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COMBINING ABILITY AND HETEROSIS ANALYSIS FOR SEED YIELD AND IT'S CONTRIBUTING TRAITS IN KARINGADA [*Citrulus lanatus* (Thumb) Mansf.]

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ABSTRACT
A research was carried out using half diallel analysis of eight parents to identify the high heterotic crosses and their relationship in terms of general combining ability (GCA) and specific combining ability (SCA) in Karingada [*Citrulus lanatus* (Thumb) Mansf.] for seed yield . The analysis for combining ability revealed significant GCA and SCA mean sum of squares for all the characters which indicated the presence of both additive and non-additive gene actions.The GCA and SCA variance ratio revealed the preponderance of non-additive gene action for all the traits except for days to flowering and days to maturity. SKNK 903 was good general combiner for most of the characters including seed yield. The line MGPK-1 was also a good general combiner for cotyledon ratio and oil content. As per SCA effects, the crosses viz., SKNK 806 X SKNK 903 for seed yield per plant and SKNK 1004 X MGPK-1 for oil content were most promising. While among crosses, cross SKNK 806 X SKNK 903 was recorded highest magnitude of economic heterosis over the standard check GK 1 for seed yield and most of contributing traits.

INTRODUCTION

Watermelon (*Citrullus lanatus* (Thunb.) Mansf.) belongs to family Cucurbitaceae. Cucurbits are among the economically most important vegetable crops worldwide and are grown in both temperate and tropical regions in Indian arid zone, cucurbits are regarded as an important source of vegetables and desserts. Their seeds, which contain oil and protein as reserve foods are eaten and seed oil of a few cucurbits are also used in Ayurvedic system of medicines (Singh, 1964).

The concept of seed purpose watermelon in Indian *Thar* desert is an innovative idea and is advocated by Central Arid Zone Research Institute, Jodhpur following the rigorous evaluation of watermelon germplasm under rainfed conditions. This seed purpose watermelon locally known as '*Karingada*' in Gujarat and Rajasthan, grouped under underutilized crops with great potential for oil and protein rich seed yield in Indian *Thar* desert. The Karingada has the potential to provide seed yield up to 10 quintals per hectare. Recently, the '*Mateera Beej*' is in great demand in the local market due to its protein and oil rich kernels popularly known as '*Magaz*'. The kernels contain 35- 50% crude protein, 28-40% oil and minerals in appreciable quantity. Further, the oil contains more than 80.0% unsaturated fatty acids with linoleic acid (18:2) being the dominant fatty acid (68.3%) (Mahla *et al*., 2014).

Heterosis breeding has proved to be a powerful method for increasing yield in most of the cross pollinated crops. Exploitation of hybrid vigor in watermelon has been advocated by many breeders for enhancing the yield potential (Brar and Sukhija, (1977), Rajan *et al*. (2002), Choudhary *et al*. (2003), Tomar and Bhalala (2006), Pichaimuthu and Swamy (2009) and Singh *et al*. (2009). For development of good hybrids, the information regarding the combining ability of the parents and the resulting crosses is very essential. The information on such aspect is very scanty in watermelon (Avramescu *et al*. 1972). Keeping in view of higher seed yield along with its contributing traits and quality parameters, an attempt has been made to examine the combing ability as well as heterosis of selected Karingada genotypes.

MATERIALS AND METHODS

Eight Karingada genotypes namely, GK 1, SKNK 679, SKNK 806, SKNK 903, SKNK 1001, SKNK 1004, CAZ JK 13-2 and MGPK-1 were crossed in diallel mating design to generate 28 one-way hybrids. All the F_1s along with their parents including GK 1, a standard variety as a check were grown at Centre for Crop Improvement, S. D. Agricultural University, Sardar krushinagar, Gujarat. All recommended agronomic package of practices were adopted in the trial sown in 2 rows of 5 m length with inter- and intra- row spacing of 3 m and 1m, respectively. Observations were recorded on five plants in each replication for fifteen characters *viz*. days to flowering, node number at which first male flower appears, node number at which first female flower appears, number of primary branches, main vine length (cm), days to maturity,number of fruits per plant, fruit yield per plant (kg) fruit diameter (cm), average fruit weight (g), seed yield per fruit (g), seed yield per plant (g), test weight (g), cotyledon ratio and oil content (%).General combining ability (GCA) and specific combining ability (SCA) variances and effects were calculated following the methods suggested by Griffing (1956). Heterobeltiosis was computed as deviation of mean performance of F_1 from that of better parent (BP) as per Fonseca and Patterson (1968). The estimates of economic heterosis was computed as deviation of mean performance of F_1 from that of the check variety (GK 1), a method given by Meredith and Bridge (1972).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed that the mean squares due to genotypes were significant for all the characters. This indicated that sufficient amount of genetic variability was present in the experimental material for all the characters under study.The hybrids differed significantly for all the characters. This indicated the existence of considerable genetic variability among the parents for all characters. The parents differed significantly for all the characters under study, indicated sufficient amount of genetic variability among the parents. Mean square due to parents Vs hybrids were significant for traits node number to first male flower, node number to first female flower, number of primary branches per plant, fruit diameter, average fruit weight, number of fruit per plant, fruit yield per plant, cotyledon ratio, seed yield per plant and oil content. This indicated the presence of considerable amount of genetic variability among the parents and the material was most useful for the study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits

The analysis of variance for combining ability (Table 2) revealed that the mean squares due to GCA and SCA were significant for all the characters except days to flowering (SCA) and test weight (GCA). This indicated that both additive and non-additive type of gene effects played a vital role in the inheritance of all the traits under studied. The magnitude of GCA and SCA variances revealed that the sca variances were higher than their respective GCA variances for all the characters except days to flowering and days to maturity. The potence ratio less than unity confirmed the preponderance of non-additive gene action for all the traits studied (except days to flowering and days to fruit maturity) and emphasized the utility of hybrid breeding approach to exploit existing heterosis in Karingada. The predominance of non-additive gene action for fruit yield and its component traits were also reported by Sachan and Nath (1976), Kale and Seshadri (1988), Sharma and Choudhury (1988), Gurav *et al*. (2000), Ferreira *et al*. (2002), Moon *et al*. (2002), Rajan *et al*. (2002), Moon *et al*. (2004), Choudhary *et al*. (2006), Salem *et al*. (2009) and Vashisht *et al*. (2010) in watermelon and Cucurbits (Koppad *et al*. 2015; Ray *et al*. 2015)

The parent SKNK 903 was good general combiner for Earliness traits which includes days to flowering, days to maturity and vine length (Table 3),SKNK 676, SKNK 903, SKNK 1004 and MGPK-1 for fruit yield per plant, CAZ JK 13-2 and MGPK-1 for seed boldness which includes test weight and cotyledon ratio and CAZ JK 13-2 for oil content. For seed yield per plant, the parent 903 was the best general combiner followed by MGPK-1, SKNK 679 and SKNK 806. These results are in accordance with the earlier findings of Gurav *et al*. (2000), Moon *et al*. (2004), Chaudhary *et al*. (2006), Jarret and levy (2012) and Protho *et al*. (2012).

It has been observed that significant specific combining ability

Table 1: Analysis of variance for experimental design for yield and its component traits in Karingada

Source of variation	Degree of freedom	Days to flowering	Node number at which first male flower appears	Node number at which first female flower appears	Number of primary branches per plant	Main vine length (cm)	Days to fruit maturity	Number of fruits per plant
Replications	2	20.48**	4.52**	0.43	4.74 **	5015.98**	0.39	1.29
Genotypes (G)	35	1.74 *	4.13**	10.58**	25.36**	4233.27**	4.65**	19.80**
Parents (P)	7	1.5	6.82**	20.74**	23.67**	6468.83**	7.77 **	7.24**
Hybrids (H)	27	1.81 *	3.50**	6.93**	21.68 **	3797.71**	4.01 **	17.27**
Parent vs. Hybrids	1	1.65	2.28 *	37.90**	136.08 **	344.50	0.19	175.95**
Error	70	1.08	0.57	0.89	0.53	405.98	0.48	0.64

Source of variation	Degree of freedom	Fruit yield per plant (kg)	Fruit diameter (cm)	Average fruit weight(g)	Seed yield per fruit (g)	Seed yield per plant (g)	Test weight (g)	Cotyledon ratio (%)	Oil content (%)
Replications	2	0.95	0.02	13505.4	5.08 *	2135.27 **	0.16	0.52	0.51
Genotypes (G)	35	9.85**	0.71**	27871.18**	8.93 **	11567.61**	0.31 **	40.52**	4.64 **
Parents (P)	7	7.42**	0.87**	37180.07**	8.151 **	6012.63**	0.27	16.69**	1.86
Hybrids (H)	27	9.00**	0.68 **	25378.65**	9.28 **	10569.99**	0.31 **	41.23**	5.34**
Parent vs. Hybrids	1	49.78**	0.63 *	30007.28 *	4.86	77388.20**	0.07	188.06**	5.32 *
Error	70	0.51	0.10	4696.49	1.57	393.64	0.16	0.52	1.18

*Significant at P ≤ 0.05, ** Significant at P ≤ 0.01

Table 2: Analysis of variance for combining ability for yield and its component traits in Karingada

Source of Variation	d.f.	Days to flowering	Node number at which first male flower appears	Node number at which first female flower appears	Number of primary branches per plant	Main vine length (cm)	Days to fruit maturity	Number of fruits per plant
GCA	7	1.24 **	3.35 **	3.29 **	17.54 **	1782.35 **	6.06 **	9.06 **
SCA	28	0.416	0.88 **	3.58 **	6.18 **	1318.27 **	0.42 **	5.98 **
Error	70	0.36	0.19	0.30	0.17	135.33	0.16	0.21
σ^2gca		0.088	0.32	0.3	1.74	164.70	0.59	0.88
σ^2sca		0.056	0.69	3.29	6.05	1182.95	0.26	5.77
σ^2gca/σ^2sca		1.57	0.46	0.09	0.29	0.14	2.23	0.15

Source of Variation	d.f.	Fruit yield per plant (kg)	Fruit diameter (cm)	Average fruit weight (g)	Seed yield per fruit (g)	Seed yield per plant (g)	Test weight (g)	Cotyledon ratio (%)	Oil content (%)
GCA	7	3.37 **	0.37 **	11162.98 **	7.19**	6197.60**	0.06	12.56**	2.35**
SCA	28	3.26 **	0.25 **	8822.24 **	1.94**	3270.43**	0.11**	13.74**	1.35**
Error	70	0.17	0.03	1565.49	0.53	131.21	0.05	0.17	0.39
σ^2gca		0.32	0.03	959.75	0.66	606.64	0.0004	1.24	0.20
σ^2sca		3.092	0.17	7256.75	1.41	3139.22	0.062	13.58	0.95
σ^2gca/σ^2sca		0.10	0.19	0.13	0.46	0.19	0.01	0.46	0.20

*Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$

Table 3: Estimation of general combining ability effect associated with each parent for yield and its component traits in Karingada

Sr.No.	Parents.	Days to flowering	Node number at which first male flower appears	Node number at which first female flower appears	Number of primary branches per plant	Main vine length (cm)	Days to fruit maturity	Number of fruits per plant
1	GK 1	0.50 **	0.92 **	0.01	-2.08**	-9.57**	0.27 *	-1.78 **
2	SKNK 679	-0.17	0.55 **	-0.28	-1.12 **	-6.71	0.43 **	0.88 **
3	SKNK 806	-0.47 *	-0.29 *	-0.53 **	0.34 **	-1.36	0.08	0.70 **
4	SKNK 903	-0.50**	-0.57**	0.07	1.71 **	15.69**	-0.77 **	0.67 **
5	SKNK 1001	0.17	-0.09	0.23	-0.56 **	-7.14 *	-0.92 **	-0.03
6	SKNK 1004	0.13	-0.01	0.02	-0.50 **	2.56	0.02	0.58 **
7	CAZ JK 13-2	0.27	0.33 *	1.18**	0.54 **	-16.53 **	-0.60 **	-1.05 **
8	MGPK-1	0.07	-0.83**	-0.71 **	1.67 **	23.07**	1.48**	0.03
	S.E.(gi)	0.18	0.13	0.16	0.12	3.44	0.12	0.14

Sr.No.	Parents	Fruit yield per plant (kg)	Fruit diameter (cm)	Average fruit weight (g)	Seed yield per fruit (g)	Seed yield per plant (g)	Test weight (g)	Cotyledon ratio (%)	Oil content (%)
1	GK 1	-0.79 **	-0.02	-12.01	0.76**	-34.58**	0.04	0.06	-0.07
2	SKNK 679	0.63 **	0.24 **	51.23 **	1.32 **	32.88**	0.05	-1.35 **	-0.38 *
3	SKNK 806	0.03	-0.18 **	-41.00**	-0.62 **	10.16 **	-0.01	-0.24 *	0.27
4	SKNK 903	0.47 **	0.05	4.73	0.25	16.85 **	0.04	-1.45 **	-0.88 **
5	SKNK 1001	-0.51 **	-0.16 **	-36.80 **	-0.20	-2.48	-0.12	0.06	0.04
6	SKNK 1004	0.57 **	0.12 *	19.13	0.27	17.20 **	-0.11	-0.04	0.15
7	CAZ JK 13-2	-0.67 **	-0.27 **	-20.12	-1.39**	-36.91**	0.08	1.92 **	0.78 **
8	MGPK-1	0.27 *	0.22**	34.86 **	-0.38	-15.07 **	0.02	1.05 **	0.10
	S.E.(gi)	0.12	0.05	11.70	0.21	3.39	0.07	0.12	0.18

*Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$

effects were observedin most of the cross combinations for all the characters. The list of crosses for each character is given in (Table 4) from which it is clear that mostly same cross combinations exhibited significant SCA effects for different character in desirable direction for yieldand related traits. The cross combinations SKNK 903 X SKNK 1004, GK 1 X SKNK 1001 and SKNK 806 X SKNK 903 which exhibited significant SCA effects for different characters of earliness, For fruit yield per plant SKNK 806 X SKNK 903, SKNK 806 X MGPK-1 and SKNK 903 X CAZ JK 13-2 were best three crosses exhibiting significant SCA. For seed yield per plant, the crosses SKNK 806 X SKNK 903, SKNK 806 X MGPK-1 and SKNK 679 X CAZ JK 13-2 exhibited significant SCA effects as leading cross combination. The cross, CAZ JK 13-2 X MGPK-1 showed significant SCA effects for seed boldness while on character basis, SKNK 1001 X SKNK 1004 and SKNK 903 X CAZ JK 13-2 were good for test weight and crosses SKNK 806 X SKNK 1001 and SKNK 806 X CAZ JK 13-2 were best for cotyledon ratio on individual character basis. Apart from these crosses, SKNK 1004 X CAZ JK 13-2, CAZ JK 13-2 X MGPK-1, SKNK 903 X SKNK 1004 and SKNK 806 X SKNK 1001 reported significant SCA effectsfor oil content. Gill and Kumar (1989), Gurav *et al.* (2000), Ferreira *et al.*(2002), Chaudhary *et al.* (2006), Salem *et al.* (2009) and Sapovadiya *et al.*(2014) also reported significant SCA effects for yield and its attributes.

The extent of heterosis fordifferent characters in relation to standard check GK 1 (Table 5) showed that the overall good heterotic crosses were SKNK 903 X SKNK 1004 for days to flowering, GK1 X SKNK 1001 for days to maturity, SKNK 806 X SKNK 903 for fruit yield per plant and seed yield per plant, SKNK 806 X SKNK 1001 for cotyledon ratio and SKNK 1004 X MGPK-1 for oil content.

From the above results, it is concluded that on the basis of *per se* performance, heterotic response and combing ability estimate for yield and its components (Table 6); with respect to seed yield per plant the parents SKNK 679, SKNK 1004, SKNK 903 and SKNK 806 were identified as good general combiners with best *per se* performance while crosses viz., SKNK 806 x SKNK 903 and SKNK 806 x MGPK-1 were most superior cross combinations. CAZ JK 13-2 x MGPK-1 and SKNK 1004 x MGPK-1 were best combination for cotyledon ratio and oil content Therefore, these crosses could be exploited for heterosis breeding programme to boost the seed yield and quality parameters in Karingada.

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