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Research Article

Combining ability analysis for yield and yield components in sesame (*Sesamum indicum* L.)

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Abstract
Combining ability for eleven characters was studied in sesame using 10 lines *viz*., ES-246, AT-24, SPS-19, BAVJ-1, TNAU-2, Kalyanpur-2, Mota Liliya-1, Ingorola-7, SI-968 and Timbi-3 as females and 4 testers RT-125, Guj.Til-1, Guj.Til-2 and Guj.Til-10 as males crossed in line x tester mating design. Combining ability analysis revealed predominance of non- additive gene action for all the characters *viz*., days to 50 per cent flowering, plant height, number of effective branches per plant, number of capsules per plant, capsule length, days to maturity, number of seeds per capsule, 1000-seed weight, yield per plant, harvest index and oil content which can be improved by bi-parental mating or reciprocal recurrent selection. The female parents ES-246, BAVJ-1, Kalyanpur-2, Ingorola-7 and male parent Guj.Til-1 were found as the good general combiners for seed yield per plant. The cross combinations Timbi-3 x Guj.Til-10, TNAU-2 x Guj.Til-2 and SI-968 x Guj.Til-2 showed high *per se* performance and significant *sca* effects for yield per plant, such crosses would be exploited for future use.

Key words
Sesame, Line x tester, general combining ability, specific combining ability

Introduction

Sesame (*Sesamum indicum* L.) is one of the important oilseed crops grown either as a pure or mixed crop in the country since ancient times. It has attracted special attention as an important salad dressing and edible oil. India is the largest sesame seed producer in the world and also the largest exporter of sesame seed in the world accounting for a share of 23%. The total global exports of sesame seed were at a level of 1.31 million tons during 2012-13. (Anonymous, 2014). Among the sesame growing states, Gujarat contributes 28.6 % of total sesame production of the country. The state also having greater potential for sesame production for domestic and export markets but the yield of this valuable crop is low especially in rainy season due to lack of improved varieties as well as resistance to pests and diseases of economic importance. Intensive efforts are needed for increasing sesame productivity. Studies on combining ability are of paramount importance to select suitable parents for hybridization. In the present investigation attempts have been made to evaluate fourteen parents (ten lines, four testers) and 40 hybrids through Line × Tester analysis to bring out the best parents and cross combinations with good general and specific combining abilities for seed yield and its component characters.

Material and method

Ten females ES-246, AT-24, SPS-19, BAVJ-1, TNAU-2, Kalyanpur-2, Mota Liliya-1, Ingorola-7, SI-968, and Timbi-3 were crossed with four males RT-125, Guj.Til-1, Guj.Til-2, Guj.Til-10 as per the line x tester mating design (Kempthorne, 1957) during the *summer* 2011 at college farm, Navsari Agricultural University, Navsari. All 40 F_1s along with 14 parental lines were evaluated in randomized block design with three replications during the *Rabi* 2011-12 for eleven different characters *viz*., days to 50 per cent flowering, plant height(cm), number of effective branches per plant, number of capsules per plant, capsule length(cm), days to maturity, number of seeds per capsule, 1000-seed weight(g), yield per plant(g), harvest index(%) and oil content(%). Each entry was planted in a single row consisting 20 plants with a spacing of 45 x 15 cm^2. All recommended package of practices were followed to raise the successful experimental crop. Observations were recorded on five randomly selected plants from each plot of all replications for all the characters except days to 50 per cent flowering and days to maturity, for which observations were recorded on plot basis. Clean seeds with 10-12 per cent moisture were used for oil estimation through Nuclear Magnetic Resonance (NMR) spectrometer (Bruker, Minispec 20pl) (Anonymous, 2014). The mean values of the character for different entries was subjected to line x tester analysis and variance due to general combining ability (*gca*) for parents and specific combining ability (*sca*) of different cross combinations were worked out based on the procedure developed by Kempthorne (1957).

Result and discussion

Combining ability analysis in self pollinated crops is generally conducted to find out suitable parents and more appropriately a cross with greater potential to produce desired recombinant lines. The combining ability analysis revealed that the mean squares among the parents were significant for days to 50 per cent flowering, plant height, number of effective branches per plant, days to maturity and oil content indicating presence of genetic variability among the parents (Table 1). The hybrids differed significantly for all the characters indicating genetic variability among the hybrids. The parents vs hybrids were significant for all the characters except capsule length, number of seeds per capsule and 1000 seed weight indicating the presence of substantial differences between the crosses. The lines showed the significant difference for all the characters except days to 50 per cent flowering, capsule length, days to maturity and 1000 seed weight, indicated the prevalence of additive variance for those traits, whereas non significant estimates of testers for all the characters indicating the prevalence of non additive variance. The mean squares due to line x tester interaction component also emerged significant for all the characters indicating that combining ability contributed remarkably in the expression of these characters and it also provided a direct test indicating that dominance or non additive variance was important for the characters under study. The variance due to sca was higher than gca as indicated by σ^2gca/ σ^2sca ratio being less than one for all the eleven characters *viz.*, days to 50 per cent flowering, plant height, number of effective branches per plant, number of capsules per plant, capsule length, days to maturity, number of seeds per capsule, 1000-seed weight, yield per plant, harvest index and oil content suggesting the significant role of non additive gene action like dominance, epistatic and other interaction effects in the expression of these characters. This was in the agreement with the findings of Manivannan and Genesan (2001), Mishra and Sikarwar (2001), Kumar and Ganesan (2002), Mothilal *et al.* (2003), Vidhyavathi *et al.* (2005), Solanki and Singh (2006), Sharmila and Ganesh (2008), Bharathi Kumar and Vivekanandan (2009) and Yamanura *et al.* (2009).

The gca values revealed that among the ten lines, ES-246 recorded highest significant gca value. The other lines BAVJ-1, Kalyanpur-2 and Ingorola-7 had also exhibited significant positive gca values for yield per plant. This implied that favourable genes for seed yield per plant were present in all these four lines and by using these lines as a parent may increase seed yield per plant. Significant negative gca value of SPS-19 and SI-968 as parent might reduce the seed yield per plant. ES-246 had also exhibited significant and desired directional gca values for the days to 50 per cent flowering, number of capsules per plant, days to maturity, number of seeds per capsule, harvest index and oil content. BAVJ-1 showed significant and desired directional gca values for plant height, number of effective branches per plant, number of capsules per plant, days to maturity, number of seeds per capsule and oil content. Kalyanpur-2 recorded significant desired gca values for plant height, number of effective branches per plant, capsule length, days to maturity and oil content. Significant and positive gca values recorded by Ingorola-7 for number of effective branches, number of seeds per capsule, 1000 seed weight and harvest index.

Among the four testers, Guj.Til-1 exhibited significantly positive gca value and Guj.Til-2 showed significantly negative gca value for seed yield per plant. This implies that favourable genes for seed yield improvement are present only in Guj.Til-1 and it may be used as a parent to improve the same character. Guj.Til-1 also exhibited significantly desired directional gca values for days to 50 per cent flowering, days to maturity and number of effective branches per plant, which indicated that along with high yielding favourable genes it also possesses desired genes for earliness and it may be used as a parent to improve both these characters at a time, whereas use of Guj.Til-2 might reduce the seed yield per plant.

Out of 40 crosses, six crosses *viz.*, AT-24 x Guj.Til-2, TNAU-2 x Guj.Til-2, Kalyanpur-2 x RT-125, Ingorola-7 x RT-125, SI-968 x Guj.Til-2 and Timbi-3 x Guj.Til-10 exhibited significant positive sca values for seed yield per plant. On the other hand eight crosses, *viz.*, ES-246 x Guj.Til-10, AT-24 x Guj.Til-10, BAVJ-1 x Guj.Til-2, TNAU-2 x RT-125, Kalyanpur-2 x Guj.Til-2, Ingorola-7 x Guj.Til-2, Timbi-3 x Guj.Til-1 and Timbi-3 x Guj.Til-2 exhibited significant negative sca values for seed yield per plant. Oil content is one of the most important quality attribute for the selection of any hybrid or variety in sesame. Timbi-3 x Guj.Til-10 is the only cross which had exhibited significant and positive sca value for oil content. If seed yield per plant and oil content are assumed to be the most important yield and quality characters than Timbi-3 x Guj.Til-10 seemed to be promising for development of both high yielding and high oil containing genotype due to its high and significantly positive sca values for seed yield per plant and oil content. Moreover, Timbi-3 x Guj.Til-10 involved average x average type of general combiners for seed yield per plant and average x poor type of combiner for oil content, indicating that the cross may be subjected to heterosis breeding and also for improving seed yield per plant and oil content in the advanced generation.

Three best specific combiners with sca values for different yield and related characters are shown in Table 2. The parental gca values were classified as high, medium and low derived from the total range of the gca values for any character which was divided into three parts where low (L) indicates the lower one third, medium (M) indicates the middle one third and high (H) indicates the upper one third in the range. The desirable combinations involved high x high, high x medium, high x low, medium x medium, medium x low and low x low type of general combiners. The desirable performance of combination like high x low may be ascribed to the interaction between dominant allele from good combiners and recessive allele from poor combiners. Moreover, a high x low cross can result in strong transgressive segregants for the desired characters due to segregation of genes with strong potentials and their specific buffers (Langham 1961). Such combinations were observed in the hybrids ES-246 x Guj. Til-2 for days to 50 per cent flowering, ES-246 x Guj. Til-1 for plant height, Kalyanpur-2 x RT-125 for number of effective branches per plant, Ingorola-7 x Guj. Til-1 for capsule length, Kalyanpur-2 x Guj. Til-10 and SI-968 x Guj. Til-10 for days to maturity and Timbi-3 x Guj. Til-10 and Ingorola-7 x Guj. Til-2 for oil content.

The sca value is a useful index to determine the usefulness of particular cross combination for exploitation of heterosis. Among the crosses, high sca values and *per se* performances for yield per plant were observed for Timbi-3 x Guj. Til-10, TNAU-2 x Guj. Til-2, SI-968 x Guj. Til-2, Ingorola-7 x RT-125, AT-24 x Guj. Til-2 and Kalyanpur-2 x RT-125. These crosses had also showed significant and desired sca values for other related yield contributing characters like number of effective branches, capsule length, number of seeds per capsule and plant height. This appeared appropriate as yield being a complex character depends on a number of component traits.

It can be summarized considering all the variance estimates that capsule length and 1000 seed weight can be controlled by non additive gene action indicating heterosis breeding may be employed to improve these characters. Whereas plant height, number of effective branches per plant, number of capsules per plant, days to maturity, number of seeds per capsule, yield per plant, harvest index and oil content were controlled by both additive and non additive gene action but predominantly by non additive gene action so the methodology such as bi-parental mating and diallel selective mating may be resorted to, than conventional pedigree and backcross techniques which would leave the unfixable components of genetic variances unexploited for yield and its components.

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Table 1. Analysis of variance for combining ability of various characters in sesame

Characters	d.f.	Days to 50 per cent flowering	Plant height (cm)	No. of effective branches per plant	No. of capsules per plant	Capsule length (cm)	Days to maturity	No. of Seeds per capsule	1000-seed weight (g)	Yield per plant (g)	Harvest index (per cent)	Oil content (per cent)
Replication	2	2.49	103.44	0.28	92.33	0.00	3.52	67.68	0.05	0.16	26.38	5.06
Parents (P)	13	13.63**	89.43**	0.46**	35.04	0.01	368.79**	34.10	0.08	2.69	11.46	15.99**
Hybrids (H)	39	12.02**	222.27**	1.96**	669.97**	0.04**	367.38**	103.06**	0.12**	10.07***	85.41**	8.79**
P Vs H	1	77.29**	181.45*	1.38**	428.35**	0.00	9.82*	17.71	0.01	51.37***	454.37**	21.43**
Lines (L)	9	8.22	575.01**	3.88*	1497.14**	0.02	327.04	204.31*	0.18	26.74**	164.71*	25.18**
Tester (T)	3	15.93	119.43	1.23	2.81	0.06	536.73	52.12	0.05	6.28	26.19	2.74
Line x Tester	27	12.85**	116.12**	1.40**	468.38**	0.04**	362.01**	74.97**	0.11**	4.94**	65.55**	3.99**
Error	78	1.06	40.55	0.11	48.52	0.004	2.42	18.25	0.05	0.70	10.66	1.57
σ^2 gca		0.53	14.86**	0.12**	33.71**	0.002	20.45*	5.04**	0.003	0.55**	4.14*	0.56**
σ^2 sca		3.94**	26.95**	0.43**	142.09**	0.01**	119.88**	17.50***	0.02**	1.41**	18.98**	0.72**
σ^2 gca/ σ^2 sca		0.13	0.55	0.27	0.24	0.15	0.17	0.29	0.15	0.38	0.22	0.80

*, ** = Significant at P=0.05 % and 0.01 level, respectively.

Table 2. Superiority of F_1 hybrids identified based on sca effects, *per se* performance and based on the gca values of parents

Characters	Best specific combination	sca effects	*Per se* performance	gca value of the parents
Days to 50 per cent flowering	ES-246 x Guj.Til-2	-3.00	37.00	H x L
	TNAU-2 x Guj.Til-10	-2.90	38.33	M x M
	Mota Liliya-1 x RT-125	-2.28	38.00	M x M
Plant height (cm)	ES-246 x Guj.Til-1	-11.69	67.49	L x H
	Timbi-3 x Guj.Til-1	-8.41	67.63	H x H
	BAVJ-1 x Guj.Til-2	-7.92	80.46	L x M
No. of effective branches per plant	Kalyanpur-2 x RT-125	1.35	5.63	H x L
	Ingorola-7 x Guj.Til-1	1.23	5.85	H x M
	BAVJ-1 x Guj.Til-2	1.05	5.83	H x M
No. of capsules per plant	SI-968 x Guj.Til-10	23.00	113.12	M x M
	Ingorola-7 x RT-125	21.23	104.11	L x M
	Timbi-3 x RT-125	19.78	121.23	H x M
Capsule length (cm)	BAVJ-1 x RT-125	0.22	3.06	M x M
	Ingorola-7 x Guj.Til-1	0.13	2.95	L x H
	Ingorola-7 x RT-125	0.12	2.88	L x M
Days to maturity	Kalyanpur-2 x Guj.Til-10	-15.87	83.67	H x L
	Mota Liliya-1 x Guj.Til-2	-13.62	87.33	M x H
	SI-968 x Guj.Til-10	-13.20	87.00	H x L
No. of seeds per capsule	Ingorola-7 x Guj.Til-2	8.52	64.51	M x M
	AT-24 x RT-125	6.99	61.06	M x L
	TNAU-2 x Guj.Til-1	6.15	57.89	L x M
1000-seed weight (g)	SPS-19 x Guj.Til-2	0.44	3.60	M x M
	AT-24 x RT-125	0.23	3.60	M x M
	Kalyanpur-2 x Guj.Til-1	0.21	3.51	M x M
Yield per plant (g)	Timbi-3 x Guj.Til-10	3.17	12.52	M x M
	TNAU-2 x Guj.Til-2	1.54	9.91	L x M
	SI-968 x Guj.Til-2	1.41	9.01	L x M
Harvest index (per cent)	SPS-19 x Guj.Til-2	7.91	36.23	L x M
	SI-968 x Guj.Til-2	7.65	44.19	H x M
	Kalyanpur-2 x Guj.Til-10	7.15	41.32	H x M
Oil content (per cent)	Timbi-3 x Guj.Til-10	2.57	48.15	L x H
	Ingorola-7 x Guj.Til-2	2.25	48.78	L x H
	SI-968 x Guj.Til-1	1.23	48.20	M x H