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The study of heterosis for seed yield and its attributes in sesame (*Sesamum indicum* L.) under normal environmental conditions of Rajasthan

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Abstract
Heterosis for seed yield and yield attributes was studied in 10 x 10 half diallel set of ten diverse sesame genotypes under normal environmental condition. The analysis of variance showed significant mean squares due to genotypes, parents, generations, F1 and parents vs generations for all the studied characters indicating the sufficient amount of genetic variability present in experimental material. Highly positive and significant heterosis over mid and better parent for seed yield per plant and its component traits suggested that there is abundant scope for exploiting heterosis commercially and possibility of isolating desirable segregants. Heterosis ranged between -25.6% (TC-25 x RT-351) to 49.53% (RT-372 x RT-103) for seed yield per plant. Out of 45 crosses, thirty six crosses exhibited positive significant heterosis and twenty four positive significant heterobeltiosis for seed yield per plant. Among these crosses, cross RT-346 x TKG-22, TKG-22 x GT-10, RT-372 x GT-10, RT-372 x RT-351 and GT-10 x RT-351for both heterosis and heterobeltiosis were found to be the most promising combinations for seed yield per plant. Out of these five crosses, only cross RT-372 x RT-351 RT-372 x RT-351 also showed desirable heterosis/heterobeltiosis for most of associated traits i.e. plant height, branches per plant, capsule per plant and 100-seed weight hence that cross may be exploited in further plant breeding programme or identification of transgressive sergeants from the advanced generation.

Keywords: Sesame, Normal environment, heterosis, heterobeltiosis, diallel

Introduction

Sesame (*Sesamum indicum* L.), is a self-pollinated crop. The chromosome number of the cultivated species (*S. indicum*) is 2n=26, first reported by Morinaga *et al.* (1929). It is the oldest cultivated oilseed crop among oilseed crops of India (Weiss, 1971) [31], belonging to the order *Tubiflorae* and family *Pedaliaceae*. *Sesamum orientale* and *Sesamum indicum* are the alternatively used scientifi c names of sesame (Bedigian 2003). However, Nicolson and Wieserma (2004) [21] proposed *S. indicum* name against *S. orientale*, which was conserved against *S. orientale* and is in use since 2005. Plants are erect to semi-erect depending on branching types; ovate to lanceolate leaves with pointed apices, the leaf margins are entire to serrate, and stem is round or square type. Flowers range in size containing small sized tubular calyx and five-lobed corollas and color, e.g., white, violet, red or maroon. Corolla is campanulate having lower corolla lobe longer than the upper one with one sterile and four functional epipetalous stamens (Najeeb 2012) [17]. Sesame is that the most important crop after the six most oil seed crop soybean, rapseed, cotton seed, sunflower, and groundnut. Several historical records indicated that sesame crop was probably originated from Ethiopia (Africa) and from there; it has been introduced into different parts of world like India, China and become a well liked food in South Europe, North-East Africa and Southern Asia. It spread early into West Asia and then to India, China and Japan which themselves became secondary distribution centers (Nayer, 1995) [19]. esame seed having high oil and protein content ranges from 40 to 60%, and 16.7 to 27.3%, respectively. In India, sesame seeds are mainly used for extraction of edible oil but it is also utilized in manufacturing hydrogenated oils, detergents and surface active agents. Its oil contains an element referred to as sisamol, which is a phenolic compound, thus oil stored for a long time. Due to its synergistic action, its oil used in insecticides and pesticides is becoming popular unlike other oils. Sesame oil with 80-85 per cent unsaturated fatty acids, is very stable and has reducing effect on cholesterol and thus reduces the chance of coronary heart diseases (Duhoon and Tripathi, 2005) [5].

Sesame oil is commonly called as the queen of oils because it is mostly used in cosmetic and skin care qualities (Diwakar *et al.*, 2002) [4]. Sesame has remarkable anti-oxidant capacity due to the presence of lignin and tocopherol. Seed protein is high in quality with good quantity of essential amino acids, especially methionine is dealt with rejuvenative and anti-aging for human body. Sesame seed is a rich source of linoleic acid, vitamin E, A, B_1, B_2, niacin and minerals including calcium and phosphorus. Vitamin E content in sesame oil helps in proctecting the skin from the damage caused by environmental factors like UV rays, pollution and toxins. The seeds are preferred for the preparation of baby food, considered as best substitute for mother milk (Duhoon and Tripathi, 2005) [5]. Sesame seed cake contains upto 42 per cent protein, rich in methionine (an essential amino acid mostly deficient in legumes) and, therefore, it forms an exquisite livestock feed and may be used as a protein supplement in human food as acceptably (Solanki, 1985).

Sesame is grown in the tropical as well as subtropical regions with in the plains upto an altitude of 1250 meters and it is sensitive to low temperature conditions. Important sesame growing countries are India, Sudan, Myanmar, China, Uganda, Nigeria, Pakistan, Mexico and Tanzania. However, it is also cultivated in Bangladesh, Somalia, Turkey, Thialand, Venezuela, Ethiopia and Egypt. The total area within the world under sesame during 2020-21 was 7784 thousand hectares Mha with the production of 3150 thousand metric tonnes MT with productivity of 405 kg per hectare (Anonymous, 2021) [1]. India is the world leader with the biggest area (1858 thousand ha), production (815 thousand MT) and productivity (438 kg/ha). Across the world, India contributes largest area (29.3%), maximum production (25.8%) and highest export of sesame seed (40%). Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Orissa, Tamil Nadu, West Bengal and Karnataka are the leading sesame growing states of the country. Among these, Rajasthan is the major sesame growing state, which contributes 14.36 per cent area and 11.37 per cent production of the entire national area and production, respectively. In Rajasthan, Pali, Nagaur, Jodhpur, Jalore, Bhilwara, Sirohi, Ajmer and Alwar are major sesame producing districts. The total acreage under sesame in Rajasthan is 266.91 thousand hectare Mha and production 92.73 MT with productivity 347 kg/ha. The productivity of the state is low as compared to the national productivity of 405 kg/ha (Anonymous, 2016-17).

In sesame, the yield could be a complex character and also the lower productivity may be attributed to the interplay of different yield related, biochemical, growth and morphological characters. Within the bygone decades, the sesame improvement was solely based on the selection for the choice of morphological characters and less importance was given to physiological characters. In spite of rapid increase in the area under the crop, the productivity has declined over the years. The major constraints identified for lower productivity could be also because of instability of yield, lack of wider adaptability, lack of availability of quality seeds and also due to genetic makeup of the crop, indeterminate growth, and abscission of floral parts, poor seed setting and cultivation under rainfed conditions. While a number of these factors are already overcome, still there is scope to enhance the productivity to a substantial extent. An insight into the genetics of morphological, growth and biochemical traits would be most effective prospects for breeding for higher yield. However, little is thought about the morphological, growth and biochemical characters that appear highly promising in improving performance of this crop (Suganthi, 2017) [27].

Material and Methods

The present investigation was conducted at the experimental area of Agronomy Research Farm, Sri Karan Narendra Agriculture collage, Jobner- Jaipur, Rajasthan during *Kharif* – 2019 and *Kharif* – 2020. Ten diverse parents namely: RT-346, TKG-22, RT-372, TC-25, PRAGATI, RT-125, RT-103, GT-10 and RT-351 were selected and crossed in diallel fashion (excluding reciprocals) in all possible combinations during *Kharif* – 2019. In *Summer* – 2020, half of the F1's seed were raised to advance the generation. In *Kharif* – 2020, ten parents along with their resulting 45 F1's were evaluated under rainfed condition with three replications in randomized block design. Row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. All recommended agronomical package of practices were adopted to raise good crop. Observations were recorded on days to 50% flowering, days to maturity, plant height, branches per plant, capsules per plant, capsule length, capsule girth, seeds per capsule, 1000-seeds weight, seed yield per plant and oil content. Heterosis over mid parent was calculated by = [(F1-MP)/ MP] x 100 and heterobeltiosis were calculated by formula proposed by Fonseca and Patterson (1968) [8] i.e. [(F1-BP)/ BP] x 100. Where F1= mean values of hybrid, MP = Mean values of mid parents and BP= Mean values of batter parents.

Result and Discussion

The analysis of variance showed significant mean squares due to genotypes, parents and generations for all the studied traits. Similarly F1 also showed significant differences for all studied traits. Likewise, the difference among the parent's vs generations was significant for all the studied traits. This significant difference between generation's vs parents showed the presence of heterosis.

The commercial exploitation of heterosis in crop plant is regarded as major breakthrough in the dominion of plant breeding. It is a phenomenon of immense practical importance, as its utilization has led to considerable yield improvement in several crop plants. The main aim of heterosis in the present study was to search out the best combination of parents giving high degree of heterosis and its exploitation to get better transgressive segregants.

The degree of heterosis varied from cross to cross for all the studied traits. High heterosis in certain crosses and low in others revealed that nature of gene action varied with the genetic makeup of the individual parents. In the present investigation, the crosses exhibited obviously heterotic response over mid-parental values for different characters. However, the measure of relative heterosis is relatively less important than heterobeltiosis and, therefore, it is better to measure the heterosis in terms of superiority over the better parent rather than mid-parent.

In this study, maximum range of heterosis has been estimated for all the studied trits.

An overall assessment of the investigation revealed that heterosis ranged from -9.45 to 42.51 for days to 50% flowering - 1.54 to 38.12 for plant height; -2.15 to 38.54 for branches per plant; -23.96 to 19.77 for capsules per plant; -

41.55 to 118.85 for1000-seeds weight and - 41.55 to 118.85 for seed yield per plant. The results for different characters are in conformity with the findings obtained by several researchers such as Arunachalam *et al.* 1984, Singh and Singh (1984), Kar *et al.* (2002), Dausane *et al.* (2002) [3], Karad *et al.* (2002) [10], Uzun *et al.* (2004) [28], Gupta *et al.* (2005) [9], Vavdiya *et al.* (2013) [29], Chemeda Daba *et al.* (2019) [2], Ragiba and Reddy (2000) [23], Krishna Devi *et al.* (2002) [13], Nijagun *et al.* (2003) [20], Ganesan (2005) [15], Sapara *et al.* (2019) [25] and Virani *et al.* (2017) [30].

A good number of crosses had significant desired heterosis and heterobeltiosis for seed yield and its attributes. For days to 50% flowering, seven crosses namely TKG-22 x RT-351, RT-372 x RT-351, RT-46 x RT-125 and RT-125 x RT-103 exhibited negative significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for days to 50% flowering.

For plant height, crosses namely RT-346 x RT-103, RT-346 x GT-10, RT-346 x RT-351, TKG-22 x RT-372 and RT-46 x RT-125 exhibited positive significant heterosis and heterobeltiosis for plant height. Therefore, these crosses were considered the most desirable for plant height.

For branches per plant, crosses namely RT-346 x TKG-22, RT-346 x GT-10, RT-346 x RT-351, TKG-22 x RT-372, RT-372 x RT-351 and RT-46 x RT-125 exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for branches per plant.

For capsules per plant, RT-346 x TKG-22, RT-346 x RT-103, RT-346 x GT-10, RT-346 x RT-351, TKG-22 x RT-372, TKG-22 x RT-351, RT-372 x RT-351, RT-46 x RT-125 and RT-46 x GT-10 crosses namely exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for seed yield per plant.

For 1000-seed weight, crosses namely TKG-22 x RT-372, TKG-22 x RT-351, RT-372 x RT-351 and RT-125 x RT-103 exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for 1000-seed weight.

For seed yield per plant, crosses namely RT-346 x TKG-22, RT-346 x RT-46, RT-346 x GT-10, TKG-22 x TC-25, RT-372 x TC-25, RT-372 x RT-103, PRAGATI x RT-351, RT-46 x GT-10 and RT-125 x RT-103 exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for seed yield per plant.

Table 1: Pooled analysis of variance showing mean squares of parents and F_1's for yield and its contributing attributes

Source of Variation	Df	Characters					
		Days to 50% flowering	Plant height	Branches per plant	Capsules per plant	1000- seed weight	Seed yield per plant
Environments	2	1811.10**	213688.19**	211.98**	55682.34**	27.65**	819.71**
Reps./env.	6	0.54	39.43	0.05	7.87	0.02	0.23
Genotypes	54	20.46**	1793.15**	1.59**	578.43**	0.25**	6.37**
Parents	9	9.56**	955.02**	0.70**	224.29**	0.16**	5.29**
F_1	44	18.49**	1608.73**	1.69**	592.01**	0.22**	5.92**
Parents *vs* F_1	1	205.46**	17450.55**	5.33**	3167.98**	2.64**	35.78**
Genotypes x Environments	108	7.11**	473.38**	0.51**	187.15**	0.11**	1.98**
Error	324	1.49	81.99	0.07	18.46	0.02	0.19

**Significant at 1 percent levels, respectively

Table 2: Top fifteen crosses showing significant heterosis and heterobeltiosis for seed yield and attributes traits

S.NO.	Crosses	Seed yield per plant		Days to 50% flowering		Plant Height	
		H	HB	H	HB	**H**	HB
1	RT-346 x TKG-22	48.91**	22.9**	-6.91**	6.57**	18.5**	7.27
2	RT-346 x RT-46	46.93**	39.02**	-2.53**	-1.46	7.46	3.45
3	RT-346 x RT-103	38.01**	22.71*	-2.53	-1.46	32.54**	23.49**
4	RT-346 x GT-10	45.16**	20.96**	-1.11	0.10	38.31**	34.95**
5	RT-346 x RT-351	37.82**	17*	1.49	3.82	29.57**	18.09**
6	TKG-22 x RT-372	40.01**	33.96**	-10.7**	-9.02**	32.25**	30.15**
7	TKG-22 x TC-25	44.84**	37.83**	-0.35	2.9	-16.87**	-20.36**
8	TKG-22 x RT-351	38.85**	34.15**	-11.52**	-9.16**	-6.3	-7
9	RT-372 x TC-25	43.2**	42.39**	0.71	6.02**	0.82	-4.89
10	RT-372 x RT-103	49.53**	16.21*	3.3	6.02**	-6.48	-10.74
11	RT-372 x RT-351	38.56**	37.17**	-6.82**	-6.11**	2.59	0.22
12	PRAGATI x RT-351	49.48**	23.84**	-5.62**	-3.82	21.34**	11.26
13	RT-46 x RT-125	39.52**	27.66**	-8.71**	-6.43**	20.28**	16.3*
14	RT-46 x GT-10	42.94**	13.99**	0.10	2.24	20.43**	13.23
15	RT-125 x RT-103	45.96**	25.82**	-10.8**	-8.57**	3.91	-3.58

Continue…..

S.NO.	Crosses	Branches per plant		Capsule per plant		1000-seed weight	
		H	HB	H	HB	**H**	HB
1	RT-346 x TKG-22	21.24**	12.95*	53.66**	32.52**	7.71*	6.27
2	RT-346 x RT-46	-14.53**	-16.67**	17.41*	15.64	11.33**	4.15
3	RT-346 x RT-103	-10.11*	-18.37**	33.42**	26.43**	3.27	-3.87
4	RT-346 x GT-10	26.07**	18.25**	61.04**	44.95**	9.13**	4.15
5	RT-346 x RT-351	21.91**	16.79**	36.98**	22.78**	9.43**	6.91

6	TKG-22 x RT-372	17.78**	14.39**	48.86**	41.85**	15.63**	11.74**
7	TKG-22 x TC-25	-18.31**	-20**	21.95**	6.03	2.49	-4.36
8	TKG-22 x RT-351	8.15	5.04	27.92**	22.43**	11.91**	10.8**
9	RT-372 x TC-25	3.62	-1.38	-6.02	-14.67	6.32	2.54
10	RT-372 x RT-103	2.88	-2.72	9.23	3.43	6.25	3.55
11	RT-372 x RT-351	25.95**	25.95**	28.12**	27.53**	16.83**	14.01**
12	PRAGATI x RT-351	19.28**	1.53	24.85**	9.28	-2.84	-9.18*
13	RT-46 x RT-125	23.81**	22.22**	43.7**	33.12**	8.39*	6.67
14	RT-46 x GT-10	4.38	-4.38	40.14**	27.89**	-0.05	-2.13
15	RT-125 x RT-103	15.15**	3.4	-9.22	-12.69	14.59**	13.37**

Conclusion

The cross TKG-22 x RT-372 and RT-46 x RT-125 for both heterosis and heterobeltiosis and RT-346 x TKG-22 for heterosis were found to be the most promising combinations for seed yield and some of the yield attributes. Among these crosses, cross TKG-22 x RT-372 also showed desirable heterosis/heterobeltiosis for associated traits like days to 50% flowering, plant height, capsule per plant and 1000-seed weight hence that cross may be exploited in further plant breeding programme or identification of transgressive sergeants from the advanced generation.

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