Global Science Research Journals

ISSN: 2449-0628 Vol. 4 (5), pp. 383-388, September, 2017

http://www.globalscienceresearchjournals.org/

Global Journal of Plant Breeding and Genetics

Full Length Research Paper

Exploiting the heterosis and heterobeltiosis of sunflower at plant maturity stage

[1]Ahsan Iqbal, *[2]Rabia Saif, [3]Rabia Zafar, [4]Rao Mahabat Khan, [5]Naeem Mahmood and [6]Sumaira Hina

[1,2,3,4,6]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad.
[5]Endowment Fund Secretariat, University of Agriculture, Faisalabad.

Accepted 6 June, 2017

Sunflower is grown all over the world. In Pakistan it is grown in variable climatic conditions and use as a main oilseed crop. Pakistan has low production of edible oil and also has problem of quality oil due to different reasons. To meet the requirements of consumers we have to import the oil at high cost. Still our struggles are of no use to increase the production. Heterosis can be used to develop hybrid to get higher oil yield. Experiment was conducted to find out the best lines by calculating the combining ability including general and specific combining ability, variances, heterosis and Heterobeltiosis. Results shown that line B-SIN-82 and tester RL-54 followed by RL-51 showed the best results for different characters. These inbred lines can be used in the development of hybrids which will be best suitable for our environment and can meet the increasing oil demand. By the use of combining ability and heterosis we can develop sunflower hybrids with better yield and oil contents.

Keywords: Morphological traits**,** combining Ability, Best crosses, hybrid development.

INTRODUCTION

Sunflower (Helianthus annuus L.) is one of the most important crops everywhere in the world, which is cultivated in an area of 21 million hectares (Shabir et al., 2010). It is one of the three crop species along with soybean and rapeseed which account for about 78% of the world vegetable oil. Because of its wide adoptability, it is grown in all the countries crossing climatic and geographical boundaries. Its seed comprises 35-55% edible oil contents.

In Pakistan Sunflower is an essential oilseed crop and is successfully grown under diverse climatic situations of the country, i.e., in the warm and harsh conditions of southern part of the country to mid and cool climate in the north. It has unlimited potential to bridge the gaps between the production and consumption of edible oil. Still Pakistan is facing a severe shortage of edible oil due to many biological and socio-economic constraints, as its domestic production can only meet 27% of the total edible oil consumption in the country. Thus the country has to import edible oil in large quantity involving a large expenditure in foreign exchange to fulfill the deficiencies. It is a matter of great concern that efforts made so far to enhance domestic production of edible oils have had little impact (Liaqat et al., 2010).

This problem could be overcome by the development of sunflower hybrid. Hybrid sunflower became a truth with the innovation of cytoplasmic male sterility and effective male fertility restoration system during 1970. For high yielding hybrid narrow genetic base of germplasm is necessary to get better hybrid. In sunflower the status

*Corresponding author. E-**mail**: rabiasaif03@gmail.com,**Telephone**: 0300-9827431

of hybrid is unique due to the reason that it is high seed yielding as compared to normal sunflower cultivars and the high heterotic value is due to the reason that it is a cross pollinated crop. Exploitation of heterosis has allowed sunflower to become one of the important oilseed in our country. Heterosis could be used efficiently for better seed and oil yield in sunflower. It is necessary to exploit the combining abilities, general and specific to exploit the genetic variability for better heterosis to get better hybrid. Hybrids are more vigorous, uniform, self-fertile and resistant to important foliar diseases.

In Pakistan the hybrids used are not local and not suitable for our environmental conditions. There is a need to develop a local hybrid to achieve maximum yield. This study will be conducted to find out the heterosis over mid parent and better parent for different morphological/physiological traits of the sunflower hybrids. By this we will be able to find out the best combination which will be suitable in our climatic conditions and we will be able to overcome the shortage of edible oil in our country by obtaining the high oil yield.

MATERIALS AND METHODS

The research work was conducted at the research area of sthe Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2014-16. Four cytoplasmic male sterile (CMS) female parents (lines) namely CM-612, HA-27, B-SIN-82, HA-314 and four sterility restorer male parents (testers) namely RL-54, RL-51, R-SIN-82, RL-46 which were obtained from Pakistan, Canada and USA were used in the research.

The seeds of eight parents (lines and testers) and sixteen hybrids were sown during the kharif growing season in 2016. A randomized complete block design RCBD with three replications was followed. At maturity the following characters such as Plant height (cm), Number of leaves per plant, Days to flower initiation, Days to flower completion, Head diameter (cm), Number of whorls of achene per head, Achene weight per head and 100 achene weight were measured.

All traits under study were subjected to analysis of variance according to Steel *et al.,* (1997). Data were further analysed for general and specific combining abilities by using the Kempthron (1957) method. Percent heterosis over mid parent and better parent (Heterobeltiosis) was computed after calculating heterosis on respective parents using formulae based on the amount of heterosis, expressed as the difference between F_1 and the mid parent values, proposed by Falconer and Mackay (1996) for heterosis.

Mid parent heterosis (MPH) = $100 * (F_1 – MP) / MP$
Better parent heterosis (BPH) = $100 * (F_1 – BP) / BP$
MP = [Female parent (♀) + Male parent (♂)] / 2
A t-test was applied (Wynne *et al*., 1970) to test the significance of heterosis over mid and better parents as under:

$t_{(Static)}$ for heterosis= $(F_1 – MP) / (3/8\ \sigma^2 E)^{1/2}$
$t_{(Static)}$ for heterobeltiosis = $(F_1 – BP) / (1/2\ \sigma^2 E)^{1/2}$

RESULTS

The results of analysis of variance shown that genotypic differences were significant (P≤0.05-0.01) in all the characters. Significant (P≤0.05-0.01) differences between parents were reflected for plant height (PL), head diameter (HD) and days to flower completion (DFC). The differences between parents and crosses were highly significant (P≤0.01) for plant height, number of leaves per plant, number of whorls of achene per head, achene weight per head and days to flower completion. Crosses showed significant (P≤0.05-0.01) differences for all characters except number of whorls of achene per head. The differences among the lines were significant (P≤0.05-0.01) for plant height, number of whorls of achene per head, achene weight per head, days to flower initiation, days to flower completion and 100-achene weight, whereas these four testers were significantly (P≤0.05-0.01) different for head diameter and achene weight per head. The line × tester interaction component was significant (P≤0.05-0.01) for plant height, number of leaves per plant, head diameter, achene weight per head and 100-seed weight.

General combining ability (GCA) effects for various morphological traits are given in Table 1. . Among the lines B-SIN-82 had the highest GCA effects for plant height, number of whorls of achene per head and achene weight per head. CM-612 showed positive GCA effects for plant height and achene weight per head. HA-27 gave positive GCA effects for number of leaves per plant. SCA effects of hybrids for morphological traits are presented in Table 2**.**The hybrid HA-27 X RL-51 showed the highest significant positive effects for plant height and it is best for the head diameter. Hybrid B-SIN-82 × RL-54 showed positive significant SCA effect for number of leaves per plant. The cross HA-27 × RL-51 showed a significant positive SCA effect for head diameter. Significant positive SCA effects for achene weight per head were shown by the hybrids HA-27 × RL-54, B-SIN-82 × RL-51, B-SIN-82 × R-SIN-82 and HA-314 × RL-54. Hybrid HA-314 × RL-51 was best having maximum negative SCA effect for plant height. Similarly the cross HA-314 × RL-46 also showed a significant positive SCA effect for 100-seed weight and No. of whorls. Variance due to GCA (σ^2_{GCA}) and SCA (σ^2_{SCA}), ratio of SCA to GCA variances ($\sigma^2_{SCA}/\sigma^2_{GCA}$), additive variance ($\sigma^2_A$), dominance variance ($\sigma^2_D$), and degree of dominance ($\sigma^2_D/\ \sigma^2_A)^{1/2}$ for investigated traits in this study in sunflower genotypes are presented in Table 3**.**

Significant negative heterosis was observed in seven hybrids over their mid parents whilst the remaining nine hybrids showed non-significant heterosis for plant height. All hybrids showed non-significant increase in their performance over their respective mid and better parents for Number of leaves per plant. All the sixteen hybrids did

Table1: General combining ability (GCA) effects of lines and testers for various morphological traits

Lines	PH	LP	DFI	DFC	HD	NWAH	AWP	SW
CM-612	8.56	-0.39	-1.47	-1.00	-0.66	-3.29	4.75	0.16
HA-27	-16.96	2.02	1.18	1.00	0.08	-0.29	-4.00	-0.42
B-SIN-82	10.04	-0.81	-1.06	-1.16	0.13	13.04	7.08	0.01
HA-314	-1.64	-0.81	1.35	1.16	0.44	-9.45	-7.83	0.24
Standard Error	***3.92***	***0.91***	***0.46***	***0.58***	***0.30***	***4.58***	***1.49***	***0.13***
Testers								
RL-54	-2.35	0.85	-0.31	-0.08	-0.08	-1.95	-0.91	-0.11
RL-51	-1.62	-1.06	0.68	0.83	0.88	-1.62	2.75	-0.03
R-SIN-82	-4.25	0.10	-0.14	0.02	-0.43	3.45	2.25	0.08
RL-46	8.23	0.10	-0.22	-0.75	-0.36	0.12	-4.08	0.04
Standard Error	***3.9***	***0.91***	***0.46***	***0.58***	***0.30***	***4.58***	***1.49***	***0.13***

Table 2: Specific combining ability (SCA) estimates for various morphological traits.

Hybrids	PH	LP	DFI	DFC	HD	NWAH	AWP	SW
CM-612 × RL-54	10.03	-2.18	0.14	0.25	-0.06	9.29	-0.16	-0.18
CM-612 × RL-51	10.54	1.72	-0.85	-0.66	-1.06	2.62	-3.83	0.23
CM-612 × R-SIN-82	-18.02	1.56	0.31	1.83	0.08	-17.12	1.00	0.16
CM-612 × RL-46	-2.54	-1.10	0.39	-1.41	1.04	5.20	3.00	-0.20
HA-27 × RL-54	-4.89	-4.27	0.14	0.58	-0.78	-0.37	5.91	0.19
HA-27 × RL-51	22.70	0.64	0.14	-0.66	2.74	1.95	-3.41	-0.01
HA-27 × R-SIN-82	-4.39	0.47	-1.35	-0.83	-1.63	2.54	-5.91	-0.76
HA-27 × RL-46	-13.41	3.14	1.06	0.91	-0.31	-4.12	3.41	0.58
B-SIN-82 × RL-54	-17.04	5.22	0.06	0.75	-0.53	5.95	-12.83	0.34
B-SIN-82 × RL-51	2.80	-1.85	-0.27	-0.50	0.01	-2.37	11.16	0.46
B-SIN-82 × R-SIN-82	9.39	-3.35	0.22	-0.66	0.51	2.87	10.33	-0.74
B-SIN-82 × RL-46	4.84	-0.02	-0.02	0.41	0.01	-6.45	-8.66	-0.06
HA-314 × RL-54	11.90	1.22	-0.35	-1.58	1.38	-14.87	7.08	-0.36
HA-314 × RL-51	-36.05	-0.52	0.97	1.83	-1.68	-2.20	-3.91	-0.68
HA-314 × R-SIN-82	13.02	1.31	0.81	-0.33	1.03	11.70	-5.41	1.35
HA-314 × RL-46	11.12	-2.02	-1.43	0.08	-0.73	5.37	2.25	-0.30
Standard Error	***7.84***	***1.82***	***0.93***	***1.16***	***0.60***	***9.17***	***2.99***	***0.26***

Table 3: Estimates of variance due to GCA(σ^2_{GCA}), SCA (σ^2_{SCA}), additive (σ^2_A), dominance (σ^2_D), ratio of SCA to GCA ($\sigma^2_{SCA}/\sigma^2_{GCA}$) and degree of dominance $(\sigma^2_{D/}\sigma^2_A)^{1/2}$

Traits	Genetic Components					
	σ^2_{GCA}= {(1+F) /4} σ^2_A	(a) with F=1, σ^2_A	σ^2_{SCA}= {(1+F) /2}^{2} σ^2_D	(b)withF=1, σ^2_D	σ^2_{SCA}/ σ^2_{GCA}	$(\sigma^2_{D/}\sigma^2_A)^{½}$
PH	60.73	60.72	6.39	319.29	0.11	0.23
LP	-0.01	-0.01	13.27	6.63	-1327.0	25.77
DFI	1.45	1.45	0.02	0.01	0.01	0.07
DFC	1.04	1.04	0.76	0.37	0.73	0.60
HD	0.02	0.02	3.74	1.86	166.00	9.11
NWAH	47.09	47.08	36.93	18.46	0.78	0.63
AWP	27.29	27.28	135.18	67.59	4.95	1.57
SW	-0.02	-0.01	0.87	0.43	-49.43	4.97

Table 4: Heterosis and Heterobeltosis for various morphological traits.

	Plant Height		Leaves per plant		Days to Flower initiation		Days to flower completion		Head Diameter		No. of whorls		Achene weight per head (g)		100 Achene Weight	
Hybrids	**Het**	**Hetbel**	**Het**	**Hetbel**	**Hete**	**Hetbel**	**Het**	**Hetbel**	**Het**	**Hetbel**	**Het**	**Hetbel**	**Het**	**Hetbel**	**Het**	**Hetbel**
CM-612 × RL-54	-32.16**	-36.02**	-6.58	-12.35	-3.17	-3.56	1.69	-2.88	-4.29	-5.80	30.33	28.08	41.80	35.35	6.70	3.75
CM-612 × RL-51	-31.17**	-36.61**	-1.91	-10.47	-2.98	-3.56	3.45	-2.88	-5.70	-6.07	38.51	18.72	39.58	35.35	15.37	6.75
CM-612 × R-SIN-82	-31.39**	-36.61**	-1.23	-12.09	-1.80	-3.16	1.10	-1.08	-6.02	-7.39	5.07	-2.96	42.72	37.38	19.38	13.27
CM-612 × RL-46	-25.42*	-34.26**	-5.88	-12.20	-1.41	-3.16	-4.19	-5.40	11.86	0.79	34.39	25.12	35.35	35.35	13.89	13.89
HA-27 × RL-54	-19.08*	-19.18	-8.28	-11.11	1.00	0.40	8.63	7.78	-5.04	-7.49	7.87	-3.61	40.78	40.00	2.30	-2.06
HA-27 × RL-51	-4.35	-6.85	0.00	-5.81	2.41	2.00	10.18	7.39	29.23	27.39	25.89	-0.40	19.78	17.20	-6.15	-14.43
HA-27 × R-SIN-82	-10.30	-12.35	0.60	-7.69	0.40	0.00	4.40	2.63	-14.70	-16.80	25.89	6.43	2.04	-6.54	-22.25	-27.34
HA-27 × RL-46	-13.51	-19.62	16.46	12.20	3.66	2.82	4.55	1.85	5.35	-5.94	10.85	-5.62	15.96	10.10	21.88*	19.94
B-SIN-82 × RL-54	-5.29	-6.57	12.20	10.84	-2.39	-2.39	4.63	2.26	-3.29	-6.38	57.37*	52.55*	19.77	14.44	6.58	-0.41
B-SIN-82 × RL-51	-13.17	-16.45	-23.08	-24.42	-1.40	-1.59	6.09	1.89	7.29	5.10	67.17*	49.46	112.57*	100.00	7.09	5.21
B-SIN-82 x R-SIN-82	-16.12	-19.03	-26.44	-29.67	-1.01	-1.99	0.56	0.38	2.11	-1.02	71.91**	66.30*	92.59*	70.09	-18.67	-22.15
B-SIN-82 × RL-46	0.29	-7.86	-10.30	-10.84	-1.01	-2.39	0.00	-1.11	7.76	-4.34	49.30*	45.65	17.13	7.07	2.59	-6.60
HA-314 × RL-54	-22.93*	-29.80**	-1.84	-2.44	1.21	0.00	5.04	3.04	15.12	12.14	-14.86	-15.92	39.64	31.11	0.05	-0.83
HA-314 × RL-51	-27.88**	-35.79**	-17.86	-19.77	4.24	3.20	12.03	7.98	-2.75	-4.13	20.23	3.48	11.63	3.23	-10.70	-14.43
HA-314 × R-SIN-82	-7.58	-17.47	-9.83	-14.29	3.87	3.66	3.97	3.38	9.40	6.72	42.09	31.84	-3.23	-15.89	49.57*	47.11*
HA-314 × RL-46	-7.78*	-21.28*	-17.07	-17.07	1.43	1.22	2.62	1.11	4.78	-6.46	25.53	17.41	5.62	-5.05	9.07	5.16

not show any significant positive or negative heterosis over their mid as well as better parents for days to flower initiation. All the sixteen hybrids exhibited non-significant heterosis over their mid as well as better parents for days to completion. None of the sixteen hybrids performed significantly better than their mid as well as better parents for head diameter. Four hybrids showed a significant positive heterosis over their mid parents for number of whorls. Only two out of sixteen hybrids showed significant positive heterosis over their mid parents for achene weight per head. Only two hybrids out of sixteen showed maximum significant positive heterosis over the mid parents for 100 seed weight. All the sixteen hybrids did not show any significant positive or negative heterosis over their mid as well as better parents rest of the characters as shown in Table 4**.**

DISCUSSION

Lines and testers and hybrids were significantly different for all the characters except number of whorls of achene per head. Hlandni *et al.,* (2006) reported significant differences among lines, testers and their hybrids for plant height, total number of seeds per head, 1000-seed weight and the seed yield per plant. The line CM-612 showed significant positive GCA effects for plant height and achene weight per head, HA-27 for number of leaves per plant, B-SIN-82 for plant height, number of whorls of achene per head and achene weight per head. HA-27 × RL-51 was best among others for head diameter but this combination showed highest SCA effects for plant height. The hybrid B-SIN-82 × RL-54 depicted to best combination for number of leaves per plant. B-SIN-82 × RL-51 showed desirable SCA effects for achene weight per head only. Hybrid HA-314 × RL-51 was best having maximum negative SCA effect for plant height. The cross HA-314 × R-SIN-82 showed maximum SCA effects for number of whorls of achene per head and 100-seed weight. Same results have been described by Radhika (1999), Javed and Aslam (1995), Limbore *et al.,* (1998), Mayor *et al.,* (2006), Khan (2004) and Sarrafi *et al.,* (1996).

In the present studies, variance due to SCA was most important for plant height, days to flower initiation, days to flower completion and number of whorls of achene per head. These results were similar to Mayor *et al.,* (2006), Khan (2004), Hladni *et al.,* (2006), Ashok *et al.,* (2000) and shekar*et al.,* (1998), Gksoy (1999), Bajaj *et al.,* (1997) and Kumar *et al.,* (1998). The crosses B-SIN-82 × RL-54 and B-SIN-82 × RL-51 showed significant positive heterosis over the mid parent and better parent for number of whorls of achene per head and 100-seed weight and showed a non-significant negative desired heterosis over their mid and better parents for plant height and days to flower initiation. This is not always true rather several hybrids in the present studies i.e., CM-612 × RL-54 (109 cm), CM-612 × RL-51 (108 cm), CM-612 × R-SIN-82 (108 cm), have shorter plant height than the shortest parent RL-46 (129.6 cm) and showed significant negative heterosis over better parents. Many breeders (Fick *et al*., 1985; Miller, 1988; Rodin, 1978; Velkov, 1970; Voskoboynik & Gorbachenko, 1977) found the potential of reduced-height germplasm to increase stem strength. The present studies give the idea of using reduced height in breeding sunflower varieties/hybrids. As most of the inbred lines are showing heterosis, so the present material may be used for the development of hybrids, especially the line B-SIN-82 and tester RL-54 followed by RL-51 are showing positive heterosis for number of achene per head and achene weight per head. Therefore, these two inbred lines may be used in the development of hybrids.

CONCLUSIONS

Our focus was on seed yield and ultimate objective was oil yield. Research was conducted to find out the best combinations which can be further used in the breeding programs for the development of hybrids. Lines B-SIN-82 and testers RL-54, RL-51 showed the best results for yield related traits. So these inbred lines will be used to develop the best hybrids which will be suitable to our local environment and will have the potential to meet the world as well as our increasing demand of oil.

RECOMMENDATIONS

Combining ability can be used to find out the best general combiner and specific combiners. It can be used to find out the genetic variability in the inbred lines. Then by using the heterosis these best combiners can be used to develop the good hybrids. So for the development of best hybrids which have the capacity to give the yield more than the yield of average parent or better parent, it is recommended to use the combining ability and heterosis to exploit the potential of these inbred lines.

REFERENCES

Alonso, L.C., G. Lopez Ruiz-Calero and F. Sallago. 1988. Agronomic characteristics and genetic potential of dwarf sunflower hybrids in Spain. p .370 .*In* : Proc . 12th Int. Sunflower Conf. Novi Sad, Yugoslavia, 25-29, 1988. Intr. Sunflower Assoc. Toowoomba, Australia.

Ashok, S., S.N. Muhammad and S.L. Narayanan. 2000. Combining ability studies in sunflower (*Helianthus annuus* L.). Crop. Res. Hiser, 20(3), 457-462.

Bajaj, R.K., K.K. Aujla and G.S. Cahal. 1997. combining ability studies in sunflower (Helianthus annuus L.) crop improvement, 24(1), 50-54.

Fick, G.N., J.J. Caroline, G.E. Auwarter and P.M. Duhigg. 1985. Agronomic characteristics and field performance of dwarf sunflower. p. 739-742. *In* : Proc . 11^{th} Int. Sunflower Conf. Mar del Plata, Argentina, 10-13, 1985. Int. Sunflower Assoc. Toowoomba, Australia.

Goksoy, A.T. 1999. A study of some agronomical characteristics of synthetic varieties obtained from inbred lines of sunflower (*Helianthus annuus* L.). Turkish. J. Agri. and Forestry, 23(2), 349-354.

Herring, M.J. 1985. The development of early dwarf and semidwarf sunflower hybrids for South Africa. Oilseeds News, p. 12-14 .

Hladni, N., D. Skoric, M. Kraljevic-Balalic, Z. Sakac and D. Jovanovic. 2006. Combining ability for oil contents and its correlation with other yield components in sunflower (*H. Annuus* L.). Helia, 29(44), 101-110.

Javed, N. and M. Aslam. 1995. Combining ability effects in sunflower hybrids. Helia, 18(23), 41-46.

Khan, H. 2004. Magnitude of heterosis and combining ability in sunflower over environment. NWFP Agri. Uni. Faculty of crop prod. Sciences.

Kumar, A.A., M. Ganesh and P. Jnila. 1998. Combining ability analysis for yield and yield contributing characters in sunflower (*Helianthus annuus L.*). Annals of Agric. Res, 19 (40), 437-440.

Liaqat, A. S., M. A.S. and N. Amjad. 2010. Present status and future prospects of mechanized production of oilseed crops in Pakistan- A review.*Pakistan J. Agric. Res, 23, 1-2.*

Limbore, A.R., D.G. Weginwar, S.S. Lande; B.D. Gite and K.M. Ghodke. 1998. Heterosis in sunflower (*Helianthus annuusL*.). Annals of Plant. Physiology, 12(1), 38-42.

Mayor, M. L.G. Nestares, R. Zorzoli and L.A. Picardi. 2006. Analysis for combining ability in sunflower organogenesis-related traits. Australian Journal of Agricultural Research, 57, 1123-1129.

Miller, J.F. 1988. Performance of lines and hybrids of short height restorers, introduction crosses, and Sclerotinia tolerant materials. Sunflower Research Workshop, Bismarck, N .D . 25 January 1988 . Nat. Sunflower Assoc . Bismarck, N .D .

Putt, E.D. 1966. Heterosis, combining ability and predicted synthetics from a diallel cross in sunflowers (*Helianthus annuus L*.). Can J Plant Sci, 46, 59-67.

Radhika, P., K. Jagadeshwar and P.S. Sharma. 1999. genetic analysis of seed yield and certain physiological parameters in sunflower. J. Res. Angrau. 27 (1-2), 5-17.

Rao, N.M., B. Singh. 1978. Inheritance of some quantitative characters in sunflower (*Helianthus annuus* L.). Pantnagar J Res, 4, 144-146,

Rodin, V.F. 1978. Production of short forms of sunflower uniform in height .SelektsiyaSemenoudstvo, 4, 37-39 .

Sarrafi, A., J.P. Roustan, J. Fallot and G. Alibert. 1996. Genetic analysis of organogenesis in the cotyledons of zygotic embryos of sunflower (*Helianthus annuus L.*). Theor. Appl. Genet, 92, 225-229.

Shabir, H. W., H. K. Saini, V. Gupta, M.A. Bhat, N.B. Singh. 2010. Present status and future prospects for heterosis breeding in sunflower (Helianthus annuus L.) Asian Journal of Science and Technology, 2, 049-054.

Shekar, G.C., H. Jayaramaiah, K. Virupakshappa and B.N. Jagadeesh. 1998. combining ability of high oleic acid in sunflower. Helia, 21(28), 7-14.

Sing, R.K. and B.D. Chaudhary. 1977. Biometrical methods in quantitative genetic analysis. Line × Tester analysis. Volume10. New Delhi, Kalyani Publishers.

Steel, R.G.D. and J.H. Torrie. 1997. Principles and Procedures of Statistics. A Bionetrical Approach. 2 Ed. McGraw Hill Book Co. Inc., Singapore, 172-177.

Velkov, V.N. 1970. Inheritance of stem height in sunflower. Genetics and Plant Breeding, 3(5), 393-401.

Voskoboynik, L.K. and F.I. Gorbachenko. 1977. Effect of self pollination on morphological and agronomical characters of sunflower with short height. Bulletin Vniimk, Vispusk, 2, 6-9 .

Watson, D. J. 1952. The physiological basis of variation in yield. Advances in Agronomy, 4, 101-145.