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ESTIMATION OF COMBINING ABILITY IN SESAME (*SESAMUM INDICUM* L.) THROUGH DIALLEL ANALYSIS

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Abstract

The present investigation was carried out to estimate the combining ability in sesame (*Sesamum indicum L.*) through diallel analysis. The six genotypes *viz.*, TMV 3, TMV 4, TMV 6, TMV 7, VRI 1 and VRI 2 were crossed in all possible combinations. The ratio of GCA/SCA was above one indicated that the role of additive gene action for the character's days to 50 percent flowering, plant height at maturity, 1000 seed weight and seed yield per plant. Hence, direct selection or recurrent selection can be employed for improvement of these traits. Based on gca effects, the parent TMV 7 was identified as superior parent followed by TMV 6, TMV 3 and TMV 4. Among hybrids TMV 6 X TMV 7, TMV 4 X TMV 7 and TMV 3 X TMV 6 were the best for exploitation of heterosis.

Keywords : Combining ability, diallel, GCA, SCA, effects, sesame

Introduction

Sesame (*Sesamum indicum* L.), belongs to the family of Pedaliaceae, a self-pollinated crop, is an ancient cultivated oil seed crop and thought to have originated from Africa. It is called as the "Queen of oilseeds" in view of its oil and protein which are of very high quality. Sesame is an important source of high quality of edible oil, the seeds contain 50-60 per cent oil. Globally sesame is cultivated in an area of 20 lakh hectares with an annual production of 8.28 lakh tonnes and productivity of 4055 kg ha^{-1} in India (INDIA STAT, 2014-2015). In 2016, globally sesame production was 6.1 million tonnes with Tanzania, Myanmar, India and Sudan are the largest producers. (FAO STAT, 2017).

Moreover similar to other crops, in sesame, the yield is a complex character and the lower productivity could be attributed to the integrity of different yield related, growth and morphological character. In spite of rapid increase in area under the crop, the productivity has declined over the years. The major constraints identified for lower productivity may be due to instability of yield, lack of wider adaptability, lack of availability of quality seeds and also due to genetic makeup of the crop, indeterminate growth, abscission of floral parts, poor seed setting and cultivation under rainfed conditions.

Though even some of these factors have been already overcome, still there is scope to enhance the productivity to considerable extent. An insight into the genetics of morphological and growth characters would be the best prospects for breeding for high yield. However, little is known about the morphological and growth characters that appear highly promising in improving performance of this crop. The task of the sesame breeder is to improve and stabilize the sesame yield, by a further breakthrough in our understanding in the genetics of the yield and yield components. Information on the genetics of seed yield and yield contributing characters and their breeding value must always be a pre-requisite for selecting suitable parents for appropriate breeding programme to enhance seed yield. Evaluation of the sesame genotypes including popular high yielding varieties on the above lines would be facilitate their use as donors.

Plant breeders have several mating designs to investigate the genetic properties of plant populations, but none of them has caused as much controversy and debate than has the diallel mating design. According to Hallauer and Miranda (1988) "The diallel mating design has been used and abused more extensively than any other in maize and other plant species." The diallel mating design is defined as making all possible crosses among a group of genotypes. Sprague and Tatum (1942) introduced the diallel cross concept to plant breeding by making all possible crosses among a set of maize (*Zea mays* L.) inbred lines. The diallel cross was first used in animal breeding by Schmidt in 1919 when crosses were made between two males and two females at different times (Lush, 1945). The term diallel cross as applied to plants, however, did not appear in the literature until 1953.

The theory and statistical analysis of the diallel mating design have been investigated in depth by several researchers (Jinks and Hayman, 1953; Hayman, 1954a, 1954b, 1958, 1960; Griffing 1956a, 1956b; Kempthorne, 1956; Gardner and Eberhart, 1966; Eberhart and Gardner, 1966). Various forms of the diallel crossing system and analysis have been developed since its conception.

Materials and Methods

The present investigation on the "studies on combining ability and heterosis in sesame (*Sesamum indicum* L.) through diallel analysis" was conducted at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar during 2017-2019. The experimental material consisted of six genotypes of wide genetic diversity. The selected six genotypes *viz.*, TMV 3, TMV 4, TMV 6, TMV 7, VRI 1 and VRI 2 were crossed in all possible combinations to produce 30 hybrids. The six genotypes were sown during January - February, 2018. They were crossed in a diallel mating design (including both direct and reciprocal crosses). The resultant 30 hybrids along with six selfed parents formed an effective complete diallel set for the present study. Thirty hybrids along with their six selfed parents were sown in June - July, 2018 in a Randomized Block Design, replicated thrice. The observations recorded were days to 50 percent flowering, plant height at maturity, number of branches per plant, number of capsules per plant, number of seeds per capsules, length of the capsule, 1000 seed weight and seed yield per plant

Combining ability analysis

The diallel analysis as described by Griffing (1956 b) method I and model I was adopted to work out the combining ability effects with the assumption of the variety and block effects were constant. The mean squares due to different sources of variation as well as their genetic expectations were estimated as follows

Analysis of variance for combining ability

Source	Degrees of Freedom	Sum of squares	Mean sum of squares	Expectation of mean squares
GCA	P-1	S_g	M_g	$\sigma^2e + 2P\,[1/(P-1)]\,\Sigma_i g_i^2$
SCA	[P(P-1)] / 2	S_s	M_s	$\sigma^2e + [2/P(P-1)]\,\Sigma_i\Sigma_j s_{ij}^2$
Reciprocal effects	[P (P-1)] / 2	S_r	M_r	$\sigma^2e + 2\,[2/P(P-1)]\,\Sigma_i\Sigma_{<j} r_{ij}^2$
Error	M	S_e	Me′	σ^2e

General combining ability effects, specific combining ability effects and reciprocal combining ability effects were estimated as follows.

$g_i = (1/2P)\,(x_{i.} + x_{.i}) - (1/P^2)\,x_{..}$

$s_{ij} = (1/2)\,(x_{ij} + x_{ji}) - (1/2P)\,(x_{i.} + x_{.j} + x_{j.} + x_{.i}) + (1/P^2)\,x_{..}$

$r_{ij} = (1/2)\,(x_{ij} - x_{ji})$

Standard error of estimates

The square root of the variance gives the standard error of that estimate. For this, the variances of different effects were calculated as follows.

Variance $(X_{ij}) = \sigma^2_e = Me'$

$$\text{Variance } (g_i) = \frac{P-1}{2P^2}\,\sigma^2_e$$

$$\text{Variance } (r_{ij}) = \frac{1}{2}\,\sigma^2_e$$

Critical difference of estimates

The critical difference to compare any two similar estimates was obtained as a product of 't' value against error degrees of freedom and standard error of difference. The square root of the variance gives the standard error of differences.

Variance (gi - gj) = (1 / P) σ2e for two gca estimates

Variance (sij - sik) = 2(P-1)/P] σ2e for two sca estimates having one parent in common

Variance (sij - skl) = [(P-2) / P] σ2e for two sca estimates with No parent in common

Variance (rij - rkl) = σ2e for a pair of reciprocal effects

Results and Discussion

The ANOVA for the yield and yield attributing characters of sesame were furnished in the Table. 1. The variance due to genotypes were highly significant for all characters which indicated the presence of the genetic variability in population and suggested that diallel analysis of gene action and combining ability were warranted. The GCA variance (6.58), SCA variance (5.72) and RCA variance (2.14) were significant for days to 50 percent flowering, plant height at maturity, number of capsules per plant and number of seeds per capsule (Table 2.) The ratio of GCA/SCA was above one indicated that the role of additive gene action for the character's days to 50 percent flowering, plant height at maturity, 1000 seed weight and seed yield per plant. Hence, direct selection or recurrent selection can be employed for improvement of these traits. The ratio of GCA/SCA was low for the traits number of branches per plant, number of capsules per plant, capsule length and number of seeds per capsule indicating preponderance of non-additive gene action for controlling these characters and hence these traits may be improved through recurrent selection or heterosis breeding. General combining ability effects and specific combining ability effects for yield and yield attributing traits were presented in Tables 3 and 4.

The ability of an inbred to transmit desirable performance to its hybrid progenies is referred as a combining ability. Spargue and Tatum (1942) further refined the idea into general and specific combining ability, which have significant impact evolution of inbred lines. The term general combining ability is used to designate the average of particular inbred in a series of hybrid combinations. In the present investigation among the parents, the *gca* effect of TMV 7 was of high for characters such as plant height at maturity, number of branches per plant, number of capsules per plant and seed yield per plant. Early reports on significant *gca* for number of branches was made by Vekaria *et al.* (2014)

A perusal of *gca* effects for yield characters like number of branches per plant, plant height at maturity, number of capsule per plant and seed yield per plant TMV 7 was good general combiner. These results are in consonance with the findings of Musibau and Morakinyo (2014) and Vekaria *et al.* (2014). VRI 2 was found to be good general combiner for days to 50 per cent flowering. The parents TMV 7 and TMV 3 exhibited negative *gca* effect and found to be good combiners for earliness. Similar findings were reported by Ramesh *et al.* (2014). Considering the *gca* effect of parents, TMV 7 was adjudged as the best parent since it had significant *gca* effect for plant height, number of branches per plant, number of capsule per plant and seed yield per plant. The parents TMV 6, TMV3 and TMV 4 were considered as next best parents since they possessed desirable *gca* effect. Thus, TMV 7 was appeared to be worthy for exploitation in breeding programme aimed at yield improvement through component characters.

The specific combining ability is considered to be the best criterion for the selection of superior hybrids. Specific combining ability refers to the performance of a combination of specific inbred in particular cross. Specific combining ability may result from several cases, such as mendelian segregation and recombination, incorrect genotype classification and various types of factor interactions (Spargue and Tatum, 1942). The specific combining ability estimates demonstrated that the cross combination TMV 7 x VRI 2 for days to 50 per cent flowering and was good combiner for earliness, the same hybrid TMV 7 x VRI 2 recorded highest positive and significant *sca* effect in plant height at maturity, for the number of branches per plant, number of capsule per plant, capsule length and seeds per capsule the hybrid TMV 6 x TMV 7 showed highest positive and significant *sca* effect, the hybrid TMV 4 x TMV 7 recorded highest positive and significant *sca* effect in 1000 seed weight and seed yield per plant. These findings are agreement with Sakhiya (2013) and Sedeck and Hassan, (2015). So, from the foregoing discussion it may be concluded that, the hybrids TMV 6 x TMV 7 and TMV 4 x TMV 7 could be used as the best hybrid for exploitation heterosis. The hybrids TMV 7 x VRI 2, TMV 6 x TMV 7 and TMV 4 x TMV x TMV 7 were the better hybrids for exploitation of heterosis (Table 4)

In the present study, the hybrid TMV 6 x TMV 7 recorded high *sca* effect with the combination of superior *gca* parent for number of capsule per plant, capsule length, seeds per capsule and 1000 seed weight. So, it is worth of mentioning that parents with consistently good general combining ability produces hybrids with high significant *sca* effects.

From the perusal of *sca* effects of the hybrids, it was evident that all types (significantly positive or negative or non-significant) of *sca* effects could be obtained in hybrids with different types (high x high, high x low, low x high and low x low) of parental *gca* combinations.

Therefore, it may not be always necessary to attempt crosses between high x high *per se* or *gca* or low x low *per se* or *gca.* However, combinations in which at least one percent had high *gca* or high *per se* may be rewarding.

So it can be observed that a good performing parent may not be good general combiner, a good general combiner need not always produce a good specific combination. However, it can be noticed that at least one general combining parent was involved in desirable specific combination and the best performing crosses involved at least one parent with high mean and crosses with significant *sca* effects can be utilized for transgressive segregants for future exploitation (Anuradha and Lakhmi Kantha Reddy, 2005). From the above discussion it may inferred that the most of the crosses involved at least one good general combiner in their percentage and could be expected to throw transgressive segregants. It is therefore, suggested that the adaptation of biparental approach followed by recurrent selection or selective diallel mating system in these crosses was a judicious approach to exploit both additive as well as non-additive kinds of gene effects (Goyal and Sudhir Kumar, 1991). The interaction between recessive alleles from poor combiner and dominant alleles from good combiner could have resulted in such potential crosses from good x poor parental combiners (Dubey, 1975).

There were instances in which involving of both poor combiners produced superior specific combining ability as evidenced from the combinations of TMV 7 x VRI 2 for plant height at maturity, TMV 3 x VRI 1 for 1000 seed weight and VRI 1 x VRI 2 for seed yield per plant. (Table 5) These findings were in concordance with the results of Salunke and Lokesha (2012) and Kumar *et al.* (2012)

Conclusion

Based on gca effects, the parent TMV 7 was identified as superior parent followed by TMV 6, TMV 3 and TMV 4. Among hybrids TMV 6 X TMV 7, TMV 4 X TMV 7 and TMV 3 X TMV 6 were the best for exploitation of heterosis. These hybrids were suitable for heterosis breeding to improve seed yield per plant and other component characters.

Table 1 : Analysis of variance for yield and yield attributing characters in sesame.

Source	df	Mean sum of squares							
		Days to 50 per cent flowering	Plant height at maturity	No. of branches per plant	No. of capsules per plant	Capsule length	No. of seeds per capsule	1000 Seed weight	Seed yield per plant
Replication	2	1.6931	0.6667	0.0284	1.1111	0.00032	0.5425	0.0083	0.1550
Genotype	35	12.9428**	85.7074**	3.7699**	411.5462**	2.1457**	80.2889**	1.7629**	4.8349**
Error	70	0.7326	4.3566	0.0723	7.5348	0.0076	4.0809	0.0068	0.2245

** Significant at 1 percent level

Table 2 : Analysis of variance for combining ability effects for yield and yield attributing characters in sesame.

Source	Mean sum of squares							
	Days to 50 per cent flowering	Plant height at maturity (cm)	Number of branches per plant	Number of capsules per plant	Capsule length (cm)	Number of seeds per capsule	1000 Seed weight (g)	Seed yield per plant (g)
GCA	6.58**	68.26**	1.24	120.63**	0.57	25.16**	0.93	3.22**
SCA	5.72**	25.05**	1.52	180.32**	0.94	29.54**	0.67	1.15
RCA	2.14	18.86**	0.98	99.55**	0.52	24.51**	0.38	1.52
GCS/SCA	1.15	2.72	0.81	0.66	0.60	0.85	1.38	2.8

** Significant at 1 percent level

Table 3 : General combining ability effects of parents for yield and yield attributing characters in sesame

Parents	Days to 50 per cent flowering	Plant height at maturity	No. of branches per plant	No. of capsules per plant	Capsule length	No. of seeds per capsule	1000 Seed weight	Seed yield per plant
TMV 3	-0.44**	2.10**	-0.24**	-3.54**	-0.13**	-0.20	-0.13**	-0.12
TMV 4	-0.13*	1.19**	0.20**	1.36**	0.03*	-0.94**	0.05**	-0.68**
TMV 6	0.05	-0.81*	0.06	1.26**	0.26**	2.18**	0.33**	0.16*
TMV 7	-0.86**	4.46**	0.50**	4.79**	0.24**	1.34**	0.31**	0.85**
VRI 1	0.05	1.00**	-0.19**	-0.59	-0.14**	-1.46**	-0.25**	0.11
VRI 2	1.33**	0.97**	0.40**	-3.29**	-0.26**	-0.91**	-0.30**	-0.31**
S.E for *gca*	0.1302	0.3176	0.0409	0.4176	0.0133	0.3074	0.0126	0.0721

Table 4 : Specific combining ability effects of crosses for yield and yield attributing characters in sesame

S. No.	Hybrids	Days to 50 per cent flowering	Plant height at maturity	No. of branches per plant	No. of capsules per plant	Capsule length	No. of seeds per capsule	1000 Seed weight	Seed yield per plant
1	TMV 3 X TMV 4	-0.97**	-0.22	0.05	1.43	-0.28**	-3.29**	-0.41**	-0.08
2	TMV 3 X TMV 6	-1.00**	-1.37	0.81**	6.98**	0.48**	1.32	0.56**	-0.06
3	TMV 3 X TMV 7	0.91**	3.01**	-0.84**	-8.24**	-0.48**	-2.29**	-0.37**	-1.00**
4	TMV 3 X VRI 1	0.06	-1.78*	-0.84**	6.02**	0.64**	-0.34	0.72**	0.51**
5	TMV 3 X VRI 2	-0.44	0.17	-0.18	-2.99**	-0.05	3.23**	-0.19**	-0.37*
6	TMV 4 X TMV 3	0.83	2.13*	-0.21	-1.93	0.05	2.14*	-0.06	0.30
7	TMV 4 X TMV 6	0.52	-1.67*	0.41**	1.61	0.24**	2.72**	0.32**	-1.01
8	TMV 4 X TMV 7	-1.05**	1.32	1.09**	11.02**	1.17**	5.84**	0.87**	1.24**
9	TMV 4 X VRI 1	-0.97**	4.10**	-0.70**	-9.54**	-0.32**	0.59	-0.20**	-0.15
10	TMV 4 X VRI 2	0.25	0.18	0.38**	8.13**	-0.12**	-1.39**	-0.02	0.12
11	TMV 6 X TMV 3	-0.66	-3.68**	1.50**	14.04**	1.13**	8.30**	0.72**	-0.18
12	TMV 6 X TMV 4	-0.50	-1.53	1.31**	12.42**	1.07**	4.89**	0.67**	2.01**
13	TMV 6 X TMV 7	-1.08**	-6.69**	1.21**	12.98**	1.24**	6.88**	0.80**	0.89**
14	TMV 6 X VRI 1	-0.33	2.12**	-0.68**	-7.02**	-0.56**	-2.58**	-0.69**	-0.54**
15	TMV 6 X VRI 2	-1.27**	1.98**	-0.52**	-2.97**	-0.36**	-2.10**	-0.25**	-0.28
16	TMV 7 X TMV 3	-0.33	-0.11	0.18	2.03	0.06	-1.00	-0.13**	-0.18
17	TMV 7 X TMV4	-0.33	5.45**	-0.06	-0.79	-0.01	1.39	0.04	0.23
18	TMV 7 X TMV 6	1.16**	-2.65**	-0.25*	0.53	0.11**	4.02**	0.16**	0.10
19	TMV 7 X VRI 1	-0.33	1.89*	-1.23**	-3.94**	-0.59**	-4.80**	-0.45**	-0.52**
20	TMV 7 X VRI 2	-1.27	5.36**	-0.61**	-9.57**	-0.48**	-3.88**	-0.23**	-1.24**
21	VRI 1 X TMV 3	1.33**	-0.42	-1.40**	-12.91**	-0.84**	-4.61**	-0.74**	-0.66**
22	VRI 1 X TMV 4	1.33**	4.80**	0.40**	3.35**	-0.10**	-0.79	0.26**	-0.40*
23	VRI 1 X TMV 6	-0.83*	1.91*	-0.11	1.55	-0.04	2.09*	0.29**	0.58**
24	VRI 1 X TMV 7	-0.33	1.23	-0.23*	-1.29	-0.02	1.71*	0.42**	0.56**
25	VRI 1 X VRI 2	-2.27**	-5.32**	1.07**	10.31**	0.87**	3.90**	0.87**	0.97**
26	VRI 2 X TMV 3	0.16	6.64**	0.03	0.68	0.07*	-3.48**	0.27**	-0.95**
27	VRI 2 X TMV 4	-0.16	0.98	-0.11	-5.84**	-0.04	-3.42**	0.29**	-0.01
28	VRI 2 X TMV 6	-2.50**	2.45**	0.26*	3.82**	0.02	1.12	0.25**	-0.95**
29	VRI 2 X TMV 7	1.33	0.77	0.11	0.66	0.09*	1.96*	0.15**	-0.81**
30	VRI 2 X VRI 1	0.83*	2.01*	-1.00**	-1.62**	-0.87**	-3.00	-0.84**	-0.66**
S.E for *sca*		**0.4118**	**0.7242**	**0.0933**	**0.9524**	**0.0302**	**0.7009**	**0.0287**	**0.1644**

Table 5 : Relationship between *gca* and *sca* effects

S. No	Character	*gca* effect	*sca* effect	Based on two criterion		
				High x High	High x Low (or) Low x High	Low x Low
1	Days to 50 per cent flowering (days)	VRI 2, TMV 7	TVT 3 x TMV 7, TMV 4 x TMV 6	-	TMV 4 x TMV 6	TMV 3 x TM 7
2	Plant height at maturity	TMV 7, TMV 3	TMV 7 x VRI 2, TMV 4 x VRI 1	TMV 7 x VR 2, TMV 4 x VRI 1	–	–
3	Number of branches per plant	TMV 7, VRI 2	TMV 6 x TMV 7, TMV 4 x TMV 7	TMV 6 x TMV 7, TMV 4 x TMV 7	-	-
4	Number of capsules per plant	TMV 7, TMV6	TMV 6 x TMV 7, TMV 4 x TMV 7	TMV 6 x TMV 7, TMV 4 x TMV 7	-	-
5	Capsule length	TMV 6, TMV 7	TMV 6 x TMV 7, TMV 4 x TMV 7	TMV 6 x TMV 7, TMV 4 x TMV 7	-	-
6	Number of seeds per capsule	TMV 6, TMV 7	TMV 6 x TMV 7, TMV 4 x TMV 7	TMV 6 x TMV 7	TMV 4 x TMV 7	-
7	1000 seed weight	TMV 6, TMV 7	TMV 4 x TMV 7, TMV 6 x TMV 7	TMV 4 x TMV 7, TMV 6 x TMV 7	-	-
8	Seed yield per plant	TMV 7, TMV 6	TMV 4 x TMV 7, VRI 1 x VRI 2	-	TMV 4 x TMV 7, VRI 1 x VRI 2	VRI 1 x VRI 2

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