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IMPROVEMENT IN ACHENE YIELD AND OIL QUALITY THROUGH HETEROSIS BREEDING IN SUNFLOWER (*Helianthus annuus* L.).

Rizwana Qamar*, Amir Bibi, Hafeez Ahmad Sadaqat, Muhammad Hammad Nadeem Tahir, Muhammad Imran Zahid
Sunflower Research Lab, Department of Plant Breeding and Genetics, University of Agriculture Faisalabad
*Corresponding author email: rizwana_pbgians@yahoo.com

ABSTRACT
The study was carried out in the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad during 2011-12 to estimate heterosis for achene yield and oil related traits. 10 accessions, seven keeping as lines were crossed with three testers to generate 21 crosses. These crosses were then evaluated for 100 achene weight (g), achene yield per plant (g), oil contents (%) linoleic acid (%), palmitic acid (%) and oleic acid (%).Variable magnitude and direction of mid parent, better parent and commercial heterosis had been observed for 21 crosses. The cross G57×G12 showed maximum heterosis for 100 achene weight and linoleic acid. G2×G53 showed highest results for 100 achene weight, oil contents and linoleic acid. G100×A26 showed maximum heterosis for achene yield and oleic acid.G57×A26 showed maximum heterosis for oil contents. G65×G12 showed highest negative heterosis for palmitic acid. These crosses can play important role in the improvement of yield and oil quality and should be introduced in sunflower breeding programe.

KEY WORDS: heterosis, oil quality, yield, fatty acid profile.

INTRODUCTION
Edible oils are key constituents of our diet, which provides us energy, essential fatty acids and act as the transporter of certain vitamins. Current situation of local oil production is very poor as local production is just about 18 % while remaining 82 % has to import from other countries (Economic Survey of Pakistan 2014-15). Sunflower had a share among the four most important oilseed crops worldwide following soybean, cottonseed and groundnuts (FAO, 2005) and it accounts for 78% of the world vegetable oil production along with soybean and rapeseed (Ahmad *et al*., 2005). Sunflower among the most important oilseed crop of the world has a great potential to be used as a leading source of edible oil in Pakistan as it can be set easily in the cropping pattern. Its oil contents ranges from 30-55% (Skoric *et al.*, 2007).
Sunflower oil has a good nutritional quality and ranks among the best vegetable oils in cultivation. Generally sunflower oil contains 90% unsaturated *viz;* oleic and linoleic fatty acids while palmitic, stearic and minor amounts of other fatty acids accounts for the remaining 10% (Skoric *et al*., 2008). The usual fatty acid composition of sunflower oil is 55-65% linoleic acid, 20-30% oleic acid and the remaining including other fatty acids primarily palmitic and stearic acid (Joksimovic *et al*., 2006). Oil quality is very important in terms of its usage and is related with its fatty acid composition, mainly with the proportion of unsaturated fatty acids. However, different fatty acid composition is required depending upon their usage either it is used in industry or for human consumption (Izquierdo, 2002). Oils having high percentage of oleic acid are more stable and can be helpful in minimizing the risks of cardiovascular diseases in humans. On the other hand, linoleic acid is an essential fatty acid for humans and it is also preferred by oil industries when its hydrogenation is required.
Main breeding objective of sunflower is to develop high yielding, disease resistant hybrids with high oil quality (Dudhe *et al*., 2009). Hybrids were preferred by farmers due to high yield and quality potential, homogeneity, uniform maturity and easy possibility of cultural applications worldwide. Hybrid vigor has played the main role for acceptance of this oilseed crop. Utilization of heterosis has allowed sunflower to become one of the major oilseed crop in many countries of Eastern and Western Europe, Russia and South America. Heterosis can also be used to improve the quality of oil by improving its fatty acid composition.

MATERIALS & METHODS
The research experiment was conducted in the research fields of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2011-12. The experimental material consisted of 10 parental genotypes of sunflower *viz*; G57, G65, G2, G9, G93, G100, G7, G53, A26 and G12. Parental genotypes consisted of 7 lines and 3 testers, obtained from the Oilseeds Research Group, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. These were grown in the field during spring 2011 and crossed in line × tester fashion to get seeds of 21 crosses. Crossed seeds were harvested separately and grown in field during spring 2012 to study heterosis. Data were collected on 100 achene weight (g), achene yield per plant (g), oil contents (%), linoleic acid (%), palmitic acid (%) and oleic acid (%) and subjected to the analysis of heterosis.

Heterosis
Percent heterosis over mid parent, better parent (Heterobeltiosis) and commercial heterosis 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

Commercial heterosis (CH) = 100 × (F_1 – CP) / CP

CP = Commercial Parent

MP = [Female parent + Male parent] / 2

A t-test was applied to test the significance of heterosis over mid and better as under.

MP heterosis = $(F_1 – MP) / (3/8\ \sigma^2 e)^{1/2}$

BP heterosis = $(F_1 – BP) / (1/2\ \sigma^2 e)^{1/2}$

Commercial heterosis = $(F_1 – CP) / (1/2\ \sigma^2 e)^{1/2}$

RESULTS & DISCUSSION

Significant genetic variability is present in the collected germplasm for all the observed traits *viz.* 100 achene weight, achene yield, oil contents, linoleic acid, palmitic acid and oleic acid (Qamar *et al*., 2015). This variability can be efficiently used in sunflower breeding programs to develop improved varieties and hybrids. Combining ability studies of these genotypes showed the preponderance of nonaditive genetic effects which showed the importance of heterosis breeding in sunflower. Heterosis for various traits has been discussed as under.

100 achene weight

Variable magnitude of mid parent, better parent and commercial heterosis was observed for 100 achene weight as indicated in table 1. Twelve crosses showed positive and significant heterosis over mid parent, seven for better parent and 12 crosses for commercial hybrid FH-385 and six for FH 352. The cross G57×G12 and G2×G53 showed highest values for heterosis over mid parent, G57×G53 and G65×A26 over better parent whereas the crosses G2×G53 and G57×G12 showed highest heterosis over commercial hybrids. Mean values for 100 achene weight ranged from 4.18 to 6.14 g. Sujatha *et al*., 2002; Goksoy *et al*., 2002; Swargaunkar and Ghodke 2008 and khan *et al*. 2009 reported heterosis for 100 achene weights. The cross G57×G12 is best for 100 achene weight. So this cross can be used in the breeding program to improve the 100 achene weight which in turn improves the achene yield in sunflower.

Achene yield per plant

Seed yield of sunflower is a complex character which depends on many traits and varies with the environment. Changeable magnitude of mid parent, better parent and commercial heterosis was observed in the crosses for achene yield per plant. Results in table 1 showed that achene yield had significant and positive heterosis for seven crosses over mid parent, six crosses over better parent, eight and three crosses over commercial hybrids FH-385 and FH-352 respectively. The cross G100×A26 followed by the cross G57×G53 had the highest significant positive values for heterosis for mid, better and commercial hybrids. Mean values for achene yield ranged from 29 to 54 g. Lande *et al*., 1997; Limbore *et al*., 1998; Goksoy *et al*., 2002; Khan *et al*., 2004 Devi *et al*., 2005; kaya 2005; Hladni *et al*., 2005; Habib *et al*., 2007; Shankar, 2007; Sawargaonkar and Ghodke, 2008; Khan *et al*., 2008 Sujatha and Reddy, 2009; Tavade *et al*., 2009 and Nasreen *et al*., 2011 reported heterosis results for achene yield per plant.

Oil contents (%)

Heterosis along with the crosses was variable both in direction and magnitude, as indicated by the table 2 showing mean performance of crosses and heterotic expression in the crosses for oil content. Significant and positive heterosis over mid parent and better parent were observed in seven crosses and six crosses respectively and over commercial hybrid it was observed in 16 and eight crosses in comparison with FH-385 and FH-352 respectively. The cross G57×A26 and G65×G12 had highest significantly positive heterosis for mid parent and better parent whereas, against commercial hybrids G2×G53 and G65×G12 had highest value. Mean values for oil content ranged from 39.86 to 34.74%. Shankar 2007; Sawargaonkar and Ghodke 2008 and Sujatha and Reddy, 2009 also reported heterosis in sunflower for oil contents. Sunflower cultivars with higher percentage of oil are needed for higher oil yield per unit area, therefore, highly significant and positive heterosis is desirable.

Linoleic acid (%)

Heterosis was observed both in direction and magnitude for linoleic acid as indicated by the table 2 showing mean performance of crosses and heterotic expression in the crosses for linoleic acid. Significant and positive heterosis over mid parent was observed in 11 crosses, over better parent it was observed in five crosses, over commercial hybrid it was observed in 10 and five crosses in comparison with FH-385 and FH-352 respectively. The cross G57×G12 followed by G7×G12 had highest significantly positive heterosis for mid parent and better parent. The cross G2×G53 followed by the cross G57×G12 had highest commercial heterosis for linoleic acid content. Mean values for linoleic acid content ranged from 35.36 to 42.74%. These results are in agreement with the results reported by Khalil *et al*., 2000; Joksimovic *et al*., 2006 and Aslam *et al*., 2010. Linoleic acid constitutes unsaturated fatty acids which is desirable from the health point of view. So significant positive hetrosis is desirable for linoleic acid to improve the quality of sunflower oil.

Palmitic acid (%)

It is evident from the table 3 showing mean performance and heterosis over mid, better and commercial parent in the crosses for palmitic acid, 10 crosses had significant and negative heterosis over mid parent, 14 crosses over better parent, 10 crosses over FH-385 and seven crosses over FH-352. G65×G12 and G9×A26 showed highest negative heterosis over mid parent, G9×A26 and G2×G12 had highest negative values for better parent and G100×A26, G9×A26 and G2×G12 over commercial hybrids. Mean values for palmitic acid ranged from 4.27 to 5.54%. Lowest value for the palmitic acid was reported for the cross combination G9×G53, G2×A26 and G65×A26 followed by the cross G57×G12 and G57×G53. These crosses were significantly different from each other and also differed from all other crosses. palmitic acid constitutes saturated fatty acid which is less desirable from the health point of view so significant negative heterosis is desirable.

Oleic acid (%)

Heterosis was observed in the cross combinations for oleic acid. Results in table 3 revealed that oleic acid had significant and positive heterosis for 12 crosses over mid parent, six crosses over better parent and against commercial hybrids; it was observed in 21 and 14 crosses over FH-385 and FH-352 respectively. The cross G2×G12 showed highest heterosis over mid parents, better parents and commercial hybrids. Mean values for oleic acid ranged from 31.74 to 50.75%. Highest oleic acid % was observed for the cross G2×G12 followed by the cross G100×A26. These crosses differed significantly from each other and also from all other crosses used in the study. Khalil *et al*. (2000); Joksimovic *et al*. (2006) and Aslam *et al*. 2010 reported mid parent and better parent heterosis for oleic acid in sunflower. Significant positive heterosis is desirable for oleic acids so that sunflower oil quality may be improved.

TABLE 1: Heterotic expression in hybrids for 100 achene weight (g) and achene yield per plant (g).

Sr. no	Crosses	100 achene weight (g)				Achene yield per plant (g)			
		MPH	BPH	CH		MPH	BPH	CH	
				FH-385	FH-352			FH-385	FH-352
1	G57×G53	19.04**	15.33**	2.2	-2.44	38.09**	32.76**	26.87**	6.86**
2	G57×A26	16.46**	2.91	11.4**	6.39*	0.09	-5.75*	1.95	-14.13**
3	G57×G12	21.24**	5.03*	19.1**	13.72*	19.64**	9.72**	25.69**	5.86*
4	G65×G53	9.03**	5.63*	-0.2	-4.70	19.71**	14.89**	1.35	-14.64**
5	G65×A26	16.70**	9.27**	18.3**	12.97*	-4.63	-16.56**	-9.75**	-23.98**
6	G65×G12	6.25**	-2.60	10.4**	5.45	2.61	-12.38**	0.37	-15.46**
7	G2×G53	20.16**	7.34**	20.9**	15.41*	-1.00	-6.37**	-17.10**	-30.18**
8	G2×A26	-13.90**	-15.56**	-4.9**	-9.21	-16.82**	-27.93**	-22.05**	-34.34**
9	G2×G12	-27.18**	-27.43**	-17.7**	-21.43	24.22**	5.06*	20.35**	1.37
10	G9×G53	16.00**	5.26*	14.2**	9.02	-29.14**	-38.20**	-26.76**	-38.31**
11	G9×A26	9.09	9.09**	18.1**	12.78*	-19.08**	-22.62**	-8.28**	-22.75**
12	G9×G12	3.02**	0.69	14.2**	9.02	-7.73**	-9.28**	7.52**	-9.44**
13	G93×G53	5.97**	-6.62**	8.3**	3.38	-14.73**	-22.76**	-31.86**	-42.61**
14	G93×A26	-1.05	-4.41	10.8**	5.83	-9.50**	-24.80**	-18.66**	-31.49**
15	G93×G12	-11.68**	-12.73**	1.2	-3.38	-27.01**	-40.70**	-32.07**	-42.79**
16	G100×G53	-10.77**	-21.36**	-8.7**	-12.78	14.90**	6.21*	10.40**	-7.02**
17	G100×A26	-21.40**	-24.07**	-11.8**	-15.79	40.90**	38.15**	49.43**	25.86**
18	G100×G12	-23.50**	-24.41**	-12.2**	-16.17	8.97**	3.91	19.03**	0.25
19	G7×G53	1.91	-2.44	-5.7**	-9.96	-10.63**	-24.08**	-4.22	-19.33**
20	G7×A26	6.92**	1.09	9.4**	4.51	-37.32**	-41.80**	-26.57**	-38.15**
21	G7×G12	8.44**	0.35	13.8**	8.65*	-11.30**	-15.38**	6.75*	-10.09**

TABLE 2: Heterotic expression in hybrids for oil content (%) and linoleic acid (%)

Sr. no	Crosses	Oil contents (%)				Linoleic acid (%)			
		MPH	BPH	CH		MPH	BPH	CH	
				FH-385	FH-352			FH-385	FH-352
1	G57×G53	3.77**	1.76**	8.92**	4.80**	6.97**	-7.56**	3.08**	-2.21**
2	G57×A26	4.30**	3.47**	8.02**	3.94**	3.56**	-6.99**	-5.17**	-10.04**
3	G57×G12	-5.05**	-6.27**	-1.01**	-4.75**	24.89**	16.73**	9.05**	3.45**
4	G65×G53	-2.72**	-3.88**	2.88**	-1.01**	-4.43**	-5.38**	5.52**	0.10**
5	G65×A26	0.66**	0.53*	5.04**	1.07**	2.42**	-1.02**	8.17**	2.62**
6	G65×G12	3.94**	3.37**	9.18**	5.05**	-2.29**	-9.38**	-0.96**	-6.05
7	G2 ×G53	3.25**	3.41**	10.34**	6.17**	4.51**	1.15**	12.80**	7.00**
8	G2×A26	1.47**	0.28	7.00**	2.96**	-23.64**	-24.52**	-21.22	-25.27
9	G2×G12	-2.61**	-3.12**	3.37**	-0.54*	6.02**	0.45**	4.84**	-0.54**
10	G9×G53	-3.27**	-3.92**	2.83**	-1.06**	-19.45**	-19.92**	-9.63**	-14.27
11	G9×A26	-8.30**	-8.90**	-3.78**	-7.42**	-13.98**	-18.14**	-7.62*	-12.36**
12	G9×G12	1.25**	1.25**	6.94**	2.89**	-2.90**	-11.26**	0.15**	-5.00**
13	G93×G53	-2.89**	-3.39**	3.40**	-0.51*	-12.57**	-18.79**	-9.44*	-14.09**
14	G93×A26	-2.13**	-2.93**	2.83**	-1.06**	1.14**	-1.98**	-0.06**	-5.19**
15	G93×G12	-9.05**	-9.19**	-3.81**	-7.45**	-14.10**	-15.12**	-18.79*	-22.96
16	G100×G53	-11.95**	-14.40**	-2.98**	-6.65**	6.01**	-3.00**	8.18**	2.62**
17	G100×A26	-4.68**	-8.52**	3.68**	-0.24	-4.13**	-8.53**	-6.73*	-11.52
18	G100×G12	-5.78**	-9.01**	3.14**	-0.77**	2.40**	1.93**	-4.77*	-9.66**
19	G7×G53	0.35	0.19	7.24**	3.18**	4.97**	-7.40**	3.27**	-2.04**
20	G7×A26	-2.44**	-3.58**	2.88**	-1.01**	-4.16**	-12.02**	-10.29*	-14.90
21	G7×G12	-9.35**	-9.82**	-3.78**	-7.42**	15.37**	10.31**	3.06**	-2.24**

TABLE 3: Heterotic expression in hybrids for palmitic acid (%) and oleic acid (%)

Sr. no	Crosses	Palmitic acid (%) MPH	Palmitic acid (%) BPH	Palmitic acid (%) CH FH-385	Palmitic acid (%) CH FH-352	Oleic Acid (%) MPH	Oleic Acid (%) BPH	Oleic Acid (%) CH FH-385	Oleic Acid (%) CH FH-352
1	G57×G53	13.89**	3.07**	8.53**	20.59**	16.53**	12.55**	30.21**	14.84**
2	G57×A26	14.61**	13.32**	-1.12**	9.87**	8.56**	-0.23**	28.30**	13.16**
3	G57×G12	13.98**	3.14**	8.40**	20.44**	6.23**	3.77**	17.29**	3.45**
4	G65×G53	-12.96**	-14.91**	-10.40**	-0.44	-13.49**	-22.61**	13.45**	0.07
5	G65×A26	15.73**	7.85**	8.70**	20.77**	-20.28**	-25.19**	9.68**	-3.26**
6	G65×G12	-14.98**	-16.73**	-12.48**	-2.76**	-19.41**	-28.64**	4.63**	-7.72**
7	G2 ×G53	-7.94 **	-14.97**	-10.47**	-0.52	3.30**	-3.34**	28.27**	13.13**
8	G2×A26	23.19**	21.57**	8.70**	20.77**	-1.57**	-3.09**	28.60**	13.42**
9	G2×G12	-10.08**	-16.79**	-12.55**	-2.83**	30.35**	20.68**	60.13**	41.24**
10	G9×G53	-1.88**	-6.67**	8.70**	20.77**	1.91**	-13.35**	43.11**	26.22**
11	G9×A26	-14.07**	-24.92**	-12.55**	-2.83**	-23.83**	-32.27**	11.86**	-1.34**
12	G9×G12	-7.018*	-11.55**	3.02**	14.47**	-4.51**	-19.62**	32.77**	17.10**
13	G93×G53	5.04**	-2.10**	3.08**	14.53**	8.07**	-3.59**	42.20**	25.42**
14	G93×A26	6.57**	4.27**	-5.13**	5.41**	-27.44**	-32.10**	0.15*	-11.67**
15	G93×G12	6.90**	-0.28	4.80**	16.45**	1.88**	-10.02**	32.71**	17.05**
16	G100×G53	-1.26**	-9.72**	-4.94**	5.62**	13.19**	11.95**	29.51**	14.23**
17	G100×A26	-4.09**	-4.09**	-16.31**	-7.01**	22.04**	14.70**	47.49**	30.09**
18	G100×G12	7.16**	-2.04**	2.96**	14.40**	2.00**	1.94**	15.36**	1.74**
19	G7×G53	6.28**	-4.01**	1.07**	12.30**	2.51**	-9.57**	36.83**	20.68**
20	G7×A26	19.50**	17.89**	2.87**	14.29**	-23.66**	-29.39**	6.83**	-5.77**
21	G7×G12	-7.79**	-16.74**	-12.49**	-2.77**	-22.01**	-31.88**	3.07**	-9.09**

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