Combining ability assessment in *Helianthus annuus* L. through line × tester analysis for quantitative traits and quality parameters

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The cross combinations of different lines and testers (L×T) for high yielding sunflower (*Helianthus annuus*) hybrids were evaluated. Plant materials were utilized by L×T mating design of 7 lines and 3 testers and their 21 hybrids were sown in the field during 2015 autumn season in RCBD design with 3 replications. Genetic variability, general combining ability (GCA) and specific combining ability (SCA) among genotypes were assessed. Lines A-12, A-2.2 and tester G-53 were found to be 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 crosses, A-12 × B-3.16 and B-12.10 × C-3.3 were reported as good specific combiners for yield-related traits. For protein content, the cross B-3.1 × B-3.16 showed the maximum SCA effects.

**Key words:** Line × tester, general combing ability (GCA), specific combining ability (SCA), protein contents, yield.

INTRODUCTION

Sunflower (*Helianthus annuus*) is an important oil producing crop after soya bean. Sunflower oil is the best due to its mild taste, low amount of saturated fatty acid and light color. Sunflower oil plays an important role in the economy of Pakistan (Imran et al., 2015). The national average yield of sunflower crop is about 1520 kg/ha (Shah et al., 2013). Sunflower plays an important role in increasing the local production of vegetable oil.

There is a huge gap between production and consumption of vegetable oil and it is increasing day by day. Pakistan is spending a huge amount of foreign exchange every year to import edible oil. Due to changing habit of people and increasing population in the country, it has the ability to decrease the gap between local production and consumption. Thus, the local production of hybrids seed with high oil contents is one of the best
goals (Habib et al., 2006). Sunflower Oil is light in taste, appearance and contains more essential vitamin E than other vegetable oils. The oil consists of monounsaturated and polyunsaturated fats. It is used in foods, cosmetics, industries, and for the treatment of cholesterol and atherosclerosis (Madhavi et al., 2010). Oil contents in cultivated sunflower show considerable variation. 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%). It 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. It is also very suitable for making vegetable ghee and margarine and its pulp is utilized for paper production. The seed cake meal is a rich protein source as its seed protein components range from 20 to 30% (Arshad et al., 2010).

In plant breeding, general combining ability (GCA) and specific combining ability (SCA) are important techniques to identify the best lines for hybrid production. Sunflower hybrids exhibit superior performance as compared to open pollinated populations due to expression of hybrid vigor. The hybrid plant seeds also have 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 which results in increased production potential. Therefore, estimating the GCA and SCA effects is helpful to select the best parent inbreds for desired hybrids in seed yield and oil contents.

The line × tester analysis is an efficient method to assess the large number of inbreds and it provides information on the relative importance of general and specific combining ability effects to understand the genetic basis of important plant characters, namely, plant height, head diameter, stem diameter, achene weight, achene yield and oil contents, etc. The GCA of a line means the average value of its performance in hybrids when crossed with other lines (Ahsan et al., 2013; Saeed et al., 2014; Naseem et al., 2015a, b). The line × tester analysis by Kempthorne (1957) may be the simplest and efficient method for evaluation of inbreds for their combining abilities. GCA was defined by Sprague and Tatum (1942). The objective of this study was to evaluate the cross combinations of different lines and testers for high yielding hybrids.

RESULTS AND DISCUSSION

Mean squares of all characters exposed significant differences among sunflower genotypes (Table 1a and b). High significant differences among crosses were observed for all traits. High significant differences were also present for all traits except plant height, internode length and oil content among parents. There was no significant difference for all characters except stem diameter among lines and testers. These results were similar to the findings of earlier researchers (Jayalakshmi et al., 2000; Kannababu and Karivaratharaju, 2000; Monotti et al., 2000; Sharma et al., 2000). However, L × T interaction was highly significant for all traits except flower initiation and complete flowering. Parents vs. crosses showed significant differences for all traits under study. Significant difference inside different components showed the presence of genetic variability in the breeding material. This genetic variability may be used 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 used for the development of high yielding sunflower hybrids. These findings were similar to 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 (Tables 2 and 3).

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 general, the minimum GCA effects were observed in 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 1. Mean squares from analysis of variance for plant related traits.

| SV                  | D.F | I.F | 50% F | C.F | P.H | I.L | L.A | H.D |
|---------------------|-----|-----|-------|-----|-----|-----|-----|-----|
| Replication         | 2   |     | 0.33 NS | 59.17 NS | 35.22 NS | 244.4 NS | 6.09 NS | 12262.6 NS | 0.50 NS |
| Treatment           | 30  |     | 56.35** | 158.14** | 166.61** | 1410.6** | 32.44** | 27068.8** | 33.22** |
| Parent              | 9   |     | 82.98** | 201.95** | 239.91** | 179.2 NS | 1.72 NS | 14412.0* | 41.51** |
| Crosses             | 20  |     | 37.60** | 123.92** | 108.38* | 858.19** | 31.68 NS | 21923.0** | 30.34** |
| C × P × C           | 1   |     | 191.71* | 448.31* | 671.72* | 23543.5** | 324.17** | 243895.4** | 16.06*  |
| Lines (L)           | 6   |     | 49.42 NS | 142.06 NS | 71.46 NS | 1070.8 NS | 14.22 NS | 25522.6 NS | 31.20 NS |
| Testers (T)         | 2   |     | 34.90 NS | 42.20 NS | 61.73 NS | 313.9 NS | 19.48 NS | 14009.6 NS | 13.79 NS |
| L × T               | 12  |     | 110.35* | 317.29** | 370.52* | 2938.9** | 70.75** | 52575.8** | 65.15** |
| Errors              | 60  |     | 14.4333 | 28.4164 | 52.9924 | 152.3295 | 1.840673 | 7364.161 | 6594437 |

Significance at 0.05% probability level; **Significance at 0.01% probability level. SV: 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: internode 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 2. General combining ability effects of lines and testers for yield and its related traits.

| Variables | I.F | 50%F | C.F | P.H | I.L | L.A | H.D |
|-----------|-----|------|-----|-----|-----|-----|-----|
| Line      |     |      |     |     |     |     |     |
| 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 |

Significance at 0.01% probability level. SV: Source of variation; I.F: days to initiation flowering; 50% F: days to 50% flowering; C.F: days to complete flowering; P.H: plant height; I.L: internode 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 2. Contd.

| Crosses | I.F | 50%.F | C.F | P.H | I.L | L.A | H.D |
|---------|-----|-------|-----|-----|-----|-----|-----|
| 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 |

**Tester**

| Crosses | I.F | 50%.F | C.F | P.H | I.L | L.A | H.D |
|---------|-----|-------|-----|-----|-----|-----|-----|
| 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 |

Significance at 0.05% probability level; **Significance at 0.01% probability level. SV: 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; L.I: internode 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 3. 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 x G-53 | -16.7** | -4.10** | -26.2** | -47.8** | -4.19** | 26.7** | -16.7** |
| B-3.1 x B-3.16 | 1.80* | 0.83** | 4.53** | -0.24 | -0.71* | -11.5** | 3.12** |
| B-3.1 x C-3.3 | 0.22 | 0.32 | 1.92* | -8.9** | -0.4 | 2.8 | -0.22 |
| A-16.1 x G-53 | -0.5 | -0.80** | 0.53 | -11.6** | -0.36 | -7.7** | -0.11 |
| A-16.1 x B-3.16 | 0.74 | 0.83** | -1.4 | 10.7** | -0.32 | 5.4** | -0.3 |
| A-16.1 x C-3.3 | -0.16 | 0.02 | 0.92 | 0.82 | 0.69* | 2.2 | 0.47 |
Table 3. Contd.

| Cross          | GCA 1 | GCA 2 | GCA 3 | SCA 1 | SCA 2 | SCA 3 | Standard error |
|----------------|-------|-------|-------|-------|-------|-------|---------------|
| 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         |

Significance at 0.05% probability level; **Significance at 0.01% probability level. SV: 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: internode 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 2a and b shows that 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 as proper general combiners 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 as proper general combiners that may be used in the improvement of the most yield related traits. The proper combinations of lines and testers may be recommended for hybrid development and breeding program in the future. These findings were similar with the results of Imran et al. (2015), Naik et al. (1999) and Skoric et al. (2000).

Table 3a and b shows that the crosses A-12 × B-3.16 and B-12.10 × C-3.3 performed as proper 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 exhibited to the 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), Shekar et al. (1998) and Kumar et al. (1998) reported similar results.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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