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Estimation of Magnitude of Heterosis for Grain Yield and Related Traits in Sesame (*Sesamum indicum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Sesame (*Sesamum indicum* L.) is an important oilseed crop which is native to India and cultivated in around 2.3 million ha across its several states. India stands way below in terms of productivity compared to several other countries across the globe. Being an often-cross pollinated crop, heterosis even in a marginal magnitude could be exploited in sesame in varietal development. Hence, the present study was performed with the objective of estimating the extent of relative heterosis, heterobeltiosis and standard heterosis in eight cross combinations for important yield attributing traits in sesame in order to select promising cross combinations for utilization in

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heterosis breeding and/or selection of superior segregants in segregating generations. Eight cross combinations derived out of crossing high yielding parents viz., TMV (Sv) 7 and VRI (Sv) 2 as female and E8, DSS 9, DS 5 and Prachi as male in L × T fashion were utilized for the analysis considering TMV (Sv) 7 as the Standard parent. The analysis showed significant differences between the genotypes for all the characters studied. The hybrids showed Relative/ Mid parental heterosis ranging from 2.02 to 26.05 per cent; heterobeltiosis from -4.55 to 15.85 per cent and standard heterosis from -11.27 to 15.85 per cent for grain yield /ha. Mid Parental Heterosis (RH) was found to be positive and significant for the characters no. of branches/plant, no. of capsules / plant, grain yield (kg/ha) in all the hybrid combinations except VRI (Sv) 2 / Prachi. Based on heterobeltiosis, the hybrids TMV (Sv) 7 / E 8, TMV (Sv) 7 / DSS 9, TMV (Sv) 7 / DS 5, VRI (Sv) 2 / DS 5 could be selected since they showed significant heterobeltiosis for important yield contributing characters *viz*., no. of branches / plant, no. of capsules /plant and grain yield. With respect to the Standard heterosis for grain yield and contributing characters like no. of branches/plant, no. of capsules/plant and grain yield/ha the hybrids *viz*., TMV (Sv) 7 / E 8, TMV (Sv) 7 / DS 5 and TMV (Sv) 7 / DSS 9 showed positive and significant heterosis. Considering all the three types of heterosis, the hybrids TMV (Sv) 7 / E 8, TMV (Sv) 7 / DS 5 and TMV (Sv) 7 / DSS 9 may be selected for yield enhancement in Sesame.

Keywords: Heterobeltiosis; productivity; relative heterosis; standard heterosis; yield enhancement.

1. INTRODUCTION

Sesame is described as the “Queen of oilseeds” due to its high oil content (38-54%), protein (18-25%), calcium, phosphorus, oxalic acid and excellent qualities of seed oil and meal [1]. *Sesamum* oil has long shelf life due to the presence of lignans (sesamin, sesamolin and sesaminol), which have remarkable antioxidant function [2]. Whole sesame seeds are rich source of mammalian lignin precursors (sesamin, sesamolin and sesaminol) and have been suggested to have potential anticancer effects [3]. Sesame oil, is also used as a solvent, oleaginous vehicle for drugs, skin softener, and used in the manufacture of margarine and soap [4]. It is resistant to drought, short in maturity duration and suitable for wide range of cropping systems. Sesame seed is an important source of edible oil and is also widely used as a spice because of its ease of extraction and its great stability. In India sesame occupies a place of prominence among oilseeds.

The annual area put under Sesame in India is about 2.3 million hectares (13.1 % per cent of the world hectarage) and the total production is nearly 81 lakh tonnes [5]. India ranks third in sesame production and second in area after Sudan in the world with productivity of 502 kg/ha (https://aicrp.icar.gov.in/sesame/about-us/).

Though the progress achieved in sesame in terms of cultivated area and production is quite high, its productivity in India is the lowest when compared to the world average. The major constraints identified for most of the countries including India are, instability in yield, lack of wider adaptability, drought, non-synchronous maturity *etc*. There are few studies on the genetics of sesame as well as on the improvement of genetic variation and root system. In-depth research on sesame is still necessary to further increase the yield and quality of sesame and to improve the related traits of sesame [6]. Heterosis breeding is a potential technique to improve yields in sesame [7]. Hybrid vigor in sesamum even a small magnitude for individual component, have additive or synergistic effects on end product [8]. The magnitude of heterosis provides a basis for genetic diversity and a guide to the choice of parents for developing superior F_1 hybrids, to exploit hybrid vigour and/or for building better gene pools to be employed in population improvement [9]. Besides, heterotic crosses may be amenable for selection of high yielding transgressive segregants in F_2 and follow up self-pollinated generations [10]. Hence the present investigation was undertaken to study the extent of heterosis present in select sesame hybrids developed for yield enhancement.

2. MATERIALS AND METHODS

The present investigation is carried out in the Research farm at Oilseeds Research Station (ORS), Tindivanam during Summer, 2020. Oilseeds Research Station, Tindivanam lies in the North Eastern Zone of Tamil Nadu at an altitude of 45.6m above Mean Sea Level and lies between 12.5°N latitude and 79.5°E longitude.

The average annual rainfall is 1158 mm and the temperature ranges from 19-21 degrees Centigrade as minimum to 33-42 degrees Centigrade as maximum. The soil is categorized as sandy loam with a pH of 7-7.5. The. The cropping pattern followed in ORS, Tindivanam is Groundnut- Groundnut/Sesame-Sesame or Castor-Sesame with the main emphasis to develop high yielding, biotic/abiotic stress resistant groundnut and sesame varieties. The experimental material included eight hybrids evolved by crossing two female and 4 male parents in line × tester fashion. The female parents taken for the study were the high yielding varieties developed by TNAU *viz*., TMV (Sv) 7 and VRI (Sv) 2 while the male parents were E8, DSS 9, DS 5 and Prachi which showed good general combining ability with the female parents selected from the All India Coordinated Research trials. The crosses were performed in L ×T fashion during Rabi and Summer, 2019 giving suitable isolation distance.

2.1 Laying Out of Experimental Plot

The resultant eight hybrids along with the 6 parents were sown directly in plot size of 4 × 3 m in a Randomized Block Design replicated thrice. All the package of practices was followed to raise a good crop. Observations other than days to 50% flowering were recorded at the time of harvest in 10 plants selected at random per replication in each cross combination and parent *viz*., plant height (cm), no. of branches/plant (No.) and no. of capsules/plant (No.) were recorded. The number of days taken from sowing for 50% of the plants in a plot to flower is recorded as days to 50% flowering. The height from the collar to tip of the plant is measured as plant height (cm). The number of primary branches originating from the main stem is recorded as no. of branches/plant (No.) and the number of capsules is counted as no. of capsules/plant (No.). The plot yield (kg/plot) of the hybrids and the parents recorded in each replication was converted to per hectare yield (kg/ha). In order to manage the grain shattering and reduction in yield, the individual plots were harvested at physiological maturity where 75% of the plants in a plot is mature. The mean of characters recorded in all the ten plants selected at random per replication were utilized for L × T statistical analysis as per Kempthorne [11] in the statistical package TNAUSTAT. The per cent of heterosis of all the three categories *viz*., relative or mid parent heterosis, heterobeltiosis or better parent heterosis [12] and standard heterosis [13] were worked out based on the mean values. For working of standard heterosis, the cosmopolitan high yielding variety released by TNAU in 2009 and one of the parents used in the study *viz*., TMV (Sv) 7 was utilized.

3. RESULTS AND DISCUSSION

The analysis of variance for different characters showed significant differences between the genotypes for all the characters studied (Table 1). The mean performance of the parents and hybrids were tabulated in Table 2.

The per cent heterosis under the three categories viz., relative heterosis, heterobeltiosis and standard heterosis is presented in Table 3. Relative/Mid parental heterosis ranged from -1.59 (VRI (Sv) 2 / Prachi) to 14.92 per cent (VRI (Sv) 2 / DSS 9) in days to 50% flowering; from -5.49 (TMV (Sv) 7 / Prachi) to 17.43 per cent (VRI (Sv) 2 / Prachi) in plant height; 15.11 (VRI (Sv) 2 / Prachi) to 96.95 per cent (TMV (Sv) 7 / DSS 9) in no. of branches / plant; 8.51 (VRI (Sv) 2 / Prachi) to 70.79 per cent (TMV (Sv) 7 / E8) in no. of capsules/plant and from 2.02 (VRI (Sv) 2 / Prachi) to 26.05 per cent (TMV (Sv) 7 / E8) in grain yield. Heterobeltiosis ranged between -4.12 (VRI (Sv) 2 / Prachi) and 7.22 per cent (VRI (Sv) 2 / DSS 9) for days to 50% flowering, -5.47 (TMV (Sv) 7 / Prachi) and 17.43 per cent (VRI (Sv) 2 / Prachi) for plant height, 5.48 (VRI (Sv) 2 / DSS 9) and 63.29 per cent (TMV (Sv) 7 / DSS 9) for No. of branches/plant, -9.95 (VRI (Sv) 2 / Prachi) and 60.0 per cent (TMV (Sv) 7 / E8) for no. of capsules/plant and between -4.55 (VRI (Sv) 2 / Prachi) and 15.85 per cent (TMV (Sv) 7 / E8) in grain yield / ha. Wide range of relative heterosis

Table 1. Analysis of variance for yield parameters in sesame

Sl. No.	Source	Degrees of Freedom	Mean Squares				
			Days to 50% flowering	Plant Height (cm)	No. of Branches/ plant (no.)	No. of Capsules/ plant (no.)	Yield/ha (kg)
1.	Genotypes	13	10.53*	405.41*	5.95*	703.24*	23514.13*
2.	Replication	2	1.45	6.88	0.02	3.24	280.27
3.	Error	26	1.84	23.69	0.20	27.45	902.70

Table 2. Mean performance of the cross combinations and parents

Genotypes	Days to 50 % flowering (days)	Plant height (cm.)	No. of branches / plant (no.)	No. of capsules / plant (no.)	Yield/ha (kg)
Hybrids					
TMV (Sv) 7 / E8	32	154.0	7.5	101.3	913.9
TMV (Sv) 7 / DSS 9	35	153.1	8.6	79	847.2
TMV (Sv) 7 / DS 5	33	141.8	6.5	75.3	880.6
TMV (Sv) 7 / Prachi	34	137.2	5.7	62	794.5
VRI (Sv) 2 / E8	33	141.6	5.9	73	800.0
VRI (Sv) 2 / DSS 9	34.7	138.3	5.1	61.9	705.6
VRI (Sv) 2 / DS 5	32.7	142.3	5.7	84.5	802.8
VRI (Sv) 2 / Prachi	31	152.2	5.3	58.2	700.0
Parents					
TMV (Sv) 7	33	145.2	5.3	63.3	788.9
VRI (Sv) 2	32.3	129.6	4.9	64.7	733.3
E8	30	140.4	5.1	55.3	661.1
DSS 9	28	123.4	3.5	47.3	647.2
DS 5	32	130.6	3.3	59.3	680.5
Prachi	30.7	112.8	4.4	42.7	638.9
SEd	1.1	4.0	0.37	4.3	24.5
CD (0.05)	2.3	8.2	0.76	8.8	50.5

and heterobeltiosis also existed in the study conducted by Rajput et al. [14] for yield, no. of capsules /plant, no. of branches and no. of seeds/capsule. (Table 3).

Standard heterosis varied between -6.06 (VRI (Sv) 2 / Prachi) and 6.06 per cent (TMV (SV) 7 / DSS 9) in days to 50% flowering, -5.49 (TMV (Sv) 7 / Prachi and VRI (Sv) 2 / DSS 9) and 6.11 per cent (TMV (SV) 7 / E 8) in plant height, -2.53 (VRI (Sv) 2 / DSS 9) and 63.29 per cent (TMV (Sv) 7 / DSS 9) in no. of branches / plant, -8.05 (VRI (Sv) 2 / Prachi) and 60.0 per cent (TMV (Sv) 7 / E 8) in no. of capsules / plant and between -11.27 (VRI (Sv) 2 / Prachi) and 15.85 per cent (TMV (Sv) 7 / E 8) in yield / ha. Significant standard heterosis has been reported for days to 50% flowering, plant height, no. of branches/plant, no. of capsules/plant and grain yield by Virani et. al. [15] and Shekawat et al. [16].

Earliness is preferred for varieties and hybrids in general in sesame. Hence, for the character days to 50% flowering alone negative heterosis is considered and for all other characters positive heterosis is considered for selection of hybrids. In the present study, for days to 50% flowering none of the hybrids showed negatively significant heterosis in all the three forms *viz*., Relative heterosis, heterobeltiosis and standard heterosis. Hence, none of the hybrids can be selected for days to 50% flowering with negative heterotic values.

Positively significant heterosis is exhibited in several hybrids for yield attributing characters. Mid Parental Heterosis (RH) was found to be positive and significant for the characters no. of branches/plant, no. of capsules / plant, grain yield (kg/ha) in all the hybrid combinations except VRI (Sv) 2 / Prachi. For plant height, all hybrids except TMV (Sv) 7 / Prachi and TMV (Sv) 7 /DS 5 showed significant relative heterosis. Significant positive relative heterosis was noticed in eleven out of fortyfive crosses for no. of primary and secondary branches/ plant, no. of capsules/plant, no. of seeds/ capsule and single plant yield in the study conducted by Meenakumari and Ganesamurthy [17]. This indicates that the cross combinations were heterotic for the yield characters and shows good scope for utilization as commercial hybrids as well as in varietal improvement.

Better parental heterosis is considered for selection of hybrids in many cases as this may benefit for yield improvement if the cross combination is for improvement of specific characters choosing one of the parents specifically showing better performance. Heterobeltiosis / better parental heterosis was positive and significant for the character plant height in hybrids TMV (Sv) 7 / E8, VRI (Sv) 2 / DSS 9, VRI (Sv) 2 / DS 5 and VRI (Sv) 2 / Prachi; for no. of branches / plant and grain yield in cross combinations *viz*., TMV (Sv) 7 / E8, TMV (Sv) 7 / DSS 9, TMV (Sv) 7 / DS 5, VRI (Sv) 2 /

E8 and VRI (Sv) 2 / DS 5 while hybrids TMV (Sv) 7 / E 8, TMV(Sv) 7 / DSS 9, TMV(Sv) 7 / DS 5 and VRI (Sv) 2 / DS 5 showed positive and significant heterobeltiosis for no. of capsules / plant. Monpara and Pawar [18] also reported significant and positive heterobeltiosis in eight cross combinations for yield attributing traits like primary branches/plant, capsules/plant, seeds/capsule, seed yield and harvest index in sesame. Tripathi et al*.* [10] identified five superior cross combinations based on heterobeltiosis for seed yield, three cross combinations for capsule number and also reported the significant contribution of capsule number in determining the seed yield in sesame.

Accordingly, the hybrids TMV (Sv) 7 / E 8, TMV (Sv) 7 / DSS 9, TMV (Sv) 7 / DS 5, VRI (SV) 2 / DS 5 could be selected since they showed significant heterobeltiosis for important yield contributing characters *viz*., no. of branches / plant, no. of capsules /plant and grain yield.

Standard heterosis is generally considered for varietal improvement as this is economically useful to the farmers and the commercial success of the new variety depends on the yield advantage of this variety over the ruling variety. Kadambavana Sundaram [19] suggested that heterotic expression over standard variety should be given due importance for exploitation of commercial hybrid. Considering the standard heterosis for plant height, only one hybrid TMV (Sv) 7 / E 8 could be adjudged as the best hybrid showing significant heterosis. For grain yield characters like no. of branches/plant, no. of capsules/plant and grain yield/ha the hybrids *viz*., TMV (Sv) 7 / E 8, TMV (Sv) 7 / DS 5 and TMV (Sv) 7 / DSS 9 are showing significant heterosis compared to other hybrids and hence can be utilized for exploitation of commercial heterosis. Saravanan and Nadarajan [20] reported high Standard heterosis for no. of primary branches/plant, no. of capsules/plant, 1000 seed weight and single plant yield in sesame. Shobana Rani et al. [21] assessed heterosis among thirty-eight cross combinations and reported two hybrids Swetha thil × VS 07-023 and Swetha thil ×JL SEL 05-3 exhibiting significantly superior standard heterosis over three standard checks. High standard heterosis has been recorded in five cross combinations over the standard parent by Chaudhari et al. [22].

Considering all the three types of heterosis, the cross combination VRI (Sv) 2 / Prachi is found to exhibit lowest values of relative heterosis, heterobeltiosis and Standard heterosis for economically important characters *viz*., no. of capsules/plant and grain yield/ha while the cross combination TMV(Sv) 7 / E 8 exhibited highest relative heterosis, heterobeltiosis and Standard heterosis for the characters *viz*., no. of capsules/plant and grain yield/ha among the eight hybrids studied. Similarly, the hybrids *viz*., TMV (Sv) 7 / DSS 9 and TMV (Sv) 7 / DS 5 also showed significant relative heterosis, heterobeltiosis and standard heterosis for no. of branches/plant, no. of capsules/plant and grain yield/ha. Hence the hybrids TMV(Sv) 7 / E 8, TMV (Sv) 7 / DSS 9 and TMV (Sv) 7 / DS 5 are adjudged as the best heterotic combinations exhibiting all the three types of heterosis for grain yield and its contributing characters. Sushila et. al. [23] reported significant positive average heterosis in six crosses, heterobeltiosis in five crosses and standard heterosis in seven and concluded positive and highly significant values for all three kinds of heterosis in two crosses, RT-351 × TKG-22 and RT-54 × TKG-22 and could be selected as promising hybrids for improving seed yield and contributing characters in sesame. Significant and positive standard heterosis and heterobeltiosis for seed yield per plant in sesame have also been reported by earlier workers like Kumar and Ganesan, [24], Kumar et al. [25], Shoba Rani et al. [21] and Karande et al. [26]. These hybrids also showed high *per se* performance in comparison to all other hybrids and their respective parents (Table 2). Dela and Sharma [27] also selected four heterotic combinations on the basis of heterosis and mean performance and also opined that the presence of large genetic diversity among the parents and also unidirectional distribution of allelic constitution contributing towards desirable heterosis.

Heterosis is generally studied for assessing the breeding value of the cross combinations. It is also studied as a measure of varietal superiority performed in selection of superior hybrids in any variety release programme. In general, genetically diverse parents are believed to put forth most heterotic combinations. Hence the superior hybrids *viz*., TMV(Sv) 7 / E 8, TMV (Sv) 7 / DSS 9 and TMV (Sv) 7 / DS 5 identified based on heterosis signifies their diverse nature and may be utilized for further improvement in yield and its contributing characters through heterosis breeding or in identification of superior segregants in further generations.

Table 3. Relative heterosis, Heterobeltiosis and Standard heterosis per cent for yield parameters in Sesame

Hybrids	Days to 50% flowering			Plant Height			No. of Branches/plant			No. of Capsules/plant			Yield		
	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
TMV (Sv) 7 / E8	1.59	-3.03	-3.03	7.87 **	6.11 *	6.11 *	45.34 **	43.04 **	43.04 **	70.79 **	60.00 **	60.00 **	26.05 **	15.85 **	15.85 **
TMV (Sv) 7 / DSS 9	14.75 **	6.06	6.06	14.03 **	5.46	5.46	96.95 **	63.29 **	63.29 **	42.77 **	24.74 **	24.74 **	17.99 **	7.39 *	7.39 *
TMV (Sv) 7 / DS 5	1.54	0.00	0.00	-2.30	-2.30	-2.30	50.39 **	22.78 **	22.78 **	22.83 **	18.95 **	18.95 **	19.85 **	11.62 **	11.62 **
TMV (Sv) 7 / Prachi	6.81 *	3.03	3.03	-5.49	-5.49	-5.49	17.24 *	7.59	7.59	16.98*	-2.11	-2.11	11.28 **	0.70	0.70
VRI (Sv) 2 / E8	5.88	2.06	0.00	9.23 **	0.83	-2.46	19.06 **	16.34 *	12.66	21.61 **	12.84	-2.11	14.74 **	9.09 *	1.41
VRI (Sv) 2 / DSS 9	14.92 **	7.22 *	5.05	6.69 *	6.69 *	-5.49	23.20 **	5.48	-2.53	10.54	-4.28	-2.26	2.21	-3.79	-10.56 **
VRI (Sv) 2 / DS 5	1.55	1.03	-1.01	9.40 **	9.01 **	-1.95	39.84 **	17.81 *	8.86	36.29 **	30.67 **	33.42 **	13.56 **	9.47 **	1.76
VRI (Sv) 2 / Prachi	-1.59	-4.12	-6.06	17.43 **	17.43 **	4.87	15.11 *	9.59	1.27	8.51	-9.95	-8.05	2.02	-4.55	-11.27 **

RH- Relative heterosis; HB- Heterobeltiosis; SH- Standard heterosis

4. CONCLUSIONS

The highly heterotic combinations are expected to through better transgressive segregants in the future generations and considered to be of high value than the low heterotic combinations. Hence considering all the three types of heterosis, the hybrids TMV (Sv) 7 / E 8, TMV (Sv) 7 / DS 5 and TMV (Sv) 7 / DSS 9 were adjudged to be good for enhancement of grain yield and its attributing characters in Sesame.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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