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Combining Ability Analysis in Sesame (*Sesamum indicum* L.)

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Abstract

India shares largest area under sesame and ranked second largest producer of sesame seeds in the world. Sesame seeds contain about 50-60% oil and it is considered as the queen of high quality vegetable oils. A diallel analysis was therefore carried out involving 12 diverse parental genotypes of sesame to study gene action and select appropriate parents/crosses using combining ability analysis. The magnitude of GCA effects were invariably higher than SCA effects for all characters including seed yield and oil content indicating preponderance of additive gene action for inheritance of the traits. TMV 5 had significantly higher number of primary branches/plant along with maximum number of capsules/plant while, CST 785 revealed highest productivity with high oil content. Phule Til-1, E8, CST 785 and Pratap were the favourably good general combiner for seed yield While, Pratap, TMV 5 and Phule Til 1 had higher estimates of general combining ability for oil content. Pratap x RT103, CST 785 x E8, BS 5-18-6 x Phule Til-1 revealed high SCA effect for seed yield. Each of these above cross combinations had at least one parent with high GCA. In contrast, B67xE8, B67xRT 103 and RT 103xT13 were good specific combiner for oil content where none of the parents with high GCA for oil content is involved indicating role of dominance and epistatic gene interaction for oil content in these crosses. The above cross combinations may be useful for genetic improvement of seed yield and oil content.

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Introduction

Sesame (*Sesamum indicum* L., Family: Pedaliaceae) is an ancient oilseed crop. It harbours wide array of phytochemicals (in seed) with antioxidant, antifungal, hypolipidaemic and hypoglycemic properties (Chakraborthy *et al.* 2008). Seeds contain about 50-60% oil (Arslan *et al.*, 2007) which is rich in carbohydrate, protein, calcium and phosphorus. Sesame oil is of superior quality nearly matching olive oil (Kapoor, 1990). The oil is used as source of biodiesel with superior environmental performance (Ahmed *et al.*, 2010) and also serves as useful ingredient in manufacture of soaps, perfumery, cosmetics, pharmaceuticals, insecticides, paints and varnishes (Bedigian, 2003). On the other hand, sesame seed is traditionally used for direct consumption as well as for confectioneries, cookies, cake and margarine and in bread making.

India is the largest exporter of sesame seed sharing 23% in the world. In India, Gujarat alone contributes 28.6 % of total sesame production. Despite enriched nutritional value and good oil quality, it remained far behind other oil seed crops in terms of genetic improvement of productivity and oil content. Any successful breeding programme depends on existence of variability, in depth understanding of genetic architecture and nature of gene action of morpho-economic traits. Therefore, the present investigation was undertaken to assess twelve diverse parental genotypes and 66 crosses using diallel analysis, for proper selection of parents and cross combinations; and to design breeding methods for recovery of promising segregants in the subsequent selfing generations.

Materials and methods

Plant materials and crossing technique

Twelve popular parental genotypes of sesame collected from different states of India were crossed in all possible combinations without reciprocals using Fevicol paste method (Das, 1990) to fit a 12x12 diallel mating design.

Field technique

Sixty six crosses along with their parents were laid out in Randomized Block Design(RBD)with three replications to raise F1 generation. Each test entry was grown in five rows of 3.5m length with a spacing of 30 x 10 cm. Observations on days to initial flowering, days to cessation of flowering, duration of flowering, days to maturity, height to first capsule(cm), plant height(cm), number of primary branches/plant, number of capsule/plant, capsule length(cm), capsule breadth (cm), number of seeds/capsule, 500-seed weight(gm), oil content(%) and seed yield/plant (gm) were recorded.

Statistical analysis

The data were subjected to combining ability analysis for diallel matting design (Parents + crosses without reciprocals) as per the standard statistical methods of Griffing (1956) using SPAR-1(version 2.0) developed by Indian Statistical Research Institute(ISRI), New Delhi.

Results and discussion

Analysis of variance

General combining ability (GCA) effects and specific combining ability (SCA) effects (Table 1) were highly significant for all the characters in F_1 generation at even 1% level of significance. The analysis showed the importance of both additive and non-additive gene actions in the inheritance of the characters in F_1 which is in agreement with Banerjee and Kole (2009). This could be due to different composition of experimental materials used. Besides, the present investigation resulted higher value of variance due to GCA effects than that of SCA effects for all characters indicating preponderance of additive gene action than non-additive gene action. Therefore, over all genetic improvement in sesame could be achieved through simple pedigree method. Singh (2004) reported higher variance due to GCA effect than the variance due to SCA effects for days to maturity, plant height and 1000-seed weight indicating greater role of additive gene action in the inheritance of these characters.

In contrast, Solanki and Gupta (2003) analysed combining ability for yield and its components in a 6-parent half diallel cross and reported that GCA and SCA effects were similar in magnitude for seed yield indicating equal importance of both additive and non-additive gene action for productivity. Similarly, Joshi *et al.* (2015) reported higher SCA effect than GCA indicating preponderance of non-additive gene action in the inheritance of most of the important morpho-economic traits. Prajapati *et al.* (2006) also reported higher variances due to SCA effects than that of GCA effects for days to maturity, plant height, primary branches per plant, capsule length, seeds per capsule, 1000-seed weight, yield and oil content except days to flowering where GCA was greater than SCA.

Table 1. Analysis of variance for combining ability for 12x12 half-diallel crosses.

Characters	Mean sum of square			C V
	GCA(11)[a]	SCA(66)	Error(154)	
Days to initial flowering(DIF)	38.41**	2.518**	0.6217	2.11
Days to cessation of flowering (DCF)	53.60**	5.327**	1.704	1.99
Period of flowering(DCF-DIF)	18.02**	4.856**	1.611	4.52
Days to maturity(DM)	62.16**	2.893**	0.826	1.17
Plant height(PHT)	390.8**	51.91**	12.25	3.30
Height to first capsule(HFC)	260.0**	27.60**	7.171	4.67
No. of primary branches(NPB)	1.476**	0.139**	0.067	14.4
No of capsules per plant(NC/P)	69.79**	21.81**	4.88	10.0
Capsule length (CL)	0.116**	0.116**	0.001	1.38
Capsule breadth (CB)	0.011**	0.0006**	0.00006	0.96
No of seeds per capsule(NS/C)	117.1**	8.94**	1.101	1.58
500 -Seed weight (SW)	0.039**	0.004**	0.0012	2.43
Oil content (OC)	29.11**	4.76**	0.887	1.84
Seed yield per plant(SY/P)	4.543**	1.082**	0.195	10.5

[a]- Figures within the parenthesis indicated degrees of freedom (df).

*, **-Significant at $p_{0.05}$ or $p_{0.01}$ respectively.

Table 2. Mean performance and general combining ability effects (within parenthesis) of twelve parental genotypes of sesame.

Parents	DIF	DCF	PF	DM	PHT	HFC	NPB	NC/P	CL	CB	NS/C	SW	OC	SY/P
B67	38.7 (1.37*)	62.3 (-0.47)	23.7 (-1.87)	75.0 (-2.02)	93.1 (-1.66)	56.8 (3.90*)	1.8 (-0.10)	16.1 (-3.04)	2.2 (-0.15)	0.8 (-0.04)	54.1 (-3.75)	1.3 (-0.07)	49.9 (-2.22)	2.3 (-0.98)
Vinayak	37.0 (0.03)	63.0 (-0.53)	26.0 (-0.63)	76.7 (0.24*)	100.4 (-1.30)	58.4 (2.10*)	1.5 (-0.13)	16.9 (-2.20)	2.7** (0.0001)	0.8 (-0.01)	69.3 (1.71*)	1.3 (-0.10)	51.3 (0.33*)	3.1 (-0.59)
TC25	30.7 (-2.49)	65.7 (-2.26)	35.0* (0.15)	71.3 (-3.26)	95.7 (-6.34)	48.6 (-6.84)	1.7 (-0.03)	17.8 (-0.86)	2.4 (-0.04)	0.8 (-0.01)	64.8 (0.43*)	1.4 (0.001)	54.6** (0.14)	3.0 (-0.16)
CST 785	36.0 (-1.34)	64.7 (-1.09)	28.7 (0.18)	78.3 (0.20)	97.7 (-4.93)	48.6 (-4.51)	1.4 (0.11*)	19.5 (1.48*)	2.5 (0.13*)	0.8 (0.0001)	66.6 (2.75*)	1.4 (0.03*)	53.8* (0.75*)	3.6** (0.59*)
Pratap	40.7* (0.91*)	71.7* (2.89*)	31.0 (2.12*)	83.7** (2.76*)	106.1 (5.81*)	65.7 (1.57*)	0.1 (-0.66)	11.5 (-1.18)	3.0** (0.15*)	1.1** (0.06*)	87.8** (4.94*)	1.4 (0.09*)	52.0 (1.41*)	2.9 (0.25*)
BS 5-18-6	36.7 (-1.16)	61.7 (-2.32)	25.0 (-1.19)	72.7 (-2.11)	90.0 (-6.47)	51.1 (-3.71)	1.2 (-0.08)	12.8 (-2.70)	2.4 (-0.09)	0.8 (-0.01)	60.9 (-2.35)	1.5* (0.03*)	47.2 (-2.18)	2.3 (-0.58)
RT 103	29.7 (-2.17)	59.7 (-2.56)	30.0 (-0.30)	69.3 (-1.99)	92.6 (-5.15)	52.9 (-6.31)	1.3 (-0.12)	15.6 (0.35)	2.4 (0.01*)	0.8 (0.0001)	60.1 (-0.09)	1.4 (0.0001)	54.8** (1.01*)	2.7 (0.07)
TMV 5	40.3* (1.56*)	71.0* (2.78*)	30.7 (1.14*)	83.0** (2.66*)	107.5 (4.49*)	71.2* (6.07*)	3.0 (0.54*)	21.4* (1.29*)	2.3 (-0.10)	0.8 (0.0001)	53.8 (-5.76)	1.4 (-0.01)	54.0* (1.40*)	3.1 (-0.18)
T 13	36.0 (-0.15)	66.0 (1.05*)	30.0 (1.25*)	80.3* (1.09*)	93.1 (-0.93)	50.9 (-0.60)	0.6 (-0.24)	12.9 (-0.28)	2.3 (-0.04)	0.8 (0.02*)	58.3 (-0.39)	1.4 (0.03*)	51.5 (0.17)	2.1 (0.04)
Madhabi	32.7 (-0.99)	60.7 (-0.57)	28.0 (0.40*)	72.7 (-1.22)	93.8 (1.74*)	56.4 (3.67*)	1.9 (0.30*)	15.2 (0.28)	2.7** (0.03*)	0.8 (-0.01)	69.9 (-0.29)	1.3 (-0.04)	51.4 (0.49*)	2.7 (-0.11)
Phuletil 1	40.0* (2.52*)	69.7 (2.28*)	29.7 (-0.19)	79.7 (2.73*)	113.8** (6.10*)	70.9* (2.09*)	1.1 (-0.07)	16.4 (2.09*)	2.5 (0.07*)	0.9** (0.03*)	64.7 (1.19*)	1.5* (0.04*)	52.7 (1.16*)	3.2 (0.63*)
E 8	40.3* (1.91*)	70.0 (0.80*)	29.7 (-1.07)	81.3* (0.92*)	109.4 (8.64*)	63.9 (2.57*)	1.6 (0.47*)	17.9 (4.77*)	2.6* (0.03*)	0.8 (-0.03)	67.0 (1.60*)	1.4 (0.01*)	44.2 (-2.44)	3.3 (1.02*)
Mean	36.5	65.50	28.94	77.00	99.43	57.96	1.42	16.17	2.49	0.815	64.8	1.39	51.45	2.86
$CD_{5\%}$	2.95	5.08	5.51	3.35	10.19	10.24	0.84	5.15	0.136	0.033	4.75	0.107	2.239	0.52
$CD_{1\%}$	4.01	6.90	7.49	4.56	13.85	13.91	1.15	7.01	0.186	0.045	6.45	0.146	3.044	0.71
SE(gi)	0.201	0.335	0.350	0.232	0.895	0.684	0.066	0.564	0.009	0.002	0.266	0.009	0.240	0.115
SE(gi-gj)	0.297	0.492	0.475	0.343	1.32	1.005	0.097	0.834	0.014	0.003	0.396	0.015	0.356	0.167

*, **- Significant at $p_{0.05}$ or $p_{0.01}$ respectively.

Mean performance

Pratap and TMV 5 were observed to be significantly late in flowering, while TC 25 exhibited longer period of flowering (Table 2). This is also reflected in terms of significantly late maturity in case of Pratap and TMV 5. Days to maturity ranged from 69.3 to 83.7days. RT 103 and TC 25 revealed very significantly early maturity. While Pratap, TMV 5, T 13 and E8 were shown to have significantly late maturity. BS 5-18-6 and RT 103 exhibited dwarf plant height, while Phule Til-1 was observed to be significantly tall plant type. Number of capsules/plant seems to be an important seed yield contributing trait. Sesame produces few primary branches in field condition and *in vogue* bore capsules along the main stem and branches.

Table 3. Scoring of parents (score 1-12) in respect of rank in GCA effects for 14 characters.

Characters	B67	Vinayak	TC 25	CST 785	Pratap	BS 5-18-6	RT 103	TMV 5	T 13	Madhabi	Phule Til 1	E 8
DIF	4	6	12	10	5	9	11	3	7	8	1	2
DCF	6	7	10	9	1	11	12	2	4	8	3	5
PF	12	9	6	5	1	11	8	2	3	4	7	10
DM	10	6	12	7	1	11	9	3	4	8	2	5
PHT	8	7	11	9	3	12	10	4	6	5	2	1
HFC	2	5	8	10	7	11	9	1	12	3	6	4
NPB	8	10	5	4	12	7	9	1	11	3	6	2
NC/P	12	10	8	3	9	11	5	4	7	6	2	1
CL	12	7	8	2	1	10	6	11	9	4	3	5
CB	12	8	7	6	1	9	5	4	3	10	2	11
NS/C	11	3	6	2	1	10	7	12	9	8	5	4
SW	11	12	8	5	1	4	7	9	3	10	2	6
OC	11	7	9	5	1	10	4	2	8	6	3	12
SY/P	12	11	8	3	4	10	5	9	6	7	2	1

Therefore, plants that start fruiting from lower height are expected to bear more fruits as in case of CST 785(19.5). It is interesting to note that TMV 5 had significantly higher number of primary branches/plant (3.0) along with maximum number of capsules/plant (21.4). Capsule length and capsule breadth determines number of seeds/capsule. Pratap had longer capsules with maximum number of seeds/capsule. Oil content is the single most economic product in sesame. TC 25, CST 785, RT 103 and TMV 5 revealed high oil content while CST 785 was the top most in terms of productivity. Considering both oil content and seed yield, CST 785, TMV 5 and TC 25 may be considered elite genotypes.

General combining ability (GCA) effects

Combining ability analysis is reported to be a better approach than graphical analysis in predicting the prepotency of parental genotypes (Tandan *et al.*, 1970). In the present study, Phule Til-1, E8, CST 785 and Pratap were the favourably good general combiner and *per se* performance for productivity (seed yield/plant).Thus, performance *per se* could be a valid indicator of its ability to transmit the desirable attributes to the progenies (Banerjee and Kole, 2009). In this context, Senthil and Kannan (2010) identified the parent IVTS 7 and TMV 6 as the good general combiners for seed yield/plant.Among above parents in the present investigation, Phule Til 1 was the good general combiner with favourably significant GCA effect for all characters except PF and NPB (Table 2). On similar consideration, E8 also seems to be a good general combiner for almost all agro-economic traits except period of flowering, capsule breadth and oil content.

Besides, Pratap was shown to be equally good general combiner with significant positive GCA effects for all traits except number of primary branches/plant and number of capsules/plant. In contrast, B67, TC 25, BS 5-18-6 and RT 103 revealed significant general combining ability effects for only a few seed yield contributing traits indicating poor general combining ability status among all the parental genotypes used. Rajaravindran *et al.* (2000) identified CO-1 as the best general combiner (among nine sesame genotypes in a diallel mating design)for number of capsules/plant, 1,000-seed weight and number of seeds/capsule,

Sesame being an oilseed crop, oil content is the most important consideration for genetic improvement in recombination breeding. In the present investigation, Pratap, TMV 5 and Phule Til 1 were estimated to have high status of general combining ability for oil content along with other important seed yield contributing traits. Praveenkumar (2009) studied heterosis in 45 hybrids and 10 parents. Among the parental genotypes; mutant 274, mutant 699, mutant353 and mutant 450 were the best the best general combiners for seed yield while; Mutant 353 and mutant 699 were found to be good general combiners for oil content.

Table 4. Frequency of characters in GCA ranking of parental lines for 14 characters in a 12 x 12 diallel crosses (F_1).

Parents	Freq. of characters in GCA ranking		
	High (1-4)	Medium (5-8)	Low (9-12)
B67	2(0)[a]	3	9(5)[b]
Vinayaka	1(0)	8	5(1)
TC25	0(0)	9	5(2)
CST 785	5(0)	5	4(0)
Pratap (C50)	10(8)	2	2(1)
BS 5-18-6	1(0)	1	12(1)
RT 103	1(0)	7	6(1)
TMV 5	10(2)	0	4(1)
T 13	5(0)	5	4(1)
Madhabi	4(0)	8	2(0)
Phuletil 1	10(1)	4	0(0)
E 8	7(3)	4	3(1)

a: No. of characters in which it is the top most combiner.

b: No. of characters in which it is the poorest combiner.

On the basis of the magnitude of GCA effects, the parents were ranked 1 to 12 ; 1 being the parent with highest favourable expression and 12, the most unfavourable one for each 14 characters in F_1 (Table 3). Lower the score better is the general combining ability of the parent. In F_1, Phule Til 1 followed by Pratap scored minimum average score and hence these parents could be considered to have merit in over all general combining ability.

On similar consideration, E8 and TMV 5 are equally good general combiner next to the above parents.

Pratap was shown to be top most general combiner(score 1) for days to cessation of flowering, period of flowering, days to maturity, capsule length, capsule breadth, number of seeds/capsule, 500-seed weight and oil content; whereas, Phule Til-1 exhibited high significant GCA effect as well as lowerscore(score 1-2) for important agro-economic traits i.e., days to initial flowering,, days to maturity, plant height, number of capsules/plant, capsule breadth, 500-seed weight and seed yield/plant(Table 3).In this context, Ranjith Rajaram and Senthil (2011) reported the parent IVTS-215-06 as the good general combiner for plant height, number of branches per plant and 1000-seed weight and the parent IVTS-24-06 was good general combiner for number of seeds per capsule and seed yield per plant in sesame.

Table 5. Specific combining ability (SCA) effects of 12x12 diallel crosses in sesame.

Chara-cters	Over all range	Range of + ve sig. mean values	Freq. of +ve sig. crosses	Best three desirable F_1s with high SCA[a]
DIF	-2.65 to 5.13	1.67-5.13	7	Pratap x Phule Til-1(5.13**), TC 25xMadhabi(3.38**), B 67xE8(3.28**),
DCF	-3.63 to 4.44	2.58-4.44	8	B67x E8(4.44**), B67x CST 785(3.65**), B67x Vinayak(3.59**)
PF	-4.4 to 4.37	3.82-4.37	3	CST 785xT13(4.37**), PratapxTMV5(3.87**) , B67xCST785(3.82**),
DM	-3.62 to 3.06	1.73-3.06	10	RT103xTMV 5(3.06**), MadhabixPhule Til-1(2.90**), B67xPhule Til-1(2.69**)
PHT	-9.42 to 15.9	7.3-15.9	14	T13xMadhabi(15.9**), BS 5-18-6xE8(14.7**), MadhabixE8(13.0**)
HFC	-11.2 to 12.2	5.5-12.2	7	Pratap x Madhabi(12.2**), MadhabiXE8 (9.7**) B67xVinayaK(9.18**),
NPB	-0.57 to 0.81	0.52-0.81	4	CST 785x E8(0.81**), TC xE8(0.68**), Vinayak x E8(0.62*)
NC/P	-5.48 to 10.26	3.39-10.26	16	CST 785xE8(10.26**), Pratap x RT 103(8.43**), BS 5-18-6xPhule Til 1(6.58**)
CL	-0.09 to 0.19	0.06-0.19	18	B67xCST785(0.19**),CST 785x Phule Til-1(0.18**),RT 103x Phule Til-1(0.16**)
CB	-5.54 to 0.04	-	1	B67xPratap(0.04*)
NS/C	-3.66 to 5.45	2.23-5.45	13	B67xCST 785(5.45**), VinayakxT13(4.16**), TC 25x Phule Til-1(3.67**)
SW	-0.14 to 0.14	0.06-0.14	14	TC 25x CST 785(0.14**), CST 785xMadhabi(0.12**), TC 25xBS 5-18-6(0.11**)
OC	-5.14 to 5.02	1.76-5.02	15	B67xE8(5.02**), B67xRT 103(4.97**), RT 103xT13(3.12**)
SY/P	-0.80 to 1.93	0.79-1.93	12	PratapxRT103(1.93**),CST 785xE8(1.79**),BS5-18-6xPhule Til-1(1.56**), T13x E8(1.47**)

[a]-Figures within the parenthesis indicates significant positive SCA value of promising crosses at $p_{0.05}$ or $p_{0.01}$.

The number of characters for which a parent indicated high (1-4), medium (5-8) and low (9-12) GCA ranks has been shown in Table 4. Pratap, TMV 5 and Phule Til 1 exhibited high GCA (Score 1-4) for ten characters each in F_1 followed by E8 exhibiting high GCA estimates and score for seven characters including seed yield/plant.

Further, it is worth to mention that Pratap maintained to be the top most general combiner for each of the eight characters (score 1) out of ten high ranking traits for GCA score (Score 1-4). Hence, Pratap may be considered as the best parental genotype for general combining ability to contribute sizeable proportion of fixable genetic variation.

Specific combining ability (SCA) effects

Performance of crosses is often determined by specific combining ability of the parents used in the crossing programme. Unlike GCA, SCA effects are the result of non-additive gene interaction. The range of SCA effects, the number of crosses showing significant SCA effects and three top ranking crosses for SCA effects are listed in Table 5.

The frequency of crosses with positive significant SCA effect was noted very high for number of capsules/plant, capsule length, plant height, seeds/capsule, 500-seed weight, oil content and seed yield/plant. Each of the component traits together accounted for heterotic behaviour of the crosses. The range of SCA effects for most of the characters appeared to be very large and this was more pronounced in plant height, height to first capsule and number of capsules/plant. In F_1, when seed yield and its important components traits such as capsule number, capsule length, capsule breadth, seeds/capsule and seed weight were considered, CST 785, B 67, E8, Pratap and Phule Til 1 were involved more frequently in hybrids showing high positive SCA effects.Further, diversity in the parental GCA effects played an important role for production of hybrids with significant positive SCA effects.

Twelve crosses were found to express significant SCA for seed yield/plant. Among these, Pratap x RT103, CST 785 x E8, BS 5-18-6 x Phule Til-1 ranked first, second and third highest for SCA effect for seed yield. Each of these above cross combinations has at least one parent with high GCA. This, agrees with the findings of Rajaravindran *et al.*(2000). They revealed that CO-1 which was identified as the best general combiner also resulted a promising cross CO -1 x DPI-1526 based on mean performance and SCA.Further, it is worth to note that Pratap x RT103 ranked second for number of capsules/plant along with its merit for grain yield. The parent CST 785 was common in highest ranking crosses for SCA effect for important component characters including number of primary branches/plant, number of capsules/plant, capsule length, seeds/capsule, seed weight and seed yield/plant. Senthil and Kannan (2010) analysed specific combining ability estimates for eight characters and reported that the cross combination IVTS 7 x TMV 6 exhibited the maximum positive and significant SCA for seed yield per plant. Similarly, Ranjith Rajaram and Senthil (2011) revealed positive significant SCA status of IVTS-3-06 x TMV-3 for number of capsules/plant and seed yield/plant.

Fifteen crosses revealed significant positive SCA effects for oil content among which B67xE8, B67xRT 103, RT 103xT13 found to be best specific combiner for the trait. None of the erstwhile mentioned good general combiner for oil content (Pratap, TMV 5 and Phule Til 1) is involved in the above crosses indicating substantial role of dominance and/or epistatic gene interaction for oil content. Therefore, a specific combination of parents may led to suitable gene combination resulting high oil content (Aladji Abatchoua *et al.*, 2015).

In the present investigation, TC 25 x Pratap, TC 25x E 8 and TC 25 x TMV 5 topped among crosses expressing negative significant SCA for days to initial flowering, days to cessation of flowering and days to maturity respectively. It is interesting to note that TC 25 is one of the parents in all above cross combinations revealing significant SCA effects in negative direction. This envisaged that TC 25 might have contributed desirable alleles for early flowering and maturity traits. In this context, Ranjith Rajaram and Senthil (2011) reported negative significant SCA for days to 50% flowering in a sesame cross combination IVTS-17-07x TMV 4.

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