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Combining Ability Assessment in Helianthus annuus L. Through Line × Tester Analysis for Quantitative Traits and Quality Parameters

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Abstract
Plant materials were utilized by L×T mating design of seven lines and three testers and their twenty one hybrids were sown in field during autumn season 2015 in RCBD design with three replications. Genetic variability, GCA and SCA among genotypes was assessed under the research area University of Agriculture, Faisalabad, Pakistan. The lines A-12, A-2.2 and tester G-53 were found good general combiners for days to flowering, plant height, number of leaves per plant, stem diameter, achene yield per head, 100 seed weight, oil content and protein content. Among the crossesA-12 × B-3.16and B-12.10 × C-3.3were performed as a good specific combiners for yield related traits. Especially for protein content the cross B-3.1 × B-3.16 showed the maximum SCA effects. Analysis of variance results were determined among entries for all the character at significant level ($p \geq 0.01$-0.05).
Keywords: Line × Tester, GCA, SCA, Protein contents and Yield.

INTRODUCTION

Sunflower is important oil producing crop after soya bean. Seed of sunflower play major role for edible oil. Sunflower is best oil due to its mild taste, low amount of saturated fatty acid and light color. Its oil quality is best. Sunflower oil plays important role in the economy of Pakistan. Sunflower can play an important role to increase the local production of vegetable oil. Because, there is a huge gap between production and consumption of vegetable oil and it is increasing day by day (Habib *et al.*, 2006). Oil of sunflower light in taste, appearance and more essential vitamin E then, other vegetable oil. The sunflower consist of monounsaturated and polyunsaturated fats. It is used like, foods, cosmetics, industries, and for the treatment of Cholesterol and atherosclerosis. (Madhavi *et al*., 2010). Oil contents in cultivated sunflower show considerable variation. However, in wild species oil contents are much less than cultivated sunflower (Seiler, 1992). Sunflower oil has greater percentage of unsaturated fatty acids such as oleic acid (90%) and linoleic acid (10%). Sunflower oil can be utilized directly for cooking and as salad oil. Sunflower oil is considered as the second best after olive oil for edible purposes due to high proportion of unsaturated fatty acids in its oil. Sunflower oil is also very suitable for making vegetable ghee and margarine (vegetable butter) and its pulp is utilized for paper production. The seed cake meal is rich protein source as its seed protein components range from 20 to 30 percent (Arshad *et al*., 2010

In plant breeding general combining ability (GCA) and specific combing ability (SCA) are important techniques to identify best lines for the production of hybrid. Sunflower hybrids exhibit superior performance as compared to open pollinated populations due to expression of hybrid vigor. The hybrid plant seeds have also uniform moisture contents that make them fit for storage (Nasreen *et al*., 2011). The hybrids also show better response to high inputs usage of fertilizers and water that results in increased production potential. So, estimating the general combining ability (GCA) effects and specific combing ability (SCA) effects is helpful to select the best parent inbreds for desired hybrids in seed yield and oil contents. The line × tester analysis by kempthorn, 1957 may be the simplest and efficient method for evaluation inbreds for their combining abilities. General combining ability (GCA) was defined by Sprague and Tatum (1942)

MATERIAL AND METHODS

The present research was conducted in the experimental area of Plant Breeding and Genetics Department, University of Agriculture, Faisalabad during autumn 2014 and spring season in 2015. The experimental material were consist of three lines G-53, B-3.16 and C-3.3 as male parents and seven lines B-3.1, A-16.1, A-12, A-14.13,A-2.2,A-22 and B-12.10 as female were obtained from Plant Breeding and Genetics Department of, University of Agriculture, Faisalabad. These lines will be planted during autumn season 2014. The Hybrid combinations were obtained by crossing these male lines with female lines in Line x Tester mating design. Plants in female lines were hand emasculated and crossed by the male parents. Male parents were used as a source of pollen only.

Seed of these hybrid combinations and its parents along with two commercial hybrids were sowed in the field during spring season 2015 following randomized complete block design (RCBD) with three replications and maintaining plant-to-plant and row-to-row distance of 25 and 75 cm, respectively. Cultural and agronomic practices were applied during the growing season of crop. The data were recorded on 10 plants per entry of each replication for the following traits:

- Days taken to first flowering
- Days taken to 50% flowering
- Days taken to complete flowering
- Plant height (cm)
- Internodal length(cm)
- Leaf area (cm)
- Head diameter (cm)
- Dry head diameter (cm)
- Stem diameter (cm)
- Number of leaves/ plant
- Achene yield per head (g)
- 100 achene weight per head(g)
- Oil content (%)
- Protein contents (%)

Oil content and protein content of all genotypes were analysis from the national institute of food and agriculture (NIFA) Peshawar.

RESULT AND DISCUSSION

Main objectives of this study evaluated the cross combinations of different lines and testers for high yielding hybrids. Mean squares of all characters revealed significant differences between sunflower genotypes (Table 1). Highly significant differences between crosses were present for all characters except complete flowering. Highly significantly were also present for all characters except plant height, Internodal length and oil content. Non significant differences presented for all characters except stem diameter between lines and testers. These results were similar with the findings of (Jayalakshmi *et al.,* 2000; Karivaratharaju, 2000; Monotti *et al.,* 2000 and Sharma *et al.,* 2000). However, line × tester interaction was highly significant for all characters except flower initiation and complete flowering. . Parents vs crosses were showed significant for all characters under study. Significant difference inside various components showed the presence of genetic variability in the breeding material. This genetic variability may be exploited in the breeding programs for improvement of sunflower achene yield and its related traits. Significant differences among parents vs. crosses showed the presence of heterosis in crosses that may be showed for the development of high yielding sunflower hybrids. These findings were similar with the results of (Alone *et al.,* 1996; Shekar *et al.,* 1998; Ashoke *et al*., 2000; Habib *et al*., 2007 and Khan et *al.*, 2008). The analysis of variance of all crosses showed significant variability.

The concept of general and specific combining ability has gained great importance for plant breeders because of the wide use of hybrid in many crops. In the general combining ability the minimum GCA effects were observed by the line A-12 and the tester G53 which were also significant in negative direction and were desirable for days to flowering and for the development of short stature hybrids. Tester G-53 and C-3.3 had positive and significant GCA effects for 100 achene weights per head and number of leaves per plant respectively, which were desirable high yielding.

Table-2. Line A-12 and tester G-53 displayed positive and significant GCA effects for fresh, dry head diameter, 100 seed weight, achene yield per head and protein content. The line A-2.2 and tester G-53 were identified good general combiner because these lines revealed the highest GCA effects for oil content which was significant in positive direction and it was desirable. The line A-12, A-2.2 and tester G-53 were identified good general combiners that may be used in the improvement of the most yield related traits. The good combinations of lines and testers may be recommended for hybrid development and breeding program in the future. These results were similar with the findings of Imran *et al*. (2015), Naik *et al*. (1999) and Skoric *et al*. (2000).

Table-3. The crosses A-12 × B-3.16 and B-12.10 × C-3.3 were performed as a good specific combiners for yield related traits. Especially for protein content the cross B-3.1 × B-3.16 showed the maximum SCA effects. So the crosses A-12 × B-3.16 and B-12.10 × C-3.3 were exibited best specific combiner followed by the hybrid G-65×A-85. These crosses may be recommended for high yielding in the future. Lande *et al.* (1997), Bajaj *et al.* (1997), Shekar *et al*. (1998), Kumar *et al*. (1998) reported the same study.

CONCLUSION

According to above research work, it is concluded that the evaluation of breeding materials had sufficient genetic variability that may be used in further breeding programs. GCA and SCA ANOVAs proposed these traits under control of non-additive gene action. Further analysis showed over-dominant gene action controlling the plant traits. Therefore, estimation of combining ability was suggested to improvement in yield and yield related traits using these sunflower breeding materials. Among the proposed genotypes i.e. A-12, A-2.2 and G-53 indicated highest GCA effects and considered to be good general combiner for almost 85% traits under study and The cross combinations A-12 × B-3.16, B-12.10 × C-3.3 and B-3.1 × B-3.16 were showed best specific combining ability whereas these genotypes can be used for further hybrid development breeding programs for seed yield and oil contents improvement.

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***= Significance at 0.05% Probability level **= Significance at 0.01% Probability level**
SOV= Source of variation,
D.F= Degree of freedom,
I.F= Days to Initiation flowering,
50% F= Days to 50% flowering,
C.F= Days to complete flowering,
P.H= Plant height,
I.L= Internodal length,
L.A= Leaf area,
H.D= Head diameter
D.H.D= Dry head diameter,
S.D= Stem diameter,
N.L/P= Number of per plant,
A.Y/H= Achene yield per head,
100-S.W= 100 seed weight,
O.C= Oil content,
P.C= Protein content

Table 1a. Mean squares from analysis of variance for plant related traits.

SOV	D.F	I.F	50% F	C.F	P.H	I.L	L.A	H.D
Replication	2	0.33NS	59.17NS	35.22NS	244.4NS	6.09*	12262.8NS	0.50NS
Treatment	30	56.35**	158.14**	166.61**	1410.6**	32.44**	27068.8**	33.22**
Parent	9	82.98**	201.95**	239.91**	179.2NS	1.72NS	14412.0*	41.51**
Crosses	20	37.60**	123.92**	108.38*	858.19**	31.68**	21923.0**	30.34**
P * C	1	191.71*	448.31*	671.72*	23543.5**	324.17**	243895.4**	16.06*
Lines (L)	6	49.42NS	142.06NS	71.46NS	1070.8NS	14.22NS	25522.6NS	31.20NS
Testers (T)	2	34.90NS	42.20NS	61.73NS	313.9NS	19.48NS	14009.6NS	13.79NS
L * T	12	110.35*	317.29**	370.52*	2938.9**	70.75**	52575.8**	65.15**
Errors	60	14.43333	28.41649	52.99247	152.3295	1.840673	7364.161	6.594437

Table 1b. Mean squares from analysis of variance for plant related traits.

SOV	D.F	D.H.D	S.D	N.L/P	A.Y/H	100 S W	O.C	P.C
Replication	2	2.18 NS	3.74 **	11.25*	17.51NS	.03NS	1.27NS	0.97**
Treatment	30	32.55**	4.15**	138.4**	573.11**	5.99**	130.75**	15.64**
Parent	9	45.03**	2.02**	23.55**	235.52**	3.81**	10.13NS	22.35**
Crosses	20	26.44**	4.60**	103.20**	685.51**	4.75**	82.17**	12.55**
P * C	1	42.40*	14.52**	1878.5**	1363.4**	50.32**	2187.8**	16.87**
Lines (L)	6	33.20NS	2.46**	84.10NS	726.3NS	4.15NS	85.73NS	16.67NS
Testers (T)	2	8.33NS	27.40**	20.90NS	854.7NS	4.32NS	26.78NS	12.82NS
L * T	12	63.40**	4.60**	300.69**	927.15**	12.18**	279.54**	28.62**
Errors	60	3.372	0.308	3.713	37.821	0.466	8.705	1.157

Table 2a. General combining ability effects of lines and testers for yield and its related traits.

	I.F	50%.F	C.F	P.H	I.L	L.A	H.D
Lines							
B-3.1	-1.5**	-2.9*	-3.9**	7.1*	0.09	66.85*	0.75
A-2.2	-0.12*	2.6	0.63	5.5	-1.50**	42.07	1.86*
A-12	-1.90**	-4.3**	-5.65**	-13.13**	-1.9**	-92.47**	2.13*
A-14.13	0.76	-0.2	-0.34	6.48	1.15**	-34.81	-3.92**
A-16.1	-0.01*	-0.17	0.2	4	0.51	29.96	1.15
A-22	0.98	0.6	1.87	7.7*	0.32	-1.03	-0.04
B-12.10	3.9**	6.60**	2.87	-18.2**	1.34**	-10.57	0.07
Standard.Error	1.266	2.512	2.426	4.114	0.452	28.6	0.855
Testers							
G-53	-1.4*	-1.6	-1.7	-3.1	-1.0**	-14.72	0.73
B-3.16	-0.51	-0.6	-0.02	4.3	0.78**	29.8	0.13
C-3.3	0.9	0.8	1.6	-1.13	0.29	-15	-0.86
Standard.Error	0.82	1.64	1.58	2.69	0.29	18.72	0.56

Table 2b. General combining ability effects of lines and testers for yield and its related traits.

	D.H.D	S.D	N.L/P	A.Y/H	100 S W	O.C	P.C
Lines							
B-3.1	0.86	0.24	-1.1*	5.0**	0.11	-2.2*	-0.36
A-2.2	1.85**	0.4*	1.1*	7.2**	0.51**	-0.7	-0.9*
A-12	2.42**	0.33*	-4.7**	10.8**	1.06**	1.8*	1.9**
A-14.13	-4.06**	0.2	4.06**	-9.1**	0.80**	-4.1**	-1.6**
A-16.1	0.93	0.06	-0.9	3.4	-0.05	4.3**	0.9*
A-22	0.35	-0.1	3.2**	-15.2**	0.32*	2.7**	-1.0**
B-12.10	0.47	-1.1**	-1.7**	2.02	-0.74**	-1.96*	1.1**
Standard.Error	0.612	0.185	0.642	2.049	0.183	0.983	0.358
Testers							
G-53	0.51	-1.1**	-1.0*	5.3**	0.36**	0.9	0.81**
B-3.16	0.18	-0.07	0.23	-7.0**	-0.20*	-1.2*	0.74**
C-3.3	-0.70*	1.17**	0.85*	1.65	-0.15	0.29	0.07
Standard.Error	0.4	0.121	0.42	1.342	0.119	0.643	0.234

Table 3a. Specific combining ability effects of crosses for yield related traits.

Crosses	I.F	50%.F	C.F	P.H	I.L	L.A	H.D
B-3.1 × G-53	-51.69**	5.14	-83.80**	-146.8**	-1.60*	-276.6**	-18.0**
B-3.1 × B-3.16	-8.23**	-10.80**	-16.14**	1.13	0.32	11.5	1.66
B-3.1 × C-3.3	3.09	5.66	10.19**	-1.54	1.28	17.5	0.23
A-16.1 × G-53	-0.68	4.95	-0.69	7.29	1.18	14.6	-0.88
A-16.1 × B-3.16	1.69	4.95	5.06	-18.8**	1.18	-62.9	0.62
A-16.1 × C-3.3	-1.01	-2.41	-4.36	11.5*	0.57	48.3	0.25
A-12 × G-53	0.42	2.63	-1.36	13.2*	0.3	115.1**	-0.82
A-12 × B-3.16	1.47	-0.22	4.06	20.2**	-0.87	149.9**	5.64**
A-12 × C-3.3	-1.9	-2.6	-2.69	-33.4**	-0.87	-165.1**	-4.82**
A-14.13 × G-53	-2.23	-2.6	-4	-4.6	-0.87	-109.1**	2.1
A-14.13 × B-3.16	-0.85	0.25	1.39	7.9	-0.77	112.2**	-5.35**
A-14.13 × C-3.3	3.09	8.63**	2.63	-3.3	-0.67	-3.1	3.21*
A-2.2 × G-53	1.87	-8.88*	-3.5	-0.64	1.44*	-43.9	-0.13
A-2.2 × B-3.16	-0.07	4.39	0.84	4.5	0.28	-19.1	-0.46
A-2.2 × C-3.3	-1.79	4.39	2.74	-3.8	0.28	63	0.6
A-22 × G-53	-3.79*	3.47	-0.58	-4	-0.08	15.7	0.59
A-22 × B-3.16	4.58*	-2.8	2.1	-3.9	2.9**	-48.4	-2.76*
A-22 × C-3.3	-0.79	-0.66	-1.5	8	-2.8**	32.7	2.16*
B-12.10 × G-53	1.31	0.28	6	17.1**	-0.13	-7.9	1.6
B-12.10 × B-3.16	-0.63	0.28	0.86	-5.5	-0.13	1.3	0.04
B-12.10 × C-3.3	-0.68	-7.7*	-6.9	22.6**	0.53	6.5	1.65
Standard Error	2.193	4.35	4.2	7.12	0.78	49.54	1.48

Table 3b. Specific combining ability effects of crosses for yield related traits.

Crosses	D.H.D	S.D	N.L/P	A.Y/H	100 S W	O.C	P.C
B-3.1 × G-53	-16.7**	-4.10**	-26.2**	-47.6**	-4.19**	26.7**	-16.7**
B-3.1 × B-3.16	1.80*	0.83**	4.53**	-0.24	-0.71*	-11.5**	3.12**
B-3.1 × C-3.3	0.22	0.32	1.92*	-8.9**	-0.4	2.8	-0.22
A-16.1 × G-53	-0.5	-0.80**	0.53	-11.6**	-0.36	-7.7**	-0.11
A-16.1 × B-3.16	0.74	0.83**	-1.4	10.7**	-0.32	5.4**	-0.3
A-16.1 × C-3.3	-0.16	-0.02	0.92	0.82	0.69*	2.2	0.47
A-12 × G-53	-0.03	0.21	1.42	-12.9**	0.59*	-3.7*	-0.27
A-12 × B-3.16	4.5**	0.92**	8.4**	12.1**	1.35**	6.6**	1.28*
A-12 × C-3.3	-4.5**	-1.1**	-9.8**	0.78	-1.9**	-2.9*	-1.01
A-14.13 × G-53	2.23*	-0.2	-2.3*	16.1**	-0.6*	4.7**	-0.54
A-14.13 × B-3.16	-5.4**	0.6*	2.3*	-7.2*	0.42	-5.4**	-2.43**
A-14.13 × C-3.3	3.2**	-0.4	0.03	-8.9**	0.21	0.7	2.97**
A-2.2 × G-53	0.43	0.04	4.3**	-10.7**	-1.2**	-0.6	1.5**
A-2.2 × B-3.16	0.23	-0.5*	-9.3**	6.6*	-0.18	1.2	1.21*
A-2.2 × C-3.3	-0.67	0.53*	5.0**	4.12	1.43*	-0.6	-2.83**
A-22 × G-53	0.01	0.17	-4.2**	19.4**	0.38	0.76	-2.83**
A-22 × B-3.16	-1.68	-0.41	5.0**	-24.6**	0.67*	-0.1	0.43
A-22 × C-3.3	1.66	0.23	-0.85	5.1	-1.06*	-0.5	-1
B-12.10 × G-53	0.29	0.73*	5.4**	2.9	0.64*	0.09	0.04
B-12.10 × B-3.16	-0.5	-1.2**	-8.2**	-9.9**	-1.7**	1.5	-1.71**
B-12.10 × C-3.3	0.24	0.48	2.80**	6.9*	1.07**	1.6	1.66**
Standard Error	1.06	0.32	1.11	3.55	0.31	1.7	0.62