Received: 21 Aug 2019 | Revised: 19 May 2020 | Accepted: 20 May 2020

Electronic Journal of Plant Breeding

Research Article

Assessment of combining ability and standard heterosis through diallel analysis in sesame (*Sesamum indicum* L.)

G. Jeeva[1*], K. Saravanan[2] and C. A. Sowmiya[1]

[1*]PG scholar,
[2]Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Tamil Nadu, India.
***E-Mail**: jeevagss@gmail.com

Abstract
Sesame is a drought tolerant oilseed crop with highest oleic acid content, which is yet to be explored for its hybrid vigour. With the view of producing elite hybrids, combining ability in sesame was studied among five sesame genotypes through diallel analysis. A set of 20 F_1s and their parents were evaluated at Plant Breeding Farm, Faculty of Agriculture, Annamalai University in RBD design with three replications. For this study, estimation of combining ability of seed yield traits *viz.,* the number of days to 50% flowering, plant height, the number of branches per plant, the number of capsules per plant, capsule length, the number of seeds per capsule, 1000 seed weight and seed yield per plant were recorded from five randomly selected plants in each replication. Among the parents, TMV 5 and TMV 3 were adjudged as superior for seed yield per plant and most of the characters. Among the hybrids, TMV 3 / TMV 5 and TMV 3 / VRI (SV) 2 were identified as best performers since these hybrids had desirable *per se* performance for all the eight characters studied followed by TMV 3 / TMV 6 and TMV 6 / TMV 3 for seven characters including seed yield per plant. The combining ability variance revealed the preponderance of additive gene action for all the characters studied. Based on *sca* effects, the hybrid VRI (SV) 2 / TMV 3 was considered as the best performing hybrid followed by TMV 3 / TMV 5 and TMV 3 / TMV 6, which could be further utilized in hybrid development in sesame. Considering standard heterosis, hybrids, TMV 3 / TMV 5, TMV 3 / TMV 6, TMV 5 / TMV 3 and TMV 6 / TMV 3 found to be the better performing. Comparing per se, sca and standard heterosis VRI (SV) 2 / TMV 3 observed to be the best along with the hybrids TMV 3 / TMV 5 and TMV 3 / TMV 6 as the better hybrids.

Keywords
Sesame, Combining ability, gene action, Heterosis, seed yield

INTRODUCTION

Sesame (*Sesamum indicum* L.), an annual plant belonging to the genus *Sesamum,* order Lamiales and family Pedaliaceae is a diploid with 2n= 2x = 26. It is an important oil seed crop and called as "Queen of oilseeds". Sesame being drought tolerant crop grows well in well drained soils of various agro climatic regions during *Kharif*, spring/summer seasons in north India and in all seasons in south India. In India, it is grown in an area of 1.74 lakh hectares with a production of 827 thousand tonnes and productivity of 474.0 kg/ha. India ranks first in area and production in the world contributing 15% among area and 13.27% among production. Increasing productivity of sesame does not meet out the demands for edible oil. This may be due to instability of yield, lack of wider adaptability, lack of availability of quality seeds, indeterminate growth, abscission of floral parts, poor seed setting or due to genetic makeup of crops and the negative correlation between yield and oil percentage (Pramitha *et al.,*2020). Thus, the productivity should be increased by improving the genetic architecture of crop through hybridization and recombination. Selection of breeding procedures and heterotic hybrids mainly relays on combining ability and heterosis. The success in identifying such parents mainly depends on combing ability analysis. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and hybrids. Whereas heterosis helps to identify the best and better performing hybrids over the standard check. The diallel crossing technique, developed by Griffing (1956) is one of the biometrical technique for evaluating the varieties or strains in terms of their combining ability and genetic makeup. Thus, in this experiment five lines of sesame were evaluated for their heterosis and combining ability.

MATERIAL AND METHODS

Five genotypes *viz*., SVPR 1, VRI (SV) 2, TMV 3, TMV 5 and TMV 6 collected from different places were crossed in a diallel manner and their 20 F_1's were evaluated at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar during 2015-2017. The observations were recorded on eight different characters *viz*., days to 50 per cent flowering, plant height, the number of branches per plant, the number of capsules per plant, capsule length, the number of seeds per capsule, 1000 seed weight and seed yield per plant. The statistical analysis was made for full diallel analysis based on Griffing (1956) Model I (fixed), Method 1. It was considered appropriate for this study since it involved the parents and F_1s of both direct and reciprocal crosses. This gives the general and specific combining ability variance and effects. Standard heterosis was calculated over the standard variety TMV 5 using formula given below

Standard heterosis (diii) = $\frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$

't' for standard heterosis(diii) =

$$\frac{\overline{F_1} - \overline{SV}}{\sqrt{(2/r)\sigma_e^2}}$$

Where, $\overline{F_1}$ and $\overline{SV}$ are the mean of F_1 hybrid and standard variety (TMV 5) respectively.

r = number of replications and σ^2_e = error mean square obtained from ANOVA.

The statistical analysis was done using TNAUSTAT.

RESULT AND DISCUSSION

The variances for all the eight characters studied were highly significant which indicated wide variability among parents and hybrids for these traits (**Table 1**). Mean performance of parents and hybrids are presented in the Table 2. The mean performance for seed yield per plant was considered as the first criterion for evaluation. Abhijit *et al.* (2016), Tripathy *et al.* (2016b) and Vaithiyalingam (2015) applied same criterion to evaluate the parents and hybrids. Based on mean performance of parents, the parent, TMV 5 followed by TMV 3 and TMV 6 had highest significant mean for seed yield per plant. In addition, TMV 5 possessed high significant mean for plant height, the number branches per plant, the number of capsules per plant, the number of seeds per capsule and 1000 seed weight and low significant mean value for days to 50 per cent flowering. The parent TMV 3, along with high seed yield per plant, also exhibited desirable mean values for plant height, the number of branches per plant, the number of capsules per plant, capsule length and 1000 seed weight. While the parent TMV 6 showed a high favorable mean for plant height and 1000 seed weight. The parent SVPR 1 exhibited a significant favorable mean for earliness, capsule length and the number of seeds per capsule. Thus TMV 5, TMV 3, TMV 6 and SVPR 1 are considered as superior parents based on mean performance.

Table 1. Analysis of variance for eight characters in sesame using diallel analysis

Source	df	Mean sum of square							
		Days to fifty per cent flowering	Plant height	Number of branches per plant	Number of capsules per plant	Capsule length	No of seeds per capsule	1000 seed weight	Seed yield per plant
Replication	2	0.16	2.13	0.06	1.14	0.01	0.004	0.37	1.43
Genotype	24	3.84**	324.17**	3.11**	1249.99**	0.07**	0.25**	50.08**	43.40**
Error	48	0.43	1.74	0.03	2.70	0.002	0.01	1.06	0.87

** 1% Significance

The mean sum of squares for combining ability revealed that the GCA (general combining ability), SCA (specific combining ability) and RCA (Reciprocal Combining Ability) variance was significant for all the characters studied (**Table 3**). The results revealed the presence of both additive and non-additive genetic variances in the inheritance of the characters of interest in sesamum. Similar reports were given by Tripathy *et al.* (2016a) for plant height, the number of branches per plant, the number of capsules per plant, capsule length, the number of seeds per capsule and seed yield per plant, Pawar *et al.* (2016) for days to 50 per cent flowering, plant height, the number of branches per plant, capsule length and seed yield per plant, Abhijit *et al.* (2016) for plant height, the number of branches per plant, capsule length, the number of seeds per capsule, 1000 seed weight and seed yield per plant. The ratio of GCA variance and SCA variance indicated a higher magnitude of GCA variance for all the characters suggesting the preponderance of an additive gene action.

Table 2. Mean performance of parents and hybrids for eight characters in sesame

	DFF (days)	PH (cm)	NBPP (No.)	NCPP (No.)	CL (cm)	NSPC (No.)	1000 SW (g)	SPY (g)
SVPR 1	43.33**	87.50	3.67	93.51	2.83**	62.27**	2.65	14.39
VRI (SV) 2	45.33	107.04	4.21	98.34	2.48	58.13	2.76	15.79
TMV 3	45.00	112.61**	5.63**	106.92*	2.69*	60.88	3.12**	17.71**
TMV 5	43.29**	116.30**	5.20**	114.10**	2.67	64.61**	2.96**	18.90**
TMV 6	45.33	112.10*	4.40	105.12	2.58	59.40	2.84*	17.08*
SVPR 1 × VRI (SV) 2	45.00	92.95	3.40	94.30	2.56	56.28	2.64	13.48
SVPR 1 × TMV 3	45.00	97.11	5.33	109.54	2.87**	64.91**	2.90	18.75
SVPR 1 × TMV 5	44.33	107.03	5.47	109.80	2.73	65.92**	3.12**	23.37**
SVPR 1 × TMV 6	45.33	102.58	3.69	97.53	2.61	60.16	3.52**	16.97
VRI (SV) 2 × SVPR 1	42.67**	107.77	4.10	99.35	2.52	69.88**	2.35	14.07
VRI (SV) 2 × TMV 3	43.00*	120.40**	5.69**	127.34**	2.70	60.61	3.03**	19.65*
VRI (SV) 2 × TMV 5	45.00	121.47**	6.35**	126.13*	2.79*	67.66**	2.87	21.49**
VRI (SV) 2 × TMV 6	46.00	104.37	5.63**	108.19	2.48	57.60	2.55	14.86
TMV 3 × SVPR 1	44.67**	106.32	3.82	111.89	2.85**	64.35	2.64	21.62**
TMV 3 × VRI (SV) 2	44.33**	115.52*	5.78**	122.88**	2.92**	66.07**	3.45**	19.43
TMV 3 × TMV 5	43.00**	124.92**	7.05**	182.03**	2.84**	72.78**	3.01*	25.86**
TMV 3 × TMV 6	44.66	121.49**	5.72**	142.71**	2.80**	68.98**	2.99*	20.33*
TMV 5 × SVPR 1	46.00	112.26**	5.10	137.45**	2.90**	63.01	2.84	23.49**
TMV 5 × VRI (SV) 2	45.83	119.55**	5.60**	103.93	2.50	67.00**	2.94*	21.34**
TMV 5 × TMV 3	43.33**	126.61**	6.79**	145.65**	2.67	64.70	3.34**	25.40**
TMV 5 × TMV 6	45.66	114.86**	5.44	111.11	2.64	59.03	3.04**	17.40
TMV 6 × SVPR 1	46.33	93.16	3.62	91.66	2.51	61.43	2.66	12.45
TMV 6 × VRI (SV) 2	46.33	108.97	4.30	118.36	2.48	63.01	2.61	17.05
TMV 6 × TMV 3	45.67	118.23**	5.53**	130.06**	2.89**	66.51*	3.00**	22.07**
TMV 6 × TMV 5	46.00	120.10**	4.30	124.95**	2.57	59.77	2.43	13.50

** 1% Significance * 5% Significance

***DFF**: days to fifty percent flowering, **PH**: Plant height, **NBPP**: Number of branches per plant, **NCPP**: Number of capsules per plant, **CL**: Capsule length, **NSPC**: Number of seeds per capsule, **1000 SW**: 1000 seed weight and **SPY**: single plant yield

Table 3. Estimates of variance for general and specific combining ability for eight characters in sesame

Source	Df	Mean sum of square							
		Days to fifty per cent flowering	Plant height	Number of branches per plant	Number of capsules per plant	Capsule length	No of seeds per capsule	1000 seed weight	Seed yield per plant
GCA	4	2.59**	508.56**	4.14**	1175.17**	0.07**	24.02**	0.13**	42.52**
SCA	4	1.38**	30.41**	0.50**	373.87**	0.02**	15.28**	0.07**	15.20**
RCA	4	0.66**	25.49**	0.33**	156.06**	0.01**	16.33**	0.08**	2.61**
Error	48	0.14	0.58	0.01	0.90	0.001	0.38	0.002	0.29
GCA/SCA		1.89	16.72	8.29	3.14	3.96	1.57	1.84	2.80
GCA/RCA		3.92	19.95	12.37	7.53	6.20	1.47	1.64	16.29

** 1% Significance

Combining ability effects of parents and hybrids are presented in **Table 4**. Based on combining ability, it was observed that the parents, TMV 5 and TMV 3 exhibited a significant and positive *gca* effect for seed yield per plant, plant height, the number of capsules per plant, the number of seeds per capsule and 1000 seed weight. The parents, TMV 5 and TMV 3 observed a negative significant *gca* effect for days to 50 per cent flowering. The parent, SVPR 1 recorded a significant and negative *gca* effect for the number of days to 50 per cent flowering and positive *gca* effect for capsule length. Thus TMV 5, TMV 3 and SVPR 1 were considered as superior parents based on general combining ability effects and the superior performance of TMV 5 as a parent is also reported by Pramitha *et al*. (2020). Thus, TMV 5, TMV 3 and SVPR 1 were evaluated as superior parents as they recorded high *per se* performance and highly significant *gca* effects for most of the economic characters could be utilized as parents in breeding for high yielding varieties.

Based on the mean performance of hybrids, two hybrids *viz*., TMV 3 / VRI (SV) 2 and TMV 3 / TMV 5 registered significant mean for all the traits. The hybrids TMV 3 / TMV 6 and TMV 6 / TMV 3 recorded significant mean for seven traits and another three hybrids namely VRI (SV) 2 / TMV 3, VRI (SV) 2 / TMV 5 and TMV 5 / TMV 3 recorded significant mean for six other traits. It could be concluded that among the twenty hybrids, TMV 3/ TMV 5, TMV 3 / VRI (SV) 2, TMV 6 / TMV 3 and TMV 3 / TMV 6 were rated as best hybrids based on the superior mean performance for seed yield and yield contributing characters. The specific combining ability is the deviation from the performance predicted on the basis of general combining ability (Allard, 1960). According to Sprague and Tatum (1942), the specific combining ability is controlled by non-additive gene action. Based on *sca* effects, seven hybrids recorded positive significant *sca* effects for seed yield per plant. Among them, the hybrids *viz*., SVPR 1 / TMV 5, TMV 3 / TMV 5, TMV 6 / SVPR 1 and TMV 3 / TMV 6 recorded significant and positive *sca* for seed yield per plant. The hybrids, TMV 3 / TMV 5, SVPR 1 / VRI (SV) 2 and TMV 5 / SVPR 1 recorded significant and negative *sca* effects for days to 50 per cent flowering.

Among the twenty hybrids, one hybrid VRI (SV) 2 / TMV 3 registered significant *sca* effect for all the traits. The hybrid TMV 3 / TMV 5, recorded significant *sca* for seven traits and the hybrid TMV 3 / TMV 6 exhibited significant *sca* effect for six traits. In addition to this, the hybrid VRI (SV) 2 / TMV 5 also reported significant *sca* for five traits. Hence, it may be concluded that, the hybrids, VRI (SV) 2 / TMV 3 and TMV 3 / TMV 5 could be considered as the best hybrids based on *sca* effect followed by the hybrids TMV 3 / TMV 6 and VRI (SV) 2 / TMV 5.

Table 4. Estimation of combining ability effects of parents and hybrids for eight characters in sesame

	DFF	PH	NBPP	NCPP	CL	NSPC	1000 SW	SPY
SVPR 1	-0.22*	-11.43**	-0.85**	-12.66**	0.04**	-0.35	-0.10**	-1.36**
VRI (SV) 2	0.07	-0.34	-0.11**	-6.80**	-0.09**	-0.96**	-0.10**	-1.36**
TMV 3	-0.45**	4.73**	-0.66**	12.08**	0.11**	1.67**	0.17**	2.20**
TMV 5	-0.24*	7.09**	0.62**	10.41**	0.01	1.51**	0.06**	2.31**
TMV 6	0.85**	-0.05	-0.33**	-3.03*	-0.07**	-1.87**	-0.04**	-1.78**
SVPR 1 × VRI (SV) 2	-0.83**	1.29**	-0.33**	-0.23	-0.09**	0.99**	-0.20**	-2.16**
SVPR 1 × TMV 3	0.68**	-2.44**	-0.23*	-5.22**	0.03	-0.03	-0.19**	0.05
SVPR 1 × TMV 5	0.81**	3.14	0.48**	9.36**	0.08**	-0.09	0.11**	3.83**
SVPR 1 × TMV 6	0.38	-1.50**	-0.20**	-6.22	-0.09**	-0.38	0.33**	-0.81*
VRI (SV) 2 × SVPR 1	1.67**	-7.41**	-0.35**	-2.53**	0.02	-6.80**	0.15**	-0.29
VRI (SV) 2 × TMV 3	-0.77**	2.72**	0.14*	3.31**	0.11**	0.77*	0.27**	0.70*
VRI (SV) 2 × TMV 5	0.78**	2.90**	0.43**	-5.097**	0.04*	3.38**	0.04	1.81**
VRI (SV) 2 × TMV 6	0.43	-3.78	0.37**	6.59**	-0.04**	-0.26	-0.17**	0.44
TMV 3 × SVPR 1	0.17	-4.60**	0.76**	-1.17	0.01	0.28	0.13**	-1.44**
TMV 3 × VRI (SV) 2	-0.67*	2.44**	-0.041	2.23**	-0.11**	-2.73**	-0.21	0.11
TMV 3 × TMV 5	-0.96**	3.09**	0.60**	24.83**	-0.05**	2.16**	0.06*	2.47**
TMV 3 × TMV 6	-0.05	4.33**	0.26**	10.82**	0.12**	4.55**	-0.03	2.13**
TMV 5 × SVPR 1	-0.83**	-2.62**	0.19**	-13.82**	-0.09**	1.45**	0.14**	-0.07
TMV 5 × VRI (SV) 2	-0.42	0.96	0.38**	11.10**	0.14**	0.33	-0.03	0.07
TMV 5 × TMV 3	-0.17	-0.85	0.13	18.19**	0.09**	4.04**	-0.17**	0.23
TMV 5 × TMV 6	0.41	-0.40	0.26**	-5.86	-0.02	-3.64**	-0.15**	-3.74**
TMV 6 × SVPR 1	-0.50	4.72**	0.035	2.94**	0.05*	0.63	0.43**	2.27**
TMV 6 × VRI (SV) 2	-0.17	-2.30**	0.67**	-5.09**	-0.01	-2.70	-0.03	-1.09**
TMV 6 × TMV 3	-0.50	1.63**	0.10	6.32**	-0.04*	1.23	-0.003	-0.87*
TMV 6 × TMV 5	-0.16	-2.62**	0.57**	-6.92**	0.03	-0.37	0.27**	1.95**

** 1% Significance   * 5% Significance

DFF: days to fifty percent flowering, **PH**: Plant height, **NBPP**: Number of branches per plant, **NCPP**: Number of capsules per plant, **CL**: Capsule length, **NSPC**: Number of seeds per capsule, **1000 SW**: 1000 seed weight and **SPY**: single plant yield

Table 5. Percentage of standard heterosis of diallel hybrids for the eight characters

	DFF	PH	NBPP	NCPP	CL	NSPC	1000 SW	SPY
SVPR 1 × VRI (SV) 2	3.95	-20.07**	-34.55**	-17.36**	-4.00**	-12.89	-10.36**	-28.68**
SVPR 1 × TMV 3	3.95**	-16.50**	2.56**	-3.99*	7.63**	0.47	-2.03**	-0.78
SVPR 1 × TMV 5	2.41**	-7.97**	5.13	-3.77**	2.25**	2.02	5.07	23.63**
SVPR 1 × TMV 6	4.72**	-11.79**	-28.97**	-14.52**	-2.25**	-6.88**	19.14**	-10.23**
VRI (SV) 2 × SVPR 1	-1.44	-7.34**	-21.03**	-12.93**	-5.38**	8.16	-20.38**	-25.57**
VRI (SV) 2 × TMV 3	-0.67	3.52	9.49**	11.61**	1.25**	-6.19	2.36**	3.97
VRI (SV) 2 × TMV 5	3.95**	4.44**	22.24*	10.55	4.50	4.73**	-3.04	13.70**
VRI (SV) 2 × TMV 6	6.26**	-10.26**	8.33	-5.18	-7.13**	-10.85**	-13.74**	-21.34**
TMV 3 × SVPR 1	3.18**	-8.59**	-26.54**	-1.93*	6.87**	-0.41	-10.92**	14.43
TMV 3 × VRI (SV) 2	2.41	-0.68	11.09**	7.70**	9.75**	2.25	16.44**	2.79
TMV 3 × TMV 5	-0.67	7.41**	35.58**	59.54**	6.75*	12.64**	1.80**	36.81**
TMV 3 × TMV 6	3.18**	4.46**	10.06**	25.07**	5.25**	6.76**	1.13	7.58**
TMV 5 × SVPR 1	6.26**	-3.47**	-1.99	20.46**	8.75**	-2.47	-4.05**	24.32**
TMV 5 × VRI (SV) 2	5.88**	2.79**	7.63**	-8.91	-6.00	3.69**	-0.90	12.91**
TMV 5 × TMV 3	0.10	8.86**	30.51**	27.65**	0.00*	0.13**	13.06**	34.39**
TMV 5 × TMV 6	5.49**	-1.24	4.68*	-2.62**	-1.0	-8.64**	2.70**	-7.92**
TMV 6 × SVPR 1	7.03**	-19.90**	-30.32**	-19.67**	-5.88**	-4.92**	-10.14*	34.13**
TMV 6 × VRI (SV) 2	7.03**	-6.31**	-17.31	3.74	-6.75	-2.48**	-11.71**	-9.75**
TMV 6 × TMV 3	5.49**	1.66**	6.28**	13.99**	8.50**	2.95**	1.35	16.79**
TMV 6 × TMV 5	6.26**	3.27	-17.18*	9.51**	-3.50	-7.50**	-15.77**	-28.57

DFF: days to fifty percent flowering, **PH**: Plant height, **NBPP**: Number of branches per plant, **NCPP**: Number of capsules per plant, **CL**: Capsule length, **NSPC**: Number of seeds per capsule, **1000 SW**: 1000 seed weight and **SPY**: single plant yield

Breeding programme largely depends on the magnitude and direction of heterosis. Heterosis for seed yield is due to simultaneous manifestations of allelic and inter-allelic interactions of innumerable number of genes controlling important morpho-economic component traits under certain environmental conditions. Hybrid vigour of even a small magnitude of individual components may have an additive or synergetic effect on the end products (Sasikumar and Saradana, 1990). Thus the extent of heterotic response of F_1 hybrids largely depends on the breeding values and genetic diversity of parents involved in the crosses (Young and Virmani, 1990). The hybrids selected based on the magnitude of heterosis, were listed in **Table 5**. The hybrids TMV 3 / TMV 5, TMV 5 / TMV 3, TMV 6 / SVPR 1 and TMV 5 / SVPR 1 exhibited highly significant and positive values for seed yield per plant in standard heterosis. The hybrid TMV 3 / TMV 5 recorded significant and positive standard heterosis for all the traits except days to fifty per cent flowering. Hence, from the foregoing discussion it may be concluded that, TMV 3 / TMV 5, TMV 3 / TMV 6, TMV 5 / TMV 3 and TMV 6 / TMV 3 can be rated as best hybrids and the hybrids VRI (SV) 2 / TMV 5 and TMV 5 / VRI (SV) 2 can be rated as better hybrids based on the magnitude of heterosis.

Evaluation of hybrids will be more effective when it passes all the three main criteria *i.e.*, *Per se*, *sca* and standard heterosis during selection of hybrids. Considering all these, among the twenty hybrids TMV3 / TMV 5 was observed as the best hybrid followed by TMV 3 / TMV 6, VRI (SV) 2 / TMV 3 and VRI (SV) 2 / TMV 5 as better hybrids

REFERENCES

Abhijit K. Pawar and Bachubhai A. Monpara 2016. Studies on gene effects for oil and some yield attributing traits in sesame (*Sesamum indicum* L.). *J. Global Agric. Ecol.,* **4**(4): 215-220.

Allard, R.W 1960. Principles of plant breeding. *John Wiley and Sons Inc*., New York.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian J. Biol. Sci.,* **9**: 463-493. [Cross Ref]

Pawar, A.K., B.M. Aher, C.S. Desale, A.S. Desai and B.A. Monpara 2016. Heterosis and combining ability in sesame (*Sesamum indicum* L.). *Advances Life Sci.,* **5**(4): 1279-1284.

Pramitha Lydia, J., B. Meenakumari and M. Kumar 2020. Analysing combining ability in a set of hybrids developed in Sesame. *Journal of Pharmacognsy and Photochemistry*; **9**(1): 179-191.

Sasikumar, B., S. Sardana 1990. Heterosis for yield and yield components in sesame. *Indian J. Genet.,* **50**(1): 87-88.

Tripathy S.K., D.R. Mishra, Mohanty, Kartik Ch. Pradhan, K.R. Reshmi Raj, M.R. Mohanty, P.M. Mohapatra, S. Dash and S. Panda 2016a. Revealing nature of gene action of morpho-economic traits in sesame (*Sesamum indicum* L.). *Int. J. current Agric. Sci.,* **6**(6): 58-61.

Tripathy, S.K., D.R. Mishra, G.B. Dash, N. Senapati, D. Mishra, P.K. Nayak, S.K. Mohanty, S. Dash, Karthik Pradhan, D. Swain, P.M. Mohapatra and S. Panda 2016b. Combining ability analysis in sesame (*Sesamum indicum* L.). *Intl. J. Biosciences,* **9**(3): 114-121. [Cross Ref]

Vaithiyalingam, M. 2015. Combining ability analysis for yield and yield components in sesame (*Sesamum indicum* L.) genotypes. *Electron. J. Plant Breed.,* **6**(4): 950-955.

Young, J. and Virmani, S.S. 1990. Heterosis of rice over environments. *Euphytica,* **51**: 87-98. [Cross Ref]