

Full Length Research Paper

Combining ability for yield and yield components in six parents and their 15 F₁ hybrids of sesame (*Sesamum indicum* L.) in half diallel mating design

Salah Balla M. Ahmed^{1*} and Shahira I. Adam²

¹Faculty of Agricultural and Environmental Science, University of Gadaref, Tawawa, Sudan.

²Ministry of Agriculture and Forestry, Gadaref, Sudan.

Received 4 August, 2014; Accepted 25 September, 2014

Combining ability estimates were studied for seed yield, yield components and other morphological traits in six sesame parental lines and their 15 F₁ hybrids crossed in half diallel for two consecutive seasons 2012/2013 - 2013/2014 at Gadaref University Farm, Gadaref, Sudan. Combining ability analysis revealed that both additive and non additive types of gene actions were important in the studied traits. For days to 50% flowering and days to maturity, Khidir was the only parent that scored negative general combining ability (GCA) effects in both seasons. Therefore it was desired to be selected for earliness. For seed yield kg/ha and the yield related characters viz., 1000- seed weight and the yield per plant, significant positive SCA effects were observed by the crosses, Kenana-2 X Gd 002SPSN-12 and Promo X Gd2002SPSN.12, whereas, negative significant effects were showed by Gadarif-1 XUmshagera. The rest of the crosses combinations were inconsistent across the seasons, some of them recorded a positive value in one season and a negative values in another one. Khidir and Promo recorded a positive significant GCA effects for the yield and its components at least in one season. Moreover, Promo was the best combiner with other parental lines for earliness since it recorded negative SCA values. Therefore, Khidir, Promo and Gd2002SPSN.12 could be recommended to produce progeny having high yield and early maturing hybrids, through recurrent selection or reciprocal cross.

Key words: Combining ability, sesame hybrids, sesame yield, yield components.

INTRODUCTION

Sesame (*Sesamum indicum* L.), commonly known as *gingelly*, *til*, *benniseed*, *simsim* is a member of the order Tubiflorae and family Pedaliaceae. It is probably the most ancient oilseed known and used by man and its domestication is lost in the mists of antiquity (Weiss, 1983). Although originated in Africa, it spreads early

through West Asia to India, China and Japan which themselves became secondary distribution centers (Weiss, 1983). It is called the "Queen of oil seeds" because of its excellent qualities of the seed, oil and meal. Sesame is highly nutritive (oil 50%, protein 25%) and its oil contains an antioxidant called sesamol which

*Corresponding author. E-mail: salahballa72@yahoo.com

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](http://creativecommons.org/licenses/by/4.0/)

imparts a high degree of resistance against oxidative rancidity. Sesame cake is nutritious feed for dairy cattle and it can also be used as fertilizer (Ashri, 1989).

Sesame is one of the most important oilseed crops in Sudan for both local consumption and for export (Ahmed, 2008). It is widely grown under rain-fed conditions; in Gadarif, Damazin, Kordofan and Darfur. Recently, sesame has been grown on small scale in River Nile State under pump irrigation (Abdelkarim and Sulieman 2008). Sesame ranks third after sorghum and millet area wise. It was grown on about 820,260 ha, and produced about 187,000 tons of seed (covering about 4% of the total world production), with average seed yield of 228 kg/ha. The world average seed yield is 511 kg/ha (FAOSTAT, 2014).

In an often cross-pollinated crop like sesame there is a good scope for exploitation of heterosis. Further, an understanding of the combining ability and gene action is a prerequisite for any successful breeding programme. For breaking the yield barrier and evolving varieties with high yield potential, it is desirable to combine the genes from genetically diverse parents. There are several techniques for evaluating the varieties or cultivars or lines in terms of their combining ability and genetic make up, of these, Diallel, partial Diallel and line X tester techniques are in common use.

The concept of combining ability analysis gives precise estimates of the nature and magnitude of gene actions involved in the inheritance of quantitative characters, which facilitate the identification of parents with good general combining ability (GCA) effects and crosses with good specific combining ability (SCA) effects.

Many researchers studied the concept of the combining ability for yield and yield related characters in sesame. Thiyagarajan and Ramanathan (1995) reported that the influence of non-additive gene action was observed for number of branches /plant, number of capsules /plant, 1000 seed weight and seed yield. The predominance of additive gene action was observed for days to 50% flowering and plant height. Zhong (1999) reported that the additive gene actions were predominant in controlling most of the characters studied although non-additive gene were also important for height to first capsule, 1000-seed weight, days to maturity and seed yield per plot. He reported that the (GCA) estimates revealed that the parent Zhongzhi 10 was the best general combiner for plant height, days to maturity and seed yield.

Saravanan et al. (2000) reported that the (SCA) variance was higher than (GCA) variance for seed yield per plant, they reported that the mean degree of dominance was less than unity for all the traits studied except 1000-seed weight. Saravanan and Nadarajan (2003) reported that the variance due to general combining ability (GCA) and the specific combining ability (SCA) were significant for all characters studied and the (GCA) variances were greater than the (SCA) variances.

The present study was set up to estimate the

combining ability in sesame among 6 parents and their 15 F₁-hybrids of sesame designed in a half-Diallel fashion under rain-fed conditions of Sudan.

MATERIALS AND METHODS

Site description

Gadarif is located in Eastern Sudan, 12° 17" N to 34° 36" E and altitude of about 600 m (a.s.l), the soil is heavy cracking clay soil (vertisol) with a very low organic matter and nitrogen (0.70, 0.03) respectively, and available phosphorus (3 mg/kg soil) and approximate pH value of 7.8. The minimum average temperature is about 17°C in January and the maximum is about 47°C in April to May. The annual rainfall is about 600 mm in the southern region, 450 mm in central region and 300 mm in the northern region. The relative humidity is about 33% in January and about 71% in August.

Plant materials

The plant materials used in the study were 5 locally developed parental lines, and one an introduced line, the parental names, designation, origin and description were presented in Table 1.

Experimental procedures, data collection and statistical analysis

Experimental procedures

For crossing, the six parents were grown in three rows of 5 m length and 0.8 m apart for each genotype. Thinning was done after two weeks from sowing and the area was weeded after three weeks from emergence. All parents were crossed manually in all possible combination in a half diallel fashion (excluding reciprocals). Thus 15 F₁ hybrids were produced and then six parents and their 15 hybrids were sown in a randomized complete block design with three replications for two consecutive seasons 2012/2013 and 2013/2014, each entry was grown on two rows of 2.5 m long and 1.6 m apart. The 21 genotypes were sown by hand on 11/7/2012 and 28th July 2013 for the first and the second seasons, respectively. To raise healthy crop, all cultural practices were carried out as recommended by the Agricultural Research Station.

The data were collected on the following parameters:

1. Number of days to 50% flowering (NDTFPF).
2. Number of days to maturity (NDTM)
3. Plant height (PHT) (cm).
4. 1000-seed weight (1000-SW) (g).
5. Seed yield/plant (SYPP) (g).
6. Seed yield (kg/ha) (SY/Ha).

Statistical analysis for estimation of combining ability

Analysis of variance was used for each season for the data to test significant differences among the genotypes. Griffing (1956) method II was used to estimate the general and the specific combining ability (GCA and SCA). Two steps were involved in the analysis; the first one was analysis of data for testing significant differences among the genotypes. The second step was carried out to estimate the combining ability shown following.

Estimation of sum squares and means squares is as follows:

$$\text{Sum of squares due to general combining ability (gca)} = 1/n+2\{\sum (Y_i+Y_{ii})^2 - 4/n Y^2 \dots\}$$

Table 1. Parental name, designation, origin and description of the plant materials used in the study.

Parents	Designation	Origin	Description
Khidir	Kh	GARS#	A white seeded locally developed variety and released in 1998.
Kenana-2	K2	GARS	A white seeded variety selected from an African introduction and released in 1991
Promo	P	GARS	A variety selected from introduction materials of temperate origin (Greece) characterized by high branching medium duration, even maturity and delayed shattering (Ahmed, 1997; Ahmed, 2008)
Gadarif -1	Gd-1	GARS	A variety selected from segregated materials of crosses between temperate and tropical cultivars, it is characterized with non-branching habit late duration to flowering and good vigorous (Ahmed et al., 2003)
Gadarif 2002 single plant selection line number 12	Gd 2002 SPS-12	GARS	Advanced line (Khalafalla and Ahmed, 2003, 2004, 2005) has very long capsule
Um shagera	Um	GARS	A variety which has white and large seeds medium duration to flowering, maturity, and high yielder

#, Gadarif Agricultural Research Station.

Sum of squares due to specific combining ability (sca) = $\sum \sum Y_{ij}^2 - 1/n+2 \sum (Y_i+Y_{ii})^2 + 2/ (n+1) (n+2) Y^2...$

Check treatment S.S = r (S.S due to gca + S.S due to sca)

Sum of squares due to error = Total sum squares - Genotype sum square – Replication sum square

Mean square for general combining ability (gca)
 Mean square for specific combining ability (sca)
 Mean square for error

For testing the significance due to general and specific combining ability analysis Griffings method II model I was applied. Estimation of genetic components is as follows:

Component due to GCA = $1/n-1 \sum g_i^2 = Mg - Me / n+2$

Component due to SCA = $2/n (n-1) \sum_{i<j} \sum s_{ij}^2 = Ms - Me'$

The ratio of GCA variance to SCA variance was calculated as follow:

$$1/n-1 \sum g_i^2 / \frac{2}{n(n-1) / \sum_{i<j} \sum s_{ij}^2}$$

Estimation of GCA effects is calculated is as follow:

$$g_i = \frac{1}{n+2} \{ \sum (Y_i + Y_{ii}) - 2/n Y.. \}$$

Estimation of SCA effects are calculated as follow:

$$s_{ij} = Y_{ij} - 1/n+2 (Y_i - Y_{ii} + Y_j + Y_{jj}) + 2/(n+1)(n+2) Y..$$

Standard errors are calculated as follow:

$$S.E.(g_i) = \{(n-1)\sigma^2_e/n(n+2)\}^{1/2}$$

$$S.E.(g_i-g_j) = \{2\sigma^2_e/(n+2)\}^{1/2}$$

$$S.E.(s_{ij}) = \{n(n-1)\sigma^2_e/(n+1)(n+2)\}^{1/2}$$

$$S.E.(s_{ii}-s_{jj}) = \{2(n-2)\sigma^2_e/(n+2)\}^{1/2}$$

Where S.E. (g_i) is standard error for GCA effects of the parents; n is the number of parents included in the analysis; σ²_e is the expected error mean square in the combining ability analysis; S.E. (g_i-g_j) is standard error difference for GCA effects between the ith and jth parent; S.E. (s_{ij}) is standard error for SCA effects of the ith and jth parent; S.E. (s_{ii}-s_{jj}) is standard error of difference for SCA effects between the ith and jth crosses.

RESULTS AND DISCUSSION

Combining ability

Table 2 shows analysis of variance of the mean squares due to the genotypes, general combining ability (GCA) and specific combining ability (SCA) and their ratios for all characters in both seasons. The mean squares due to genotypes were highly significant in both seasons for all characters under study. This indicated that an adequate amount of variability is present in the parental material, and thus suggested the effectiveness of selection for the development of new genetic lines possessing improved traits. Variance due to the general combining ability was highly significant for all characters in both season except for the number of days to maturity in the first season and the seed yield per plant in the second season. Dhillon (1975) reported that combining ability of parents gives useful information on the choice of parents in terms of expected performance of the hybrids and their progenies. Like the GCA, the mean squares due to specific combining ability (SCA) was highly significant for the yield and its components, but it was not significant for the days to 50% flowering, days to maturity in both seasons and for the plant height in the first season only.

This indicated that both additive and non-additive gene actions were responsible for the inheritance of the studied traits. This suggests the use of reciprocal recurrent

Table 2. Mean squares for the genotypes, general (GCA) and specific combining ability (SCA) and their ratios for six traits in sesame genotypes seasons 2012/2013 and 2013/2014 grown at Gadaref University Farm under rain-fed condition.

Source of variation	df	NODTFPF		NODTM		PH		1000- SW		SYPP		SYTPH	
		012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014
Reps	2	18.79	26.16	83.76	11.29	620.37	69.54	0.05	0.31	1.82	31.53	1589.26	1922.02
Genotypes	20	28.89**	45.39 ***	37.43 N.S	20.12 **	201.58 **	203.31 ***	0.50 **	0.65 ***	128.69 ***	44.24 **	138304.94 ***	50677.32 ***
GCA	5	90.13**	126.84**	50.47 N.S	54.13**	352.31**	372.84**	1.03**	0.65**	128.04**	8.56 N.S	190909.38**	21242.99**
SCA	15	8.47 N.S	18.23 N.S	33.09 N.S	8.79 N.S	151.33 N.S	146.80**	0.33**	0.65**	128.91**	56.14**	120770.12**	60488.76**
Error	40	10.81	10.03	23.10	5.37	83.60	33.66	0.17	0.07	0.71	18.16	1567.52	1507.75
GCA:SCA		10.64	6.96	1.53	6.16	2.33	2.54	3.12	1	0.99	0.15	1.58	0.35

Table 3. Estimates of general combining ability (GCA) effects for six sesame parents grown at Gedarif University Farm, seasons 2012/2013 and 2013/2014.

Parent	NODTFPF		NODTM		PH		1000-SW		SYPP		SYKPH	
	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014
Khidir	-0.286	-1.80	-0.250	-1.06	-2.50	-8.17**	0.28	0.00	1.67**	-4.22	182.18**	-76.99**
Kenana-2	-0.616	0.87	0.500	1.11	-1.85	-5.33	-0.12	0.06	-2.79**	-4.65*	15.16	-195.16**
Promo	-0.119	2.04	1.083	1.11	0.33	5.25	-0.02	0.05	-2.57**	-1.31	-84.76**	105.60**
Gedarif-1	1.964	2.5	2.000	-1.56	-10.1*	-6.08*	0.33	-0.26	-3.68**	-4.32*	-26.09	-148.41**
Gd2002SPSN.12	3.798*	-1.38	5.417*	-2.81*	-11.6*	-12.75**	-0.30	-0.13	-12.86**	-4.52*	-211.17**	65.93**
Umshagera	-0.119	1.87	-0.417	-0.98	-0.85	-1.58	0.52*	0.05	2.35**	-6.45**	-0.09	-78.07**
SE (gi)	1.06	1.02	1.55	0.75	2.95	1.87	0.13	0.09	0.27	1.38	12.78	12.53
SE or SE(gi-gj)	1.64	1.58	2.40	1.16	4.57	2.90	0.21	0.14	0.42	2.13	9.80	19.41
CD ,t 5%	3.32	3.20	4.86	2.34	9.23	5.86	0.41	0.27	0.85	4.31	40.00	39.24
CD,t 1%	4.45	4.28	6.50	3.13	12.36	7.84	0.55	0.37	1.14	5.76	53.53	52.50

*, ** Significant at 0.05 and 0.01 probability levels respectively.

selection for exploiting both types of genetic variances. Similar findings were reported by Zhong (1999) in sesame.

GCA:SCA

The ratio for the general combining ability (GCA) to that of specific combining ability (SCA) were

almost more than one for all characters under study, in both seasons, except for the seed yield per plant. This result indicating that the inheritance of these traits were due to general combining ability effects and were mostly controlled by the additive gene actions. The ratios were less than one in both seasons for seed yield/plant and seed yield kg/ha in the second season only, indicating that the inheritance of this

trait was due to non- additive gene actions. Thiyagarajan and Ramanathan (1995) reported that the non- additive gene action was observed for seed yield in sesame.

Table 3 shows the estimates of general combining ability (GCA) effects, magnitudes and their directions. The best combiners were (Gd2002sps-12, Gadaref-1), since they recorded significant general combining ability (GCA) effects

Table 4. Estimates of specific combining ability (SCA) effects for yield and yield components of F₁ sesame hybrids grown at Gedarif University season.

Crosses	NODTFPF		NODTM		PH		1000-SW		SYPP		SYKPH	
	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014	012/013	013/014
Khidir*Kenana-2	-0.12	-0.46	1.29	-0.48	-4.24	5.58	0.11	-0.00	-6.19**	-0.38	163.57**	149.10**
Khidir*Promo	1.46	-0.05	4.25	-1.48	-1.82	0.54	-0.45	0.21	-1.69	5.67	-262.39**	-40.36
Khidir*Gedarif-1	0.67	1.33	0.38	1.02	3.48	4.04	-0.21	0.35	0.85	3.61	-180.06**	176.97**
Khidir*Gd2002SPSN.12	-1.58	1.74	-3.42	3.90	0.23	1.38	0.04	0.55*	-1.54	-3.85	-98.60*	-253.36**
Khidir*Umshagera	0.13	1.04	-2.00	-0.85	7.36	4.79	-0.05	-0.01	5.24**	3.40	13.11	121.64**
Kenana-2*Promo	1.96	1.29	2.79	-0.23	1.51	-3.71	0.21	-1.00	3.05**	0.12	-332.46**	1.39
Kenana-2*Gedarif-1	-0.16	-2.67	-0.75	-0.73	2.20	-2.21	-0.11	0.75**	-0.81	1.75	26.54	-22.61
Kenana-2*Gd2002SPSN.12	-1.08	1.74	-3.88	-0.19	3.48	8.46	0.28	0.41	8.61**	3.87	76.00	138.39**
Kenana-2*Umshagera	0.63	-1.63	-0.45	-0.60	0.75	2.54	-0.25	-0.28	0.91	3.93	36.04	124.05**
Promo*Gedarif-1	-1.58	-3.59	-1.46	0.27	8.89	2.08	-0.15	-0.20	-0.25	-1.24	292.58**	78.93*
Promo*Gd2002SPSN.12	-1.83	-3.17	-6.25	-0.19	-0.83	-1.92	0.31	0.19	6.71**	0.41	363.37**	-134.07**
Promo*Umshagera	0.21	1.45	-1.50	-0.60	-8.43	-7.50	0.12	0.70*	-2.70**	-2.34	108.41**	-117.07**
Gedarif-1*Gd2002SPSN.12	-2.62	3.54	-2.13	0.32	11.93	11.25	0.32	0.17	13.83**	2.62	76.04	76.60
Gedarif-1*Umshagera	-0.24	-3.51	-0.04	2.23	-6.33	-3.00	-0.51	-0.55*	-6.26**	1.90	-162.92**	-13.07
Gd2002SPSN.12*Umshagera	-0.49	-1.09	4.83	1.77	8.35	6.33	-0.35	0.04	-1.89*	6.00	5.54	40.60
SE (sij)	2.41	129.78	3.52	94.97	6.69	237.79	0.30	11.09	0.62	174.65	28.98	1591.55
SE or SE(sii-sjj)	3.29	3.17	4.81	2.32	9.14	5.80	0.41	0.27	0.84	4.26	39.59	38.83
CD,t 5%	6.65	6.40	9.71	4.68	18.48	11.72	0.83	0.55	1.70	8.61	80.02	78.47
CD,t 1%	8.89	8.56	12.99	6.27	24.72	15.69	1.11	0.73	2.28	11.52	107.06	105.00

*,** Significant at 0.05 and 0.01 probability levels respectively.

for most of the traits measured.

For days to 50% flowering and days to maturity, Khidir was the only parent that scored a negative general combining ability (GCA) effects in both seasons. Therefore it was desired to be selected for earliness while the parent Gd2002SPSN.12 recorded a highly positive significant general combining ability (GCA) effects in the first season only. Therefore it was the latest maturing parent. For plant height Gadaref-1 and Gd2002SPSN.12 showed significant negative general combining ability (GCA) effects in both seasons, while Promo showed a positive general combining ability

(GCA) effects in both seasons. Therefore, Promo was recommended as tallest parent.

1000 seed weight was the most yield related character. Khidir and Umshagera recorded a positive general combining ability (GCA) effects in both seasons, while Gd2002SPSN.12 recorded a negative general combining ability (GCA) effects in both seasons.

For seed yield/plant and seed yield kg/ha, Khidir and Promo recorded a positive significant general combining ability (GCA) effects in the first and the second season respectively, while Kenana-2 recorded significant negative general combining

ability (GCA) effects in both seasons. Therefore, the former parents (Khidir and Promo) were recommended for future breeding program to improve seed yield in sesame.

Specific combining ability (SCA) effects

Table 4 shows the estimates of specific combining ability (SCA) effects, for 15 sesame crosses. The specific combining ability (SCA) is considered to be the best criterion for selection of superior hybrids. Considerable number of crosses showed

significant specific combining ability (SCA) effects, but they were inconsistent across the seasons.

For days to 50% flowering and the days to maturity, the crosses Kenana-2 X Gadaref-1 and Promo X Gd2002sps-12 showed negative specific combining ability in both seasons. On the other hand, Khidir X Gadaref-1 recorded positive SCA in both seasons. The other crosses were inconsistent across the seasons regarding the directions of this character. The former crosses (Kenana-2 X Gadaref-1 and Promo X Gd2002sps-12) were good for earliness. The best hybrids combination with negative SCA effect exhibited by these diverge crosses may be due to contribution of favorable alleles by their parents. Singh and Naryanan (1993) stated that unrelated inbreds from different open-pollinated varieties will generally combine to produce high yielding early flowering single crosses than inbreds derived from related parents, which may have more of the same genes in common. This might be the case with this result.

For Seed yield kg/ha and the yield related characters viz 1000- seed weight and the yield per plant, significant positive SCA effects were observed by Kenana-2 X Gd 002SPSN.12 and Promo X 002SPSN.12, whereas, negative significant effects were showed by Gadarif-1 X Umshagera. The rest of the crosses combinations were inconsistent across the seasons, some of them recorded positive value in one season and negative values in another one. From the results of this study it could be concluded that both additive and non-additive gene action were important for improving seed yield in sesame, Khidir and Promo recorded a positive significant general combining ability (GCA) effects in the first and the second season, moreover, Promo was the best combiner with other parental lines for earliness science it recorded negative SCA values. Therefore Khidir and Promo could be recommended to produce progeny having high yield and early maturing hybrids.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

- Abdel KI, Sulieman I (2008). Sesame Production and Export Performance: Comparative Advantage Analysis. University of Khartoum Journal of Agricultural Science, University of Khartoum, Sudan 16(2):230-240.
- Ahmed ME (1997). Adaptability of new varieties of sesame to the central rain lands of the Sudan. Variety Release Committee of Sudan.
- Ahmed ME (2008). Evaluation of new sesame (*Sesamum indicum* L.) genotypes for yield, yield components and stability. University of Khartoum. J. Agric. Sci. 16:380-394.
- Ahmed ME, Taha MB, Khalafalla AA (2003). Assessment of new promising sesame cultivars for the central rain lands and irrigated systems. Variety Release Committee of Sudan.
- Ashri A (1989). Sesame breeding objectives and approaches. In: Oil Crops: Sunflower, Linseed and Sesame, Ed. Omran, A., IDRC-MR205E, IDRC, Ottawa.
- Dhillon BS (1975). The application of partial-diallel crosses in plant breeding - A review. Crop Improv. 2:1-7.
- FADSTAT (2014). FAO Statistical year book, Food and Agriculture Organization of the United Nations.
- Griffing B (1956). Concept of general and specific combining ability in relation to diallel crossing system. Austral. J. Biol. Sci. 9:463-493.
- Khalafalla AA, Ahmed ME (2003). Sesame breeding. Annual Report, Oil Seed Crops Research Center. ARC. Sudan.
- Khalafalla AA, Ahmed ME (2004). Sesame breeding. Annual Report, Oil Seed Crop Research Center, ARC. Sudan.
- Khalafalla AA, Ahmed ME (2005). Sesame breeding. Annual Report, Oil Seed Crops Research Center, ARC. Sudan.
- Saravanan T, Kumar ST, Ganesan J (2000). Genetic of earliness characters in sesame (*Sesamum indicum* L.). Sesame and Safflower Newslett. 15:14-18.
- Sarvanan S, Nadarjan N (2003). Combining ability studies in sesame (*Sesamum indicum* L.). Sesame and Safflower Newslett. 18:1-6.
- Singh P, Narayanan SS (1993). Biometrical Techniques in Plant Breeding. 1st edition Kalyani Publishers, New Delhi.
- Thiyagarajan K, Ramanathan T (1995). Combining ability analysis for yield components of sesame in different environments. Madras Agric. J. 82:445-449.
- Weiss EA (1983). Oilseed Crops, First edition, Longman Group Ltd. London, P. 282.
- Zhong YZ (1999). Combining ability analysis of agronomic characters in sesame (*Sesamum indicum* L.). Sesame and Safflower Newslett. 14:1-4.