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Combining Ability Analysis—A Comparison of Methods in Sesame (*Sesamum indicum* L.)

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Abstract

The F_1 of an 11-parent half diallel in sesame along with the parental varieties was evaluated for 8 characters. A partial diallel with s = 6 and a 6 × 5 set of line × tester crosses were derived and the data on capsules/plant, seeds/capsule and yield/plant was analyzed for combining ability and nature of gene action by four methods, i.e., diallel method 2 and method 4, partial diallel and line × tester cross. All methods gave similar results with regard to GCA effects of the parental varieties for all the three characters. Diallel method 4, partial diallel and line × tester cross gave similar results and the diallel method 2 gave slightly different result with regard to nature of gene action involved in the inheritance of the characters. When the number of lines/varieties to be evaluated is large, a partial diallel with s = 5 or 6 or a line × tester cross that uses 5 or 6 testers can be used instead of a diallel cross without any serious loss of information.
Key words : Combining ability analysis, Diallel, Partial diallel, Line × tester, Sesame.

Combining ability analysis helps in identifying superior parental stock for hybridization method of breeding for productivity. It also permits analysis of nature of gene action involved in the inheritance of quantitative traits. The information on gene action helps in deciding upon appropriate breeding method and efficient selection procedure. Thus, plant breeders go for combining ability evaluation almost as a pre-requisite in breeding for productivity. The mating design commonly used for this is the half diallel cross which includes the parents and a set of all possible crosses among them without reciprocals. Griffing (1) has described four methods of diallel analysis of combining ability. Two of these use reciprocal crosses with and without parents (method 1 and method 3) and the other two use a half diallel with and without parents (method 2 and method 4). In diallel, the number of crosses increases rapidly with increase in number of parents. When the number of lines/varieties to be evaluated is large, one would not go for a diallel because of practical difficulties. This led to development of the concept of partial diallel, which uses a sample of all possible crosses among a set of parents (2). Another method used for combining ability evaluation is line × tester design (3). Some workers have compared the results obtained from diallel and partial diallel analyses and tried to find optimum value of s (number of crosses per parent) in partial diallel (4, 5). It would be useful to examine as to how the results from such alternative methods as diallel, partial diallel and line × tester analyses compare. Singh and Singh (6) have made such a comparison with regard to nature of gene action in mustard. The present study in sesame makes a comparison of results obtained from diallel (method 2 and method 4), partial diallel and line × tester analyses with regard to combining ability of the parental varieties and the nature of gene action for yield component traits.

Methods

The material of the study consisted of an 11-parent half diallel cross in sesame. The parental varieties included three improved varieties (Uma, Prachi and Kalika) of Orissa and eight improved varieties (Pragati, TKG-2, GT-10, HT-1, VRI-1, TC-25, B-67 and AKT-64) of eight other states. The F_1 of the 55 crosses along with the 11 parental varieties was grown in an randomized block design with four replications during summer, 2005. Each entry was represented by one row of 2.5 m in each replication. Sowing was done with 35 cm × 10 cm spacing and normal agronomic practices including fertilizer application and plant protection measures were followed. The crop was irri-

Table 1. ANOVA of combining ability for three characters in F_1 of crosses among 11 varieties of sesamum using different methods. *, ** Significant at 5 and 1%, respectively.

Methods	Source	df	Capsules/plant MS	Seeds/capsule MS	Yield/plant MS
Diallel method-2	Genotype	65	86.029**	20.485**	1.661**
	GCA	10	305.013**	62.859**	3.990**
	SCA	55	46.213**	12.780**	1.127**
	Error	195	18.581	5.059	0.458
Diallel method-4	Genotype	54	71.722**	12.988**	1.189
	GCA	10	227.141**	38.166**	1.801**
	SCA	44	36.399**	7.266	0.822
	Error	162	17.322	5.369	0.491
Partial diallel (s=6)	Genotype	32	87.700**	10.464**	1.211**
	GCA	10	201.344**	21.540**	2.146**
	SCA	22	36.043*	5.429	0.785*
	Error	96	21.289	4.914	0.481
Line × Tester (6 × 5)	Genotypes	29	80.451**	13.461**	1.397**
	GCA (L)	5	155.655**	13.000*	2.388**
	GCA (T)	4	209.565**	44.187**	2.408**
	SCA	20	35.828*	7.431	0.947*
	Error	87	21.057	4.921	0.497

gated as and when required . Observations were taken on days to flowering and maturity on plot basis and on six other characters including yield per plant from eight random plants per plot. The present study has been limited to 3 characters, i.e. number of capsules per plant, number of seeds per capsule and yield per plant.

The parental varieties of the diallel cross were renumbered by draw of lots and a partial diallel was derived using the circulant scheme of Kempthorne and Curnow (2). With this same ordering of the varieties, a set of line × tester crosses was derived taking the first six varieties as lines and the remaining five as testers. General ANOVA was carried out on plot mean values for the three characters – capsules/plant, seeds/capsule and yield/plant. The diallel cross was analyzed by Griffing's (1) method 2 (DM-2) and method 4 (DM-4). The partial diallel (PD) was analyzed following Kempthorne and Curnow (12) and the line × tester crosses (L × T) analyzed following Kempthorne (3). In all the four methods, GCA effects of the parental varieties were estimated under model I. Also, assuming the set of parental varieties to be a random sample of genotypes, GCA variance (σ^2_{gca}) and SCA variance (σ^2_{sca}) were estimated from ANOVA of combining ability and the nature of gene action was analyzed.

Results and Discussion

Analysis of variance revealed significant differences among parents and F_1 hybrids in diallel method 2 (DM-2) and among the F_1 hybrids in other methods (DM-4, PD & L × T) for all the three characters (Table 1). Means of the parental varieties ranged from 28.84 to 61.19 for capsules/plant, 46.37 to 71.50 for seeds/capsule and 3.96 to 7.62 g for yield per plant. Among the full set of 55 F_1 hybrids among 11 varieties, the range was 34.32—64.69 for capsules/plant, 53.72—70.53 for seeds/capsule and 5.07—9.75 g for yield per plant. ANOVA of combining ability and *F* test under model I revealed significant differences in GCA effects of the parental varieties for all the three characters in all 4 methods . All methods revealed significant differences in SCA effects of crosses for capsules/plant. Diallel method 4, partial diallel and line × tester methods indicated no significant differences in SCA effects for seeds/capsule, while diallel method 2 indicated significant differences in SCA effects for seeds/capsule, while diallel method 2 indicated significant differences in SCA effects for the character, which could be due to the inclusion of parents in this method. All methods except diallel method 4 revealed significant differences in SCA effects for yield. F test under model II revealed significant contribution of GCA component to genetic variation for all charac-

Table 2. GCA effects of parents for three characters estimated by different methods in F_1 of crosses among 11 varieties of sesame H, L – High and Low GCA effects and rest moderate GCA effect.

		Capsules/plant				Seeds/capsule	
	Varieties	DM-2	DM-4	PD	L × T	DM-2	DM-4
1.	Pragati	-3.82 L	-3.72 L	-5.33 L	-1.20	-3.20 L	-1.72 L
2.	Uma	2.77	2.64	1.52	3.99	0.31	0.18
3.	TKG-22	-6.77 L	-6.92 L	-7.78 L	-7.30 L	-0.75	-0.94
4.	Prachi	3.81 H	5.63 H	5.33 H	6.41 H	-0.44	0.33
5.	GT-10	4.06 H	4.56 H	5.21 H	3.64	0.48	-2.00 L
6.	HT-1	-1.97	-3.16	-3.46	-5.54	2.57 H	2.60 H
7.	VRI-1	8.92 H	8.55 H	12.33 H	7.82 H	-2.54 L	-2.37 L
8.	Kalika	2.52	2.03	5.56 H	4.52 H	4.63 H	4.41 H
9.	TC-25	-5.46 L	-5.66 L	-4.59 L	-6.05 L	-1.42 L	1.08 L
10.	B-67	-0.06	-0.54	-2.96	-2.24	0.64	1.08 H
11.	AKT-64	-3.99 L	-3.42	-5.83 L	-4.06 L	-0.28	-0.49
	SE (g_i)	1.14	1.32	2.77	L 2.22 T 2.05	0.60	-0.74

Table 2. Continued.

		Seeds/capsule		Yield/plant (g)			
	Varieties	PD	L × T	DM-2	DM-4	PD	L × T
1.	Pragati	-1.92 L	-2.12 L	0.056	0.169	-0.072	0.332
2.	Uma	-0.62	1.51	0.639 H	0.533 H	0.122	0.696 H
3.	TKG-22	-0.90	0.15	-0.789 L	-0.763 L	-0.944 L	-0.834 L
4.	Prachi	-0.88	-0.36	-0.115	0.106	-0.033	-0.067
5.	GT-10	-1.52 L	-1.29 L	0.744 H	0.640 H	0.796 H	0.672 H
6.	HT-1	3.76 H	2.11 H	-0.434 L	-0.536 L	-0.191	-0.800 L
7.	VRI-1	-1.13 L	-3.20 L	0.186	0.229	0.955 H	0.024
8.	Kalika	4.48 H	3.96 H	0.442 H	0.337 H	0.597 H	0.646 H
9.	TC-25	-1.01 L	-1.11 L	-0.901 L	-1.001 L	-0.783 L	-0.886 L
10.	B-67	0.92	1.23 H	-0.249	-0.246	-0.585 L	-0.326
11.	AKT-64	-1.18 L	0.88	0.421 H	0.532 H	0.138	0.543 H
	SE (g_i)	1.08	L 1.07 T 0.99	0.179	0.223	0.409	L 0.340 T 0.315

ters in all methods except the line × tester cross indicating no significant contribution of this component to genetic variation for yield.

GCA Effects

The estimates of GCA effects of the varieties from the four methods of analysis are presented in Table 2. The results from diallel method 2 and method 4 with regard to GCA of the varieties were similar for all the three characters (Table 2). The results from partial diallel and line × tester analyses were nearly similar to those from DM-2 and DM-4, although there were minor differences between the results of PD and L × T analyses. All the methods showed that VRI-1 and Prachi were good general combiners for capsules/plant, while TKG-22, TC-25 and AKT-64 were poor combiners for this character. All four methods showed Kalika as the best general combiner and HT-1 as the second best general combiner for seeds/capsule, while Pragati, VRI-1and TC-25 were poor combiners for the character. The diallel methods (DM-2 and DM-4) showed GT-10 as the best general combiner for yield and this variety ranked second in GCA for the character under partial diallel and line × tester analyses. All four methods showed that Kalika was also a good general combiner, while TC-25 and TKG-22 were poor combiners for yield/plant. There were only a few minor variations in ranking of the varieties for GCA effect for the traits.

Considering the GCA estimates and their standard errors under different methods, the varieties were categorized as high, medium and low general combiners, which has been indicated in Table 2. Going by

Table 3. Estimates of variance components and heritability for three characters from different methods in F_1 of crosses among 11 varieties of sesame. DM-2, DM-4 and PD : $\sigma^2_A = 2\sigma^2_{gca}$, $\sigma^2_{NA} = \sigma^2_{sca}$, $\sigma^2_G = \sigma^2_A + \sigma^2_{NA}$ L × T : $\sigma^2_A = \sigma^2_{gca.\,l} + \sigma^2_{gca.t}$ $\sigma^2_{NA} = \sigma^2_{SCA}$

	σ^2_{gca}	σ^2_{sca}	σ^2_e	σ^2_A/σ^2_G	σ^2_{NA}/σ^2_G	h^2_{BS}
Capsules/plant						
Diallel method-2	19.908	27.633	18.581	0.590	0.410	78.40
Diallel method-4	21.193	19.077	17.322	0.690	0.310	78.01
Partial diallel (s = 6)	31.486	14.754	21.289	0.810	0.190	78.50
Line × Tester (6 × 5) L	23.965					
T	28.956	14.771	21.057	0.782	0.218	76.27
Seeds/Capsule						
Diallel method-2	3.852	7,721	5.059	0.499	0.501	75.30
Diallel method-4	3.433	1.897	5.369	0.783	0.217	62.01
Partial diallel (s = 6)	3.069	0.515	4.914	0.922	0.078	57.51
Line × Tester (6 × 5) L	1.114					
T	6.126	2.511	4.921	0.742	0.258	66.46
Yield/plant						
Diallel method-2	0.212	0.779	0.458	0.352	0.648	72.39
Diallel method-4	0.220	0.331	0.491	0.571	0.429	61.07
Partial diallel (s=6)	0.259	0.304	0.481	0.630	0.370	63.07
Line × Tester (6 × 5) L	0.288					
T	0.244	0.450	0.497	0.542	0.458	66.40

this, 7 of the 11 varieties fell into the same high or medium or low GCA category for capsules/plant under all methods. Similarly, 8 varieties for seeds/capsule and 6 varieties for yield/plant fell into same GCA category under all methods. In other cases, there were minor deviations such as from high to medium or medium to low but not from high to low. For example, DM-2, DM-4 and PD showed Pragati as a low general combiner and GT-10 as a high general combiner for capsules/plant, while L × T put these two varieties under medium category. L × T showed Uma as a high general combiner for seeds/capsule but the other methods put it under medium category. For yield/plant, the varieties Uma, HT-1, VRI-1, B-67 and AKT-64 in DM-2, DM-4 and L × T methods fell in same GCA category, while it was slightly different in PD. How the estimates of GCA effect from different methods compared was also examined by correlations (Table 3). The correlation coefficients ranged between 0.744 and 0.988 across characters. All correlations among the four methods for GCA of parental varieties were high for all characters except the one (r =.744) between PD and L × T in case of yield. By and large, the results with regard to GCA of parents from the 4 methods were similar, apart from minor deviations in ranking that could happen as a result of sampling fluctuations.

Nature of Gene Action

The nature of gene action involved in the inheritance of a character was inferred from the relative proportions of additive genetic variance (σ^2_A) and non-additive genetic variance (σ^2_{NA}) taking 2 σ^2_{gca} as σ^2_{gca} as σ^2_A in diallel methods 2 and 4 (DM-2 and DM-4) and partial diallel (PD), $\sigma^2_{gca.l} + \sigma^2_{gca.t}$ as σ^2_A in line × tester (L × T) and σ^2_{sca} as σ^2_{NA} in all methods. Estimates of variance components and heritability from the four methods are presented in Table 4. In DM-2, σ^2_A constituted 59% and σ^2_{NA} constituted 41% of the genetic variance (σ^2_G) for capsules/plant, indicating that additive gene action played a greater role in the inheritance of the character. But the two components – σ^2_A and σ^2_{NA}, constituted 69% and 31% of σ^2_G in DM-4, 81% and 19% in PD and 78.2% and 21.8% in L × T, all indicating a predominant role of additive gene action in the inheritance of capsules/plant. Sprague (7) noted that estimates of variance components are usually subject to large sampling fluctuations, but they are the most general measures of genetic properties of quantitative traits. There were differences between estimates from different methods, but they appeared to be within the limits of sampling fluctuations.

In DM-2, σ^2_A constituted 49.9% and σ^2_{NA} constituted 50.1% of σ^2_G for seeds/capsule,indicating that both additive and non-additive gene action played equally important role in the inheritance of the character. But the two components —σ^2_A and σ^2_{NA}, constituted 78.3% and 21.7% of σ^2_G in DM-4, 92.2% and 7.8% in PD and 74.2% and 25.8% in L × T, all indicating a predominant role of additive gene action in the inheritance of seeds/capsule. In DM-2, σ^2_A constituted 35.2% and σ^2_{NA} constituted 64.8% of σ^2_G for yield, indicating that non-additive gene action played a more important role in the inheritance of the character. But the two components—σ^2_A and σ^2_{NA}, constituted 57.1% and 42.9% of σ^2_G in DM-4, 58.1% and 41.9% in PD and 54.2% and 45.8% in L × T, all indicating that both additive and non-additive gene action played equally important role in the inheritance of yield. Three methods i.e., DM-4, PD and L × T, showed that gene action was predominantly additive for capsules/plant and seed/capsule and both additive and non-additive gene action were equally important for yield/plant, while DM-4 gave slightly different result. According to Griffing (1) diallel method 4 is better than method 2.

Broad-sense heritability estimates (h^2_{bs}) from the four methods, ranging between 76.27 and 78.50%, were similar for capsules/plant. For other two characters, DM-2 gave higher estimates of 75.30% for seeds/capsule and 72.43% for yield. The other three methods (DM-4, PD and L × T) gave similar estimates, ranging between 57.52 and 66.46% for seeds/capsule and 61.09 and 66.40% for yield. Thus, the results from PD and L × T with regard to GCA effects, nature of gene action and heritability were closer to those from diallel method 4 than to those from method 2.

By and large, all the four methods gave similar results with regard to the general combining ability of the parental varieties and the nature of gene action involved in the inheritance of the characters studied. The results on the nature of gene action were in general agreement with those of Singh and Singh (6) who compared diallel method 2, partial diallel and line × tester analyses of gene action in mustard. Murty et al. (4) reported that a partial diallel with s close to n/2 gave similar results as a diallel. Dhillon (8), reviewing the work on partial diallel, noted that 5—7 crosses per parent appeared to be adequate for evaluating the GCA of parents. These results were kept in view while deciding on s = 6 for the partial diallel and number of testers (t = 5) for the line × tester cross in this study. The results of the study showed that when the number of lines/varieties to be evaluated is large, a partial diallel with s = 5 or 6 or a line × tester cross that uses 5 or 6 testers can be used instead of a diallel cross without any serious loss of information sought to be gathered from such a study.

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