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Research Article

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Heterosis and Combining Ability Analysis in Sunflower Through Line × Tester Breeding Scheme

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ABSTRACT
Sunflower (*Helianthus annuus* L.) is considered a superior oil seed crop due to its high oil and protein content. Due to their cross-pollinated mode, its hybrids are very popular. Several crosses were evaluated for their oil and yield-related traits. To achieve this goal, seven parent genotypes were collected, including four female and three male parents each. Three repetitions of the Randomized Complete Block Design were used to evaluate twelve crosses and seven parental lines. The following traits were measured at maturity: days to flower initiation, days to 100% flowering, head diameter, plant height, leaf area, and 100 achene weight. To find the significance of parents, crosses, and general and specific combinations, data were analyzed using line x-tester analysis. The parents A-10, A-20, and R-70 performed well for days to 100% flowering, whereas A-30 and A-40 performed well for leaf area and head diameter. In terms of days to flower initiation, the hybrids A-30 x R-74 and A-40 x R-72 displayed negative and significant heterosis compared to the mid-parent, better parent, and standard. Crosses A-20 x R-70 and A-30 x R-74 functioned exceptionally well for 100 achene weight. The best-performing crosses were selected for further use in breeding programs.
Keywords: Sunflower, Heterosis, Combining ability, Breeding, and Lines × Testers.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the fourth-highest oil-producing crop in the world, behind soybeans, palm, and rapeseed/canola (Nehru et al. 2000). It belongs to the family of Asteraceae. Its chromosome number is 2n= 34, and it is considered a very high cross-pollinated oilseed crop. The highest producers of sunflower in recent years have been Ukraine, Argentina, and Russia. About 72% of the production of edible oil locally comes from cotton seed oil, followed by 9% from brassica and 4% from sunflower. It has a protein content of 17–20% and a range of 40–60% oil content. (Cicek et al., 2019). In addition to its high concentration of polyunsaturated fatty acids, sunflower oil is an excellent source of monounsaturated fatty acids (50-60% linoleic acid). Besides its light color, mild taste, and high-temperature resistance, the oil has excellent qualities.

The oil is also utilized in cosmetic and industrial products. Sunflower is used in a variety of breeding programs and has enormous potential in terms of oil and achene production (Zia et al., 2016). With the shift in eating habits, there is an increase in the need for edible oil. In the period of July-March 2022, Pakistan imported 2.754 million tons of edible oil worth Rs 662.657 billion (US$3.618 billion). The total available edible oil from different sources during this time was 3.214 million tons, based on estimates of 0.460 million tons of edible oil being produced locally (Govt. of Pakistan, 2022). Sunflower is a crop that requires specific climatic conditions, such as warm temperatures and abundant sunlight, to grow well. In Pakistan, several factors contribute to the low sunflower yield, including seed availability, less research into sunflower crops, an imbalanced marketing system, and high prices for local hybrid seeds. By producing new local hybrids with higher yields, by improving oil and seed quality, and by expanding seed cultivation areas, the gap could be reduced. Genetic variability is essential to the development of an effective plant breeding program. (Kaya and Atakisi, 2004; Khalid and Amjad, 2019). Assessing the variability in cross combinations provides insight into the genetic variability of crop varieties. The selection of the appropriate parental lines is crucial to the success of the breeding program. Sunflower crop enhancement requires combining ability and estimating gene action. It allows the breeder to select better parental pairings for advancement.

Heterosis breeding has been a valuable tool in improving the yield and quality of crops, particularly in cross-pollinated plants like sunflowers. To meet the growing oil demand, heterosis breeding can improve the oil quality and seed yield. Heterosis is more reliable in cross-pollinated plants as compared to self-pollinated plants (Kinman, 1970).

Combining ability refers to an estimation of genotype importance based on progeny success in a mating design that is reliable. The term "combining ability" is known as the ability of a particular parent to contribute desirable traits to a hybrid offspring. GCA refers to the effects of dominant genes, and SCA refers to the effects of additive genes. Both GCA and SCA values can be affected by the presence of epistasis genes. GCA and SCA values can be used by plant breeders to identify the best parent plants to use in breeding research. By studying the GCA and SCA values of different parent plants, breeders can identify which parents are likely to produce hybrids with high yields of vegetable oil and achene. The line × tester method is commonly used to analyse combining ability, and it is considered to be an efficient approach for identifying parents with desirable yield traits. (Kempthrone, 1957).

MATERIALS AND METHODS

Experimental Conditions

The trial was performed at the experimental fields of Raja-wala in 2012. The experimental material that is used in this study was comprised of four lines (A-10, A-20, A-30, and A-40) and three testers (R-70, R-72, and R-74) were sown at the distance of 25 cm P*P and 75 cm R*R distance. Agronomic practices are recommended from seed to harvest. During the first spring season, all lines of testers were crossed, and in the following autumn season, by replicating the complete block design three times, a hybrid seed from these crosses was sown along with Hysun-33. The objective of the present experiment was to determine the proportion of heterosis in hybrids and examine general and specific combining capacities of newly established sunflower inbred lines utilizing line x tester analysis (Kempthorne, 1957). Achene weight (g) of 100 was computed using plot yield data after observations were made on five randomly selected plants for the following characteristics: Days to flower initiation, days to 100% flowering, leaf area (cm2), plant height (cm), head diameter (cm), and 100 achene weight (g).

Data Recording

Data was collected for three plants in each genotype per plot based on pre- and post-harvest characteristics at maturity. The following parameters are being Recorded: times to flower initiation, days to 100% flowering, head diameter, leaf area, plant height, and 100 achene weight.

Statistical Analysis

Every characteristic was examined in relation to Steel et al, (1997). Line x tester analysis would be used to analyse estimates for GCA and particular combining ability for parents and hybrids.

Table.1 (Lines and Testers exploited in experiment)

Sr. No	Testers	Sr. No	Lines
1.	R-70	1.	A-10
2.	R-72	2.	A-20
3.	R-74	3.	A-30
		4.	A-40

RESULTS AND DISCUSSION

The results of a study that examined the GCA of different sunflower lines and testers. It states that lines and testers exhibit a flexible degree and direction of GCA possessions. Among the lines, A-20 had the greatest GCA possession for days to complete flowering. It is also stated that line A-20 exhibited the greatest positive. GCA possessions for plant height, line A-30 for leaf area, and line A-40 for head diameter. GCA refers to the performance of an individual genotype in combination with different testers. It is an important trait which is used to know how well a variety or line can combine with other varieties or lines. GCA values can be positive or negative, indicating whether a line performs better or worse than the average of the parents when crossed with different testers. Positive GCA values indicate that the line is a good general combiner and negative indicates a poor general combiner. These findings were related to Kumar et al. (1998), Goksoy (1999), Khan (2004), Mayor et al., (2006), Hladni et al., (2006), Bajaj et al., (1997), Ashok et al., (2000) for the plant height days to flowerings and 100 seed weight

Days to flowering Initiation

Six crosses showed positive and significant SCA for initial flowering days. A combination of A-10 x R-70, A-20 x R-70, A-30 x R-74, and A-30 x R-74 had negative and significant SCA for initial flowering days as shown in Table 3. The same was reported by Sharma et al., (2003), Kaya and Atakisi (2004).

Days taken to 100% flowering

Positive and significant SCA for days to 100% flowering was shown by five crosses. The combination of A-20 x R-70, A-20 x R-74, A-30 x R-74, A-40 x R-74 had negative and significant SCA for days to 100% flowering as shown in Table 3. Same results were reported by, Kaya and Atakisi (2004).

Plant height (cm)

Six crosses have significant SCA for initial flowering days. A-40 x R-70, A-40 x R-74 had negative and significant SCA for Plant height as shown in Table 3. The same was reported by Sharma et al., (2003), Kaya and Atakisi (2004).

Leaf area (cm2)

Significant and positive SCA in six crosses for leaf area. The combination of A-20 x R-70 had significant and highest SCA while the combination of A-20 x R-72 had significant and negative SCA as shown in Table 3. Hladni et al. (2006) also reported the same results.

Head diameter

Significant and positive SCA in three crosses for head diameter. Combination A-40 x R-70 had significant and negative SCA estimates as shown in Table 3.

100 Achane Weight

Crossovers for 100 achene weight that have a significant and beneficial SCA. Combining A-20 x R-70 and A-30 x R-74 resulted in a positive and substantial SCA for 100 achene weight, as shown in Table 3. Hladni et al. (2006), Ashoke et al (2003). Kang et al., Andarkhor et al., and and Machikowa et al. (2011). (2013). At an achene weight of 100, heterosis was found to be positive and significant. Machikowa et al. (2011). (2013). At an achene weight of 100, heterosis was found to be positive and significant. It states that genotypic variances were significant (P<0.00.01) for all the parameters studied. It also states that parents and their crosses had extremely significant results (P<0.01) for all traits studied. The hybrids also showed significant differences (P<0.05-0.01) for all traits. The inbred lines also had significant differences (P<0.05-0.01) for certain traits like days to flower completion, times to flower initiation, plant height, leaf area, no. of leaves per plant, Inter-nodal distance, head diameter, 100 achene weight. Testers also had significant differences (P<0.05-0.01) for all traits. The interaction between line and tester was significant (P<0.05-0.01) for certain traits like days to flower completion, times to flower initiation, leaf area, plant height, head diameter and 100 achene weight. Significant genetic variation for characteristics associated with yield was also demonstrated in Siddiqui et al. (2000). Ashoke et al. (2000). Tahir et al. (2002) and Nasreen et al. (2011).

CONCLUSION

The GCA effects have been strong on lines A-10, A-20, and A-30, whereas testers R-70 and R-74 were observed to be good general combiners. The analysis of variance demonstrated highly significant variations among genotypes for all characters evaluated. The most effective cross for SCA was A-40 x A-70, and it was regarded as the best. For further genetic exploitation and to expand the genetic base, they can be used in breeding. This breeding material has been found to effectively boost sunflower achene production and oil quality. Given that it has enough genetic variation, to meet the need for oil we can use this breeding material in subsequent breeding operations.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

Table 2. The results of a statistical analysis of variance (ANOVA) that was conducted on various parameters

SOV	DF	D.F.I	D.C.F	P.H	L.A	H.D	100 A.W
Rep	2	1.70	1.18	16.75*	16.33*	0.59	0.86
Genotype	18	49.72**	51.79**	321.22**	645.97**	2.77*	49.33*
Cross	11	59.38**	69.73**	459.84**	428.08**	3.37*	17.96*
Line	3	6.33*	69.74**	111.40**	482.77**	7.33*	2.89*
Tester	2	15.86*	27.25*	38.36*	57.73*	2.58	21.19*
LxT	6	100.41**	83.88**	774.56**	524.27**	1.66	24.42*
Parent	6	19.21*	11.54*	103.36**	120.32**	2.07	5.76*
Line	3	13*	7.33*	52.82*	55.78*	0.23	5.64*
Tester	2	31.4*4	5.33*	69.57*	103.44**	1.34	0.44
L vs T	1	13.35*	36.56*	322.55**	347.68**	9.10*	16.77*
Cross vs Parent	1	126.47**	96.01**	101.76**	6196.70**	0.21	655.80**
Error	36	1.52	2.32	66.40	14.22	0.33	1.23

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

Crosses	D.F.I	D.F.C	P.H	L.A	H.D	100 A.W
A-10 x R-70	-5.42**	-0.36	19.57**	-8.92**	0.66	-1.22
A-10 x R-72	3.67**	-1.94	-23.95**	7.33**	-0.23	0.19
A-10 x R-74	1.75*	2.31*	4.38	1.58	-0.44	1.03
A-20 x R-70	-3.97**	-2.92*	-5.22	10.75**	-0.53	3.78**
A-20 x R-72	3.44**	5.83**	0.79	-16.33**	0.02	-0.14
A-20 x R-74	0.53	-2.92*	4.43	5.58**	0.51	-3.64**
A-30 x R-70	5.36**	-0.47	-3.57	5.97**	0.75	-3.22**
A-30 x R-72	-0.22	3.61**	5.38	9.56**	-0.21	0.53
A-30 x R-74	-5.14**	-3.14**	-1.82	-15.53**	-0.55	2.69**
A-40 x R-70	4.04**	3.75**	-10.78**	-7.81**	-0.89*	0.67
A-30 x R-74	-6.89**	-7.50**	17.77**	-0.53	0.42	-0.58
A-40 x R-74	2.86**	3.75**	-6.99*	8.36**	0.48	-0.08
Standard Error	0.633	1.036	3.091	1.88	0.389	0.623

Table 4. General Combining ability effects of lines and testers for yield related traits

	D.F.I	D.F.C	P.H	L.A	H.D	100 A.W
Lines						
A-10	0.17	3.94**	1.00	0.08	1.14**	0.22
A-20	1.06**	-2.50**	-4.71*	0.75	0.30	0.56
A-30	-0.28	-0.28	3.73*	8.53**	-0.74**	-0.78*
A-40	-0.94*	-1.17	-0.02	-9.36**	-0.70**	-0.00
Standard Error	0.3165	0..5981	0.107	1.0854	0.225	0.3597
Testers						
R-70	0.86*	1.58**	-2.06	1.69	0.51*	0.89**
R-72	0.44	-0.17	1.19	0.78	-0.13	-0.64
R-74	-1.31**	-1.42**	0.86	-2.47*	-0.39	1.53**
Standard Error	0.3165	0.3165	1.5457	0.94	0.1949	0.3115

Abbreviations

*= significance at 0.05% probability level ** significance at 0.01% probability level

SOV = Sources of variation P.H= Plant hieght

D.F = Degrees of freedom L.A = Leaf area

D.F.1= Days of flowering initiation H.D = Head Diameter

D.C.F= Days taken to complete flowering 100-A.W= 100 Achene weight

SCA = Specific combining ability GCA = General combining ability

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