	4.23
8	IC-611625	145.33	1,005.67	5.18	7.57	42.69	220.85	9.267	2.25
9	EC-829872	130.67	387.67	3.50	8.70	38.89	44.87	9.4	4.12
10	EC-829870	130.67	195.00	6.52	9.20	28.14	135.59	11.567	4.06
	Testers								
1	EC-829827	124.00	461.00	6.07	9.30	77.67	77.76	10.46	2.84
2	EC-829852	130.67	356.67	5.47	8.50	78.48	129.54	9.7	3.64
3	Sugar Baby	100.00	333.67	4.50	9.90	78.85	129.09	9.3	4.01
4	Arka Manik	132.00	407.00	4.07	9.63	72.89	81.40	12.16	4.32

Table 2 contd….

S.No	Lines	Fruit shape	Flesh colour	Days to anthesis	Number of fruits plant^{-1}	Average fruit weight (kg)	Fruit length (cm)	Fruit width (cm)	Average fruit weight (kg)
1	EC-829823	Broad, Elliptic	Red	63.00	1.67	2.97	20.37	17.07	2.97
2	EC-829858	Broad, Elliptic	Red	60.67	1.67	2.77	21.17	17.27	2.77
3	WM-53	----	Red	62.00	2.00	3.23	19.5	16.33	3.23
4	EC-829826	Elliptic	Red	65.00	1.33	3.23	17.83	17.20	3.23
5	WM-14	Broad, Elliptic	Red	58.33	1.33	3.00	25.03	17.23	3.00
6	KFF 1-1-2	Broad, Elliptic	Dark red	59.00	1.33	3.03	16.53	15.77	3.033
7	EC-829875	-----	Red	62.00	2.00	3.13	26.5	18.20	3.133
8	IC-611625	Broad, Elliptic	Pinkish red	61.67	2.00	3.50	21.83	7.60	3.5
9	EC-829872	Broad, Elliptic	Red	61.67	1.33	3.20	18.33	18.20	3.2
10	EC-829870	Narrow, Elliptic	Orange	60.33	2.00	4.43	22.7	15.17	4.433
	Testers								
1	EC-829827	Elliptic	Pinkish Red	63.00	1.33	4.13	17.47	17.20	4.133
2	EC-829852	Elliptic	Red	62.33	2.33	3.97	17.17	17.50	3.967
3	Sugar Baby	Broad, Elliptic	Dark red	61.00	2.67	2.77	14.00	14.37	2.767
4	Arka Manik	Broad, Elliptic	Red	61.67	2.67	3.63	17.40	16.10	3.633

percentage both over the better parent and check, respectively.

Gvozdanoviæ et al. (2011) reported negative heterosis in relation to the parental average for the fruit size in most of the hybrids. These lines can be used for development of hybrids with small fruits. In case of total yield, sixteen hybrids exhibited non-significant and negative heterosis over the respective better parent and that of thirty-one hybrids recorded significant positive heterosis over standard check. Maximum heterosis for total yield recorded was 63.32% (EC-829875 × Arka Manik) to minimum 13.69% (IC-611625× Sugar Baby). The hybrids that showed significant heterosis over standard check were EC-829875 × Arka Manik (63.32), EC-829826 × Sugar Baby (62.76), EC-829826 × Arka Manik (48.17), EC-829875 × EC-829827 (40.51) and EC-829872 × Arka Manik (45.83). Eight hybrids exhibited non-significant and negative heterosis over the respective better parent. All the hybrids showed significantly and positive heterosis over the standard check for 100 seed weight. The negative heterosis was ranged from -29.39 percent (EC-829823 × EC-829852) to -6.8 (EC-829826 × EC-829827) over better parents and followed by KFF 1-1-2 × EC-829827 (-27.5), KFF 1-1-2 × EC-829852 (-20.52) hybrids showed best significant negative heterosis to reduce in seed weight. Total soluble solids are one of the most important traits, which deserve highest consideration in any breeding programme for water melon. With relevance to TSS, the crosses revealed a significant and positive heterosis over better parent with a range from 1.01 percent (EC-829823 × Sugar Baby) to 28.53 percent (WM-14 × EC-829852) and heterosis over standard check was from 5.4 (WM-53 × Arka Manik) to 13.3 per cent (WM-14× Sugar Baby). The cross combinations, namely WM-14 × EC-829852 (28.53 and 5.4%), WM-14 × Sugar Baby (20.20 and 13.3%), KFF1-1-2 × Sugar Baby (20.20 and 13.3%), EC- 829875 × Arka Manik (21.08 and 13.10%), EC 829870 × EC 829827 (27.95 and 13.3%),

Table 2 Heterosis (%) over better parent and commercial check for days to anthesis, number of fruits plant^{-1}, average fruit weight, fruit length and fruit width in watermelon

S. No	Hybrids	Characters														
		Days to anthesis			Number of fruits plant^{-1}			Average fruit weight (kg)			Fruit length (cm)			Fruit width (cm)		
		Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check
1	EC-829823 ×EC-829827	68	7.97**	9.67**	1.67	0	-33.3	2.97	-8.06**	65.22*	22.33	9.66	27.62**	16.33	-5.03**	42.01**
2	EC-829823 ×EC-829852	67.7	7.41**	9.14**	2.33	0	-6.67	2.77	-24.37**	34.33	16.2	-20.48	-7.43	15.53	-11.24**	35.1**
3	EC-829823 ×Sugar Baby	66.7	5.82**	7.52**	2.67	0	6.67	3.23	3.26**	31.43**	20.167	-0.92	15.24*	16.43	-3.7**	42.9**
4	EC-829823 ×Arka Manik	64	1.59*	3.22*	2.67	0	6.67	3.23	31.19	113.4**	25.5	25.25	45.71**	16.1	-5.67**	40.0**
5	EC-829858 ×EC-829827	57	-9.52**	-8.06**	2.33	40**	-6.67	3	-11.29**	59.42*	25.6	20.95	46.28**	16.43	-4.82**	42.9**
6	EC-829858 ×EC-829852	62	-0.54	0.00	2.33	0	-6.67	3.03	-29.42**	25.4**	18.3	-13.53	4.57	17.23	-1.5**	49.9**
7	EC-829858 ×Sugar Baby	64	4.92*	3.22*	2.67	0	6.67	3.13	-12.05	4.3**	22	3.97	25.71**	18.15	5.11**	57.9**
8	EC-829858 ×Arka Manik	57	-7.56**	-8.06**	2.67	0	6.67	3.5	-3.67*	56.75**	21.	2.32	23.81**	19.4	12.35**	68.7**
9	WM-53×EC-829827	59.33	-5.82**	-4.30**	2.33	16.67*	-6.67	3.2	-33.07**	20.3**	23.83	22.22	36.19**	17.9	4.07	55.62**
10	WM-53 ×EC-829852	60	-3.74**	-3.22*	2.33	0	-6.67	4.43	-4.2	70.2**	19.73	1.17	12.76*	18	2.86**	56.52**
11	WM-53 ×Sugar Baby	61	-1.62	-1.61	3.67	37.5**	46.67*	4.13	-24.7	4.28**	22.97	17.78	31.24**	18.7	14.49**	62.69**
12	WM-53 ×Arka Manik	61.67	-0.54	-0.53	2.67	0	6.67	3.97	-27.5	17.9**	21.03	7.86	20.19**	19.1	16.94**	66.07**
13	EC-829826 × EC-829827	61.33	-5.64**	-1.07	2.33	75**	-6.67	2.77	-36.29**	14.49	20.67	15.88	18.1**	20.93	21.71**	82.09**
14	EC-829826 × EC-829852	60	-7.69**	-3.22*	2.67	14.28*	6.67	3.63	-13.45**	53.7**	19.5	9.34	11.43	18	2.85**	56.52**
15	EC-829826 × Sugar Baby	58.33	-10.26**	-5.91**	3.67	37.5**	46.67*	3.8	34.15**	85.7**	24.03	34.76	37.3**	21.97	27.7**	91.05**
16	EC-829826 ×Arka Manik	59	-9.23**	-4.83**	2.67	0	6.67	3	51.38	146.3*	23.37	31.03	33.53**	20.53	19.38**	78.51**
17	WM-14 × EC-829827	58.33	-7.40**	-5.91**	3.33	150**	33.3	3.07	-27.49**	30.44*	24.2	-3.33	38.29**	17.43	1.16*	51.54**
18	WM-14 × EC-829852	58.66	-5.88**	-5.37**	2.67	14.28*	6.67	4.77	-27.73	28.36**	22.47	-10.26	28.38**	17.4	-0.57	51.34**
19	WM-14 × Sugar Baby	58	-4.92**	-6.45**	3.67	37.5**	46.67*	3.67	-7.78	18.57**	20.9	-16.51	19.42**	17.87	3.67**	55.32**
20	WM-14 × Arka Manik	59	-4.32**	-4.83**	2.67	0	6.67	2.8	-7.39**	50.75	22.05	-11.91	26.0**	18.37	6.57**	59.7**
21	KFF1-1-2× EC-829827	59	-6.35**	-4.83**	2.67	100**	6.67	2.43	-27.4**	30.44	24.83	42.17*	41.91**	19.33	12.40**	68.12**
22	KFF1-1-2× EC-829852	68	9.09**	9.67**	2.67	14.28*	6.67	3.5	-29.4**	25.37**	22	28.16	25.7**	18.23	4.19**	58.55**
23	KFF1-1-2× Sugar Baby	69	13.12**	11.29**	3.67	37.5**	46.67*	2.77	-21.98**	1.43	24.87	50.4*	42.1**	20.4	29.38**	77.39**
24	KFF1-1-2× Arka Manik	59	-4.32**	-4.83**	3.67	37.5**	46.67*	3.8	-23.85	23.88	16.3	-6.3	-6.86	14.07	-12.69**	22.32**
25	EC-829875 × EC-829827	59	-6.35**	-4.83**	1.67	-16.67*	-33.33	2.43	-23.4**	37.68	25.03	-5.54	43.05**	20.57	13.0**	78.84**
26	EC-829875 × EC-829852	58	-6.95**	-6.45**	2.67	14.28*	6.67	2.63	-40.34**	5.97	18.9	-28.68*	8.0	18.27	0.36	58.84**
27	EC-829875 × Sugar Baby	55	-11.29**	-11.29**	3.7	37.5**	46.67	2.63	2.13	37.14	22.17	-16.35	26.66**	20.4	12.1**	77.39**
28	EC-829875 ×Arka Manik	67.33	8.6**	8.60**	2.67	0	6.67	3.43	15.6	88.1**	21.17	-20.12	20.95**	19.77	8.6**	71.88**
29	IC-611625 × EC-829827	67	6.35**	8.06**	2.33	16.66*	-6.67	4.33	-39.5	8.69**	22.67	3.82	29.52**	18.47	7.36**	60.6**
30	IC-611625 × EC-829852	65	4.28**	4.83**	2.33	0	-6.67	5.5	-36.1	13.43**	21.5	-1.52	22.86**	20.23	15.62**	75.94**
31	IC-611625 × Sugar Baby	66.67	8.11**	7.52**	2.67	0	6.67	3	-18.1**	22.85*	17.7	-18.93	1.14	17.33	20.65	50.73**
32	IC-611625 ×Arka Manik	58	-5.95**	-6.45**	2.67	0	6.67	2.87	-31.19**	11.94*	24.4	11.75	39.43**	20.47	27.12**	77.97**
33	EC-829872 × EC-829827	61	-3.18**	-1.61	2.33	75**	-6.67	2.77	-21.74**	40.58	25.47	38.9*	45.52**	17.93	-1.47**	55.94**
34	EC-829872 × EC-829852	57	-8.56**	-8.06**	2.33	0	-6.67	3.37	-24.37**	34.32**	20.47	11.64	16.95**	17.37	-4.58**	51.0**
35	EC-829872 × Sugar Baby	57.33	-7.03**	-7.52**	2.67	0	6.67	3	-11.46**	21.42*	18.93	3.27	8.19	19.97	9.7**	73.62**
36	EC-829872 ×Arka Manik	58.33	-5.40**	-5.91**	2.67	0	6.67	2.8	2.75	67.16	20.2	10.18	15.43**	21.27	16.85**	84.93**
37	EC-829870 × EC-829827	59	-6.35**	-4.83**	2.33	16.67*	-6.67	2.37	-24.82**	44.92	27.77	22.3	58.67**	21.3	23.87**	85.23**
38	EC-829870 × EC-829852	58	-6.95**	-6.45**	2.33	0	-6.67	2.77	-29.33**	40.29	24	22.32	37.14**	18.2	4**	58.26**
39	EC-829870 × Sugar Baby	61	0	-1.61	2.67	0	6.67	3.17	-36.84**	20**	24.7	5.73	41.14**	19.47	28.35**	69.27**
40	EC-829870 ×Arka Manik	61.67	0	-0.53	3.67	37.5**	46.67*	2.37	-24.06**	50.74	27.47	8.81	56.95**	21.13	31.26**	83.76**
	SE±		0.70	1.01		0.05	0.47		0.05	0.29		3.28	1.04		.08	0.34
	CD at 1%		1.80	2.60		.012	1.21		.012	0.71		8.44	2.67		0.20	0.87
	CD at 5%		1.37	1.97		0.09	0.92		0.09	0.54		6.42	2.03		0.15	0.66
	Range for Mean		57 to 67.66			1.66 to 3.66			2.36 to 5.5			16.2 to 27.76			14.06 to 21.96	

Table 3. Heterosis (%) over better parent and commercial check for total yield, seed number per fruit, 100 seed weight and TSS (º Brix) in watermelon

S. No	Hybrids	Characters											
		Total yield (q/arce)			Seed number per fruit			100 seed weight (g)			TSS (º Brix)		
		Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check
1	EC-829823 ×EC-829827	110.67	-10.75	9.570	401.68	12	60.67*	5.44	-10.33**	117.6**	10.63	11.93**	1.27
2	EC-829823 ×EC-829852	456	248.9	19.00**	599.3	-2.43	139.73**	3.86	-29.39**	54.4**	11.2	18.59**	7.30**
3	EC-829823 ×Sugar Baby	80	-31.03	-18.75*	335	4.16	34.0	4.84	7.70*	93.86**	10	1.01**	-4.76*
4	EC-829823 ×Arka Manik	122.67	-7.071	36.11**	454.67	21.73	81.87**	5.09	27.20**	103.8**	11.233	16.6**	6.98**
5	EC-829858 ×EC-829827	90.67	-41.88	-8.91	544.67	-8	117.87**	4.94	-18.46**	97.86**	10.033	5.98**	-4.44*
6	EC-829858 ×EC-829852	120	-23.07	19.00*	813.33	1.62	225.3**	5.44	-0.48	117.6**	10.3	8.80**	-1.91
7	EC-829858 ×Sugar Baby	129.33	-17.09	23.61**	742	16.6	196.8**	4.67	3.92	87.06**	11.4	15.15**	8.57**
8	EC-829858 ×Arka Manik	156	0	42.97**	419	16.6	67.6*	5.44	32.69**	117.6**	11.4	18.33**	8.57**
9	WM-53×EC-829827	162.67	31.18	38.54**	514	-4	105.6**	5.1	-15.93**	104.0**	9.86	2.77**	-6.03**
10	WM-53 ×EC-829852	141.33	8.16	25.85**	690.67	20	176.27**	5.55	1.58	122.1**	9.9	3.12**	-5.7**
11	WM-53 ×Sugar Baby	152	34.11	32.69**	346.67	8	38.67	6.58	34.88**	163.4**	10.2	3.03**	-2.86
12	WM-53 ×Arka Manik	152	15.15	31.88**	310.6	0	24.27	4.74	-2.86	89.73**	11.07	14.89**	5.4**
13	EC-829826 × EC-829827	130.67	5.37	18.54**	353.6	12	41.47	5.65	-6.8**	126.1**	10.3	8.80**	-1.9
14	EC-829826 × EC-829852	133.33	2.04	26.94**	740	3.25	196.00**	5.48	0.3	119.3**	10.5	10.91**	0
15	EC-829826 × Sugar Baby	181.33	56.32	62.76**	839.3	0	235.73**	5.47	21.4**	118.6**	10.767	8.75**	2.54
16	EC-829826 ×Arka Manik	180	36.3	48.17**	763	27.5	205.20**	4.38	0.53	75.07**	11.433	18.68**	8.89**
17	WM-14 × EC-829827	110.67	-10.75	5.75	663	20	165.20**	5.1	-15.8**	104.1**	11.03	18.6**	5.1
18	WM-14 × EC-829852	114.67	-12.24	13.67	493.3	0	97.33**	5.31	-2.8	112.4**	11.067	28.53**	5.4**
19	WM-14 × Sugar Baby	134.67	12.22	28.06**	533	24.16	113.20**	4.31	-4.3	72.4**	11.9	20.20**	13.3**
20	WM-14 × Arka Manik	136	3.03	25.00**	524.3	-4.34	109.73**	4.77	19.2**	90.9**	11.8	22.49**	12.38**
21	KFF1-1-2× EC-829827	90.67	-26.88	-8.61	544.3	-1.48	117.73**	4.39	-27.5**	75.7**	10.9	15.95**	3.8
22	KFF1-1-2× EC-829852	101.47	-22.34	0.53	633	0	153.20**	4.35	-20.4**	74.0**	10.633	13.12**	1.2
23	KFF1-1-2× Sugar Baby	98.67	-7.5	-2.01	520.3	-2.22	108.13**	5.25	16.7**	110.1**	11.9	20.20**	13.3**
24	KFF1-1-2× Arka Manik	120	-9.09	19.00*	537.7	6.66	115.06**	5.85	40.32**	133.8**	11.833	22.83**	12.7**
25	EC-829875 × EC-829827	158.67	21.42	46.51**	690	14.4	176.0**	5.17	-14.72**	106.9**	10.867	10.88**	3.49
26	EC-829875 × EC-829852	140	7.143	24.38**	867.7	15.2	247.07**	4.3	-21.34**	72.0**	10.767	9.86**	2.54
27	EC-829875 × Sugar Baby	114.66	-12.2	10.68	645	10.4	158.0**	4.66	3.7	86.6**	11.8	19.19**	12.38**
28	EC-829875 ×Arka Manik	169.33	28.28	63.27**	668	17.6	167.20**	6.81	70.05**	172.5**	11.867	21.08**	13.1**
29	IC-611625 × EC-829827	165.33	13.76	35.74**	624.7	3.2	149.8**	5.13	-15.33**	105.4**	8.9	-4.30**	-15.3**
30	IC-611625 × EC-829852	162.66	11.92	39.53**	888.3	7.31	255.3**	5.03	-7.9**	101.3**	8.6	1.1	-18.1**
31	IC-611625 × Sugar Baby	124	-14.6	13.69**	530	20	112.0**	6.3	21.7**	152.0**	9.24	-6.66**	-12**
32	IC-611625 ×Arka Manik	136	-6.42	27.34**	543.3	19.16	117.3**	5.86	13.2**	134.5**	11.2	16.26**	6.67**
33	EC-829872 × EC-829827	145.33	11.22	31.67**	852.7	10.76	241.0**	5.63	-7.14**	125.3**	9.7	1.79**	-9.8**
34	EC-829872 × EC-829852	146	11.73	31.25**	952	6.15	280.8**	6.04	10.54**	141.7**	9.433	8.42**	-10.19**
35	EC-829872 × Sugar Baby	120	-8.16	13.57*	481.7	13.07	92.6**	6.60	46.81**	164.3**	9.6	-3.03**	-8.57**
36	EC-829872 ×Arka Manik	156	18.18	45.83**	297	-0.76	18.8	5.54	38.43**	121.8**	11.03	14.53**	5.08
37	EC-829870 × EC-829827	160	22.44	37.82**	642.3	1.5	156.93**	7.07	8.59**	183.1**	11.9	27.95**	13.3**
38	EC-829870 × EC-829852	157.33	20.40	36.11**	859.7	10.76	243.86**	6.35	-2.5	154.0**	9.767	6.15**	-6.98**
39	EC-829870 × Sugar Baby	153.33	17.34	31.91**	872.7	10	249.06**	5.37	-17.5	115.1**	11.03	11.44**	5.08
40	EC-829870 ×Arka Manik	161.33	22.22	41.90**	930.3	10.76	272.1**	8.09	24.04**	223.3**	11.833	22.83**	12.7**
	SE±		2945.94	7.37		2618.16	68.57		0.13	0.45		0.03	0.21
	CD at 1%		7585.79	21.55		6741.76	176.56		0.35	1.15		0.09	0.54
	CD at 5%		5774.05	16.40		5131.59	134.39		0.27	0.88		0.07	0.41
	Range for mean		80 to 181.33			297 to 952			3.86 to 8.08			8.6 to11.86	

Table 4. Heterosis (%) over better parent and commercial check for total carotenoids, lycopene, vitamin C and total dry matter in watermelon

S. No	Hybrids	Characters											
		Total carotenoids (µg/g)			Lycopene (µg/g)			Vitamin C (mg/100ml)			Total dry matter (%)		
		Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check	Mean	Over Better Par	Over check
1	EC-829823 ×EC-829827	83.22	-4.27**	-12.40**	71.40	-2.10**	-10.75**	8.28	-50.07**	-19.74**	3.26	-15.61**	27.62
2	EC-829823 ×EC-829852	110.04	26.58**	15.83**	89.15	22.24**	11.44**	10.49	-36.74**	1.68	3.11	-19.41**	-7.43
3	EC-829823 ×Sugar Baby	90.05	3.59**	-5.21**	80.38	10.22**	0.48	8.37	-49.56**	-18.98**	3.28	-18.2**	15.24
4	EC-829823 ×Arka Manik	101.07	16.27**	6.39**	91.07	24.87**	13.84**	4.87	-70.66**	-52.82	2.68	-38.01**	45.71
5	EC-829858 ×EC-829827	99.91	-7.53**	5.17**	89.16	-3.92**	11.45**	11.25	-22.05**	9.02	2.51	-49.15**	46.29
6	EC-829858 ×EC-829852	99.04	-8.34**	4.26**	86.08	-7.24**	7.60**	9.16	-36.51**	-11.28	3.44	-30.38**	4.57
7	EC-829858 ×Sugar Baby	98.15	-9.16**	3.32**	90.46	-2.51**	13.08**	10.67	-26.09**	3.36	4.28	-13.3**	25.71
8	EC-829858 ×Arka Manik	95.33	-11.77**	0.35	85.62	-7.73**	7.02**	10.53	-27.02**	2.07	3.27	-33.8**	23.81
9	WM-53×EC-829827	90.14	-9.89**	-5.11**	81.22	-7.56**	1.53**	9.17	-31.76**	-11.17	2.69	-29.03**	36.19
10	WM-53 ×EC-829852	79.00	-21.02**	-16.84**	66.15	-24.71**	-17.31**	10.53	-21.58**	2.07	3.39	-10.37**	12.76
11	WM-53 ×Sugar Baby	82.33	-17.69**	-13.33**	71.40	-18.74**	-10.75**	10.64	-20.79**	3.1	3.14	-21.69**	31.24
12	WM-53 ×Arka Manik	95.06	-4.97**	0.07	84.01	-4.39**	5.01**	10.17	-24.61**	-1.87	3.09	-28.52**	20.19
13	EC-829826 × EC-829827	87.15	22.68**	-8.26**	78.11	32.72**	-2.36	9.37	-10.7**	-9.43	3.28	-26.38**	18.1
14	EC-829826 × EC-829852	83.22	-2.59**	-12.40**	70.07	-3.04**	-12.42**	8.85	-8.76**	-14.24*	4.35	-2.39**	11.43
15	EC-829826 × Sugar Baby	98.69	23.30**	3.89**	88.46	33.47**	10.57**	10.24	10.14	-0.74	2.24	-49.70**	37.33
16	EC-829826 ×Arka Manik	98.81	25.00**	4.01**	87.20	30.13**	9.00**	9.25	-24**	-10.4	2.95	-33.85**	33.52
17	WM-14 × EC-829827	108.3	77.52**	14.05**	98.05	91.00**	22.55**	12.47	19.14**	20.83**	4.04	-16.70**	38.29
18	WM-14 × EC-829852	100.2	17.37**	5.55**	95.05	31.53**	18.82**	9.49	-2.13	-8.01	2.31	-52.37**	28.38
19	WM-14 × Sugar Baby	104.6	30.70**	10.12**	89.13	34.49**	11.41**	8.48	-10.14	-17.86**	2.21	-54.5**	19.43
20	WM-14 × Arka Manik	100.6	27.34**	5.97**	90.57	35.15**	13.21**	11.70	-3.80	13.4*	4.02	-17.2**	26.0
21	KFF1-1-2× EC-829827	100.5	52.24**	5.84**	98.11	87.32**	22.63**	11.47	9.5**	11.1	3.03	0	41.91
22	KFF1-1-2× EC-829852	90.85	6.34**	-4.37**	81.17	12.33**	1.47	11.14	12.5**	7.98	3	-17.7**	25.71
23	KFF1-1-2× Sugar Baby	100.7	25.87**	6.05**	91.26	37.70**	14.07**	10.56	6.65*	2.31	2.98	-25.6**	42.1
24	KFF1-1-2× Arka Manik	87.80	11.06**	-7.58**	78.31	16.86**	-2.11	12.12	-0.38	17.44**	3.04	-29.7**	-6.86
25	EC-829875 × EC-829827	98.79	2.61**	3.99**	89.02	7.82**	11.28**	11.69	11.65**	13.24*	3.64	-13.8**	43.05
26	EC-829875 × EC-829852	95.97	-0.32	1.02	85.20	3.19**	6.50**	11.06	14.05**	7.2	3.66	-13.4**	8.0
27	EC-829875 × Sugar Baby	93.44	-2.95**	-1.64	82.29	-0.34	2.86**	10.47	10.17**	1.42	3.73	-11.6*	26.67
28	EC-829875 ×Arka Manik	89.40	-7.15**	-5.89**	86.23	4.44**	7.79**	9.62	-20.93**	-6.78	4.59	6.2**	20.95**
29	IC-611625 × EC-829827	70.29	19.89**	-26.01**	59.13	24.84**	-26.09**	11.6	10.86**	12.44*	4.02	41.2**	29.52
30	IC-611625 × EC-829852	71.62	-16.17**	-24.61**	60.26	-16.61**	-24.67**	8.76	-9.72	-15.15*	4.25	16.54**	22.86
31	IC-611625 × Sugar Baby	76.48	-4.45**	-19.49**	67.13	1.30**	-16.08**	11.22	20.64**	8.7	3.0	-25.1**	1.14
32	IC-611625 ×Arka Manik	79.55	0.62	-16.27**	67.13	0.18	-16.08**	11.59	-4.76	12.27*	3.51	-18.7**	39.43
33	EC-829872 × EC-829827	73.23	9.05**	-22.91**	63.20	6.51**	-21.00**	13.99	33.63	35.53	4.37	5.98**	45.52
34	EC-829872 × EC-829852	74.19	-13.16**	-21.91**	62.30	-13.79**	-22.13**	11.57	19.24	12.08*	3.57	-13.42**	16.95
35	EC-829872 × Sugar Baby	74.25	-7.24**	-21.84**	61.10	-7.81**	-23.63**	10.88	15.78	5.45	4.27	3.47**	8.19
36	EC-829872 ×Arka Manik	56.25	-28.85**	-40.79**	49.14	-26.67**	-38.58**	12.99	6.79	25.9**	4.1	-4.62**	15.43
37	EC-829870 × EC-829827	52.97	-9.66**	-44.24**	60.95	28.67**	-23.82**	12.56	8.61	21.7**	4.02	-1.14	58.67
38	EC-829870 × EC-829852	44.32	-48.13**	-53.35**	54.11	-25.13**	-32.36**	11.67	0.89	13.08*	3.9	-3.93	37.14
39	EC-829870 × Sugar Baby	56.50	-29.41**	-40.52**	44.16	-33.37**	-44.80**	12.81	10.77	24.16**	3.99	-1.88	41.14
40	EC-829870 ×Arka Manik	61.37	-22.37**	-35.40**	51.67	-22.90**	-35.42**	12.43	2.219	20.51**	3.92	-9.406	56.95
	SE±		0.31	0.86		0.42	0.81		0.263	0.61		0.02	1.17
	CD at 1%		0.82	2.28		1.09	2.13		0.67	1.57		0.05	1.45
	CD at 5%		0.62	1.72		0.83	1.60		0.51	1.20		0.04	1.34
	Range		44.56 To 108.30			44.16 To 98.05			8.73 to 16.59			2.25 to 4.94	

showed positive and significant heterosis which were best cross combinations over both better parent and check hybrid. Kumar and Prabhakar (2005) and Moon *et al* (2006) in muskmelon reported significant and positive heterosis for TSS.

The range of significant positive heterosis for total carotenoids over the better parent was from 2.61 (EC-829875 × EC-829827) to 77.52 (WM-14 × EC-829827) highest percent heterosis and followed by KFF1-1-2 × EC-829827 (52.24), WM-14 × Sugar Baby (30.70), WM-14 × Arka Manik (27.34) and EC-829823 × EC-829852 (26.58) cross combinations have best heterosis percentage and 3.32 (EC-829858 × Sugar Baby) to 15.83 (EC-829823× EC-829852) had highest heterosis percentage and followed by WM-14 × EC-829827 (14.05), WM-14 × Sugar Baby (10.12), KFF1-1-2 × Sugar Baby (6.05) and WM-14 × Arka Manik (5.97) over better parent and hybrid check, respectively. In case of lycopene, the maximum heterosis percentage exhibited in 91.00 (WM-14 × EC-829827) and followed by KFF1-1-2 × EC-829827 (87.32), KFF1-1-2× Sugar Baby (37.70), WM-14 × Arka Manik (35.15) and WM-14 × Sugar Baby (34.49) which showed the best hybrids over the better parent. However, the hybrids KFF1-1-2 × EC-829827 (22.63) followed by WM-14 × EC-829827 (22.55), WM-14 × EC-829852 (18.82), KFF1-1-2 × Sugar Baby (14.07) and EC-829823 × Arka Manik (13.84) were better over the standard check. The range of positive heterosis for vitamin C was 9.5 (KFF1-1-2 ×EC 829827) to 33.63% (EC-829872 x EC-829827) In case of dry matter only five hybrids exhibited significantly positive heterosis over the respective better parents and only one hybrid shows significantly positive heterosis over the standard check. The hybrids IC-611625 × EC-829827 and IC 611625 x EC-829852 were better over better parent and EC-829858 × EC-829827 (46.29), EC-829823 × Arka Manik (45.71), KFF 1-1-2 × Sugar Baby (42.09) and KFF 1-1-2 × EC-829827 (41.90) hybrids were best in per cent heterosis over check for dry matter. From the above discussion it may be concluded that cross combination WM-14 x EC-829852, EC829870 x EC829827, KFF-1-1-2 x Arka Manik, WM-14 x Sugar Baby had good heterotic potential for TSS, less seed number and total yield which can be tested for their commercial values.

सारांश

तरबूज में 10 लाइनों व 4 टेस्टर का प्रयोग कर लाइन × टेस्टर प्रजनन विधि से वर्ष 2018 में प्राप्त 40 संकरों के विविध कार्यकीय गुणों व गुणवत्ता घटकों के लिये मूल्यांकन किया गया। सार्थक माध्य वर्ग लाइनों, टेस्टरों, संकरों, लाइन × टेस्टर प्रजनन तथा पित्रषें × संकरों में अधिकतम गुणों के लिए विविधता पाया गया। परिणामों से स्पष्ट हुआ कि सार्थक नकारात्मक ओज अगेतीपन ईसी 829875 × सुगर बेबी में रहा। इसी प्रकार फल संख्या, कुल उपज, लाइकोपीन व कुल विलेय ठोस हेतु डब्ल्यू एम–53 × सुगर बेबी, ईसी 829875 × अर्का मानिक, डब्ल्यू एम–14 × ईसी 829827 तथा ईसी 829823 × सुगर बेबी में क्रमशः पाया गया। वर्तमान परीक्षण से स्पष्ट हुआ कि संकर डब्ल्यू एम–14 × ईसी 829852, ईसी 829870 × ईसी 829829 के एम.एफ.–1–1.2 × अर्का मानिक तथा डब्ल्यू एम–14 × सुगर बेबी में अच्छा ओज क्षमता कुल विलेय ठोस बीज की कम मात्रा तथा कुल उपज के लिए पाया गया जिन्हें व्यवसायिक स्तर पर उपयोग में लाया जा सकता है।

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