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FACTOR ANALYSIS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.) TO INVESTIGATE DESIRABLE HYBRIDS

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Abstract

Thirty-seven sunflower hybrids were evaluated for 8 agronomic characters under field conditions to estimate genetic parameters, correlation coefficient, path analysis and principal components analysis. Analysis of variance and mean performance for yield and its components revealed significant differences among all the hybrids for all the characters indicating the diverse nature of hybrids. Days to flower initiation, completion and days to maturity had positive correlation with plant height. Head diameter had negative association with all the traits except 100 seed weight. Seed yield had negative correlation with oil contents that is suggested to break either through conventional or novel breeding techniques to breed high yielding hybrids with maximum oil contents. Positive direct effect was observed with days to maturity, plant height and head diameter, highest being by head diameter. Among 8 characters, 5 days to flower initiation, flower completion, days to maturity, plant height and oil contents contributed for PC_1, whereas, 100-seed weight contributed to PC_2 with populations possessing low oil contents. On the basis of these results, the best hybrids (LG 56-35 and LG 54-15) were grouped together in the upper test half and are suggested for general cultivation. The PCA could help for identification of the best hybrids although seed yield, 100 seed weight and head diameter did not contribute for PC_1.

Introduction

Sunflower (*Helianthus annuus* L.) of the family *Compositae* (*2n*=34). Sunflower is native in origin from temperate regions of North America. During early 18th century, it is undertaken as an oil crop in Russia. In *H. annuus*, there are two types, Oil-type and confectionary. Its growth habit is annual in nature with plant height ranged from 1.50 to 2.50m while head diameter range is 15 to 30cm. Sunflower is highly cross pollinated crop. A best temperature for production is 20-25 ºC. Its 1000 seed weight is ranging from 40-60g with oil content of 40-50%. Its oil composition comprises 90 % oleic and 10 % linoleic acids or vv. Its protein contents ranged from 20-30 %.

Now sunflower is fourth biggest source of vegetable oil at world level after soybean, palm and rapeseed. The second in Europe after rapeseed and also second in Pakistan after cotton seed. Area under sunflower (world) is more than 26 mha, with production of 28 m tons. Major sunflower growing countries in world are Russia, CIS, Argentina, Europe, China, USA and India.

In Pakistan it is cultivated on area of 397,306 ha, with the production of 603,894 tons (Anon., 2008-09). It is successfully cultivated in Thatha, Badin, Hyderabad, Mirpur Khas, Tando Allah Yar, Umar Kot and Nawab shah Districts in Sindh. In Punjab, it is successfully cultivating in the district of Multan, Vehari, Lodhran, Bahawalpur, Bahawal Nagar, Muzafar Garh, Rajan Pur and Layyah. While in NWFP, it is grown in D. I. Khan. Average yield at farmer's field is 1520 Kg/ha, while potential yield at progressive farmers field is 3800 Kg/ha. However, potential yield at research station/institute is > 4500 kg/ha.

In Pakistan, sunflower was introduced during early sixties as oilseed crop, but now it is the second importance source of vegetable after cottonseed. Increase in area, production and yield since its introduction showed it progress and adaptation in the country (Fig. 1). Sunflower hybrids grown in the country contain from 39 to 52% oil in the seed and still have better yield potential. The knowledge of genetic parameters is essential for understanding and their manipulation in any crop improvement programme. Seed and oil yield in sunflower are complex characters which are products of interactions between a number of other traits. Thus, an evaluation of different traits and a study of their interrelationships are of great importance. Such interdependence of contributory characters, as well as the characters of economic importance often misleads and thus makes correlation coefficient by and large unreliable during selection (Dewey & Lu, 1959), particularly in crop like sunflower, which is highly cross pollinated and heterozygous and envisages enormous variability in succeeding generation. Earlier in sunflower, Shankar *et al*. (2006), Arshad *et al*., (2007) and Hidyatullah *et al*. (2008) applied path coefficient by partitioning the genotypic correlations into direct and indirect effects of the traits. Moreover, other researchers have used these techniques along with diversity study for investigating genetic parameters (Arshad *et al*., 2006). Ghaffari, (2004) and Sankar *et al*., (2004) also applied principal components analysis and reported considerable conformity with conventional methods, indicating its potential for use in cultivar development program for selection of superior three way cross hybrids in sunflower. Keeping in view the importance of this technique the present study was planned to investigate the correlation coefficient, path analysis and principal components analysis for seed yield traits to identify the best genotypes on the basis of result for future exploitation cultivation.

Materials and Methods

Thirty-seven sunflower hybrids of diverse origin collected from various public and private sector (Table 1) were grown in a Randomized Complete Design (RCBD) with three replications during the year 2008 at National Agricultural Research Center (NARC), Islamabad, Pakistan. The hybrids were grown in 4 rows of 5m lengths with row-to-row and plant-to-plant spacing of 75 and 25cm apart, respectively. Sowing was done manually on ridges by dibbling 3-4 seeds per hill to a depth of 2 to 3 cm to maintain optimum plant population per plot. All other recommended cultural practices were adopted for healthy crop growth during whole season. Optimum fertilizers (120 kg/ha Nitrogen, 60 kg/ha phosphorus and potassium each) were applied to each hybrid to exploit their potential. After emergence of seedlings, thinning was done to achieve the optimum plant population. Ten randomly sampled plants were used for recording data viz., days to flower initiation, completion and maturity, plant height (cm), head diameter (cm), 100 seed weight (g), oil content percentage and seed yield per plot and then converted to kg ha^{-1}. The oil content of the oven-dried seeds was determined by nuclear magnetic resonance (NMR).

Genetic parameters, correlation coefficients (phenotypic, genotypic and environmental) were computed according to the method suggested by Singh & Chaudhary (1979). The significance of genotypic correlation coefficients was tested with the help of standard errors as suggested by Reeve & Rao (1981). Path coefficient was worked out by the methods used by Dewey & Lu (1959). Heritability (broad sense) was computed using the procedure of Steel & Torrie (1980). Genetic Advance was calculated by using the formula [$G = Kh^2 \; x \; Op$, K at 5% selection intensity is 2.06, h^2 is heritability in broad sense and Op is phenotypic standard deviation]. The PCA was calculated using ward's method from the mean of the hybrids (Sneath & Sokal, 1973).

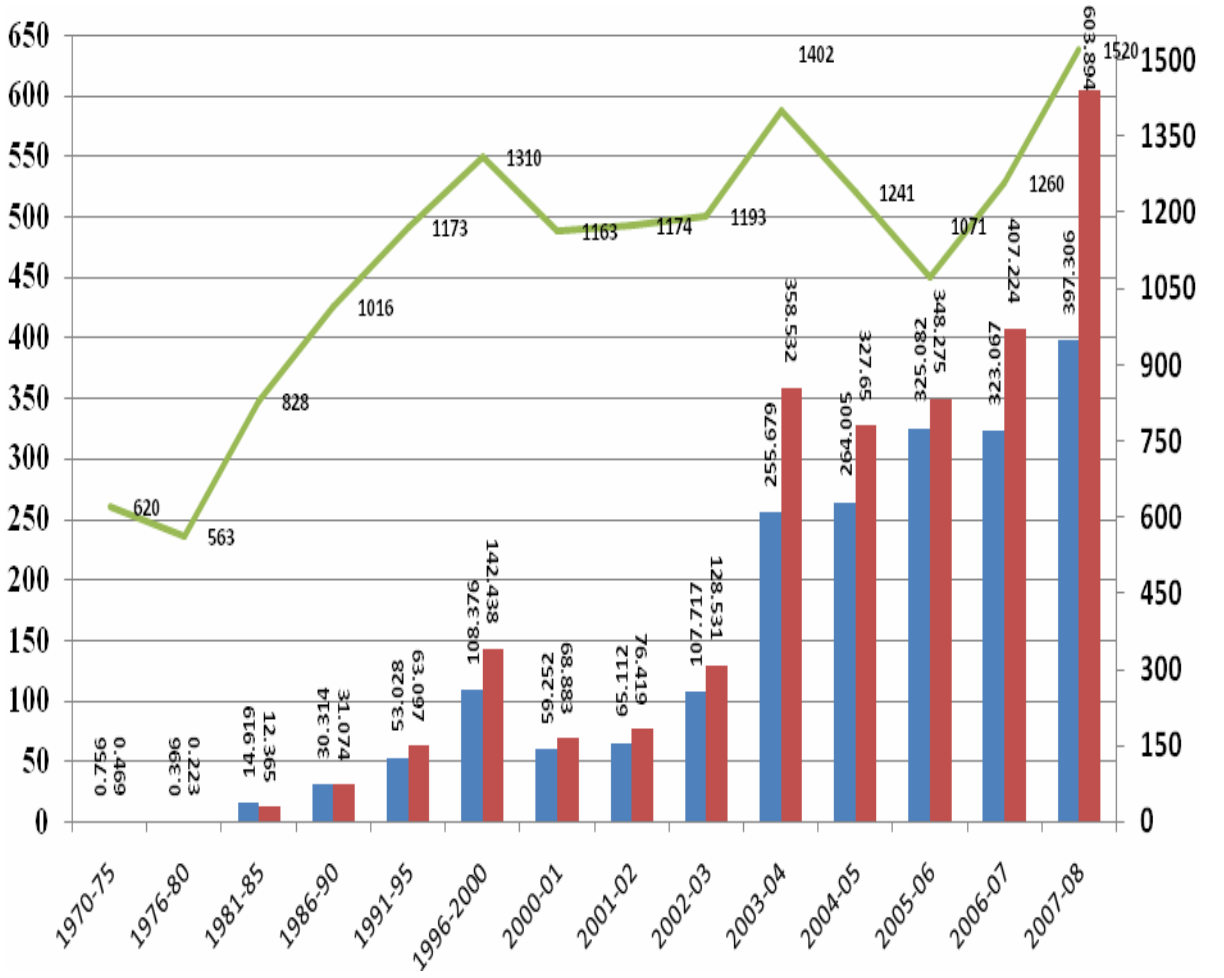

Fig. 1. Average area, production and yield of sunflower since 1970 in Pakistan. First six bar clusters are average of 5 years and others are yearly data.

Results and Discussion

Significant differences were observed for flower initiation, completion and maturity. Insignificant differences for replications revealed high acceptance of the result due to negligible influence of environment (Table 2). Due to less variation between genotypic and phenotypic variance for almost all the characters indicated negligible influence of environmental fluctuations. Partitioning of variance revealed that high heritability associated with high genetic advance of days to flower initiation (90%), days to flower completion, days to maturity, plant height and seed yield (kg ha^{-1}), while the characters having low heritability was observed for head diameter and seed yield, that indicated the need to build strong breeding programme to develop diverse inbred lines for hybrid development (Table 3). Khan *et al*., (2007) also reported similar results while studying in sunflower for these parameters.

Correlation coefficient: Genotypic correlation coefficients were higher as compared to phenotypic and environmental correlation coefficient in most of the cases (Table 4). Days to flower initiation, completion and days to maturity had positive and highly significant correlations with plant height. Head diameter had negative association with all the traits except 100 seed weight where it had highly significant genotypic

correlation (0.480). Similarly, seed yield had negative correlation with oil contents that is suggested to break this undesirable linkage to breed high yielding hybrids with maximum oil contents. Oil contents had positive associations with days to flower initiation (0.356), days to flower completion (0.293), maturity, plant height (0.320) indicating that we can increase the oil contents by increasing the maturity duration of the hybrids. However, it had negative genotypic association with head diameter (-0.094), seed yield (-0.184) and 100 seed weight (-0.314). But Manivannan *et al*., (2005) reported that days to 50% flowering had a significantly positive association with head diameter and a significant negative association with oil contents. Moreover, plant height had significant positive association with head diameter, while present study revealed results against the finding of Manivannan *et al*., (2005). Habib *et al*., (2007) observed significant positive correlation between days to maturity, plant height and oil content on one side and oil yield on the other side which are partially coincide with this study. Whereas, correlation coefficient for days to flower initiation and days to flower completion were negatively correlated with oil yield. But in present study results revealed positive correlation coefficient among these characters. Loganathan & Gopalan (2006) suggested that independent improvement of characters in sunflower without affecting each other could made in sunflower breeding programme.

Path coefficient study: Genotypic correlations were partitioned into direct and indirect effects through various yield contributing characters to investigate the selection criteria in sunflower breeding (Table 5). The direct effects of days to flower initiation, days to maturity, plant height and head diameter were positive while the remaining characters exhibited negative direct effects. The highest direct effect (0.825) was exhibited by head diameter, and it was followed by days to maturity (0.723). Moreover, days to flower initiation and plant height had also positive direct effect (0.161 and 0.199) on seed yield. Madhavilatha *et al*., (2004) and Farratullah *et al*., (2006) reported similar findings in their studies conducted on sunflower. The results of present study concluded that days to flower initiation, plant height and head diameter are the main seed yield components. Singh & Labana (1990); Visic (1991) and Marinkovic, (1992) also reported similar results in their study conducted on sunflower, whereas Hidyatullah *et al*., (2008) reported promising results based on path analyses in tomato. While concluding the results of present study, the characters viz., days to flower initiation and plant height should get due attention in sunflower breeding programmes along with head diameter and 100 seed weight which indirectly contributed to seed yield and oil contents. Similar results had been reported by Arshad *et al*., (2007).

Sridhar *et al*., (2005) also reported similar results for plant height, head diameter and 100 seed weight which had positive direct effect on seed yield per plant indicating that yield was a function of both growth and yield components. Vidhyavathi *et al*., (2005) also reported that plant height and head diameter had high and medium positive direct effects on seed yield, respectively. Thus, they recommended that plant height and head diameter can be used as selection indices for sunflower crop improvement programme. They also reported similar results for 100 seed weight and oil content that had no association with seed yield. This indicates the possibility of simultaneous selection for non-oilseed or confectionery types.

Table 1. Name, origin, source and character mean for yield and its related components in 37 sunflower hybrids.

S. No.	Hybrids	Origin	Source	DFI	DFC	DM	PH (cm)	HD (cm)	Seed Yield (kg ha^{-1})	100 Seed weight (g)	OC (%)
1.	65 A 41	USA	Pioneer Pakistan Seeds (Pvt.) Ltd. Sahiwal	81	89	118	194	18.1	2689	5.17	47.2
2.	LG-Tregor	France (EU)	Bari Seeds, Lahore	73	79	106	147	18.9	2932	4.64	45.8
3.	XIYU-04	China	Agri Farm Services, Multan	88	93	119	201	17.3	2294	4.84	49.8
4.	Hysun-33	Australia	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	79	85	113	202	18.9	2372	5.21	45.3
5.	AG.Sun-5383	S. Africa	Sethi Seed Co; Sahiwal	85	91	122	205	17.3	2940	4.85	47.2
6.	NK-Armoni	USA	Syngenta Pakistan Seeds (Pvt.) Ltd; Lahore	78	84	113	180	19.0	3067	5.03	48.0
7.	FH-37	Pakistan	Oilseeds Research Institute, Faisalabad	77	83	110	171	18.6	3150	3.23	44.4
8.	64 S 99	USA	Pioneer Pakistan Seeds (Pvt.) Ltd. Sahiwal	83	89	121	193	17.9	2906	5.85	46.4
9.	LG 56-35	France (EU)	Bari Seeds, Lahore	74	80	105	157	18.6	3495	6.19	41.2
10.	M-3255	USA	Dagha Corporation, Karachi	74	79	108	178	18.5	3243	5.29	50.8
11.	Super Sun	Argentina	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	77	82	111	178	19.0	2625	4.60	47.0
12.	AG.Sun-5551	S. Africa	Sethi Seed Co; Sahiwal	73	79	104	146	17.9	2866	4.95	45.4
13.	NK-Melody	USA	Syngenta Pakistan Seeds (Pvt.) Ltd; Lahore	81	86	120	212	18.6	3003	5.24	46.3
14.	FH-106	Pakistan	Oilseeds Research Institute, Faisalabad	81	86	114	168	19.9	3086	4.62	48.5
15.	64 A 57	USA	Pioneer Pakistan Seeds (Pvt.) Ltd. Sahiwal	79	87	116	197	18.8	2682	4.85	48.8
16.	LG 56-65	France (EU)	Bari Seeds, Lahore	80	86	117	185	17.7	2697	5.12	46.1
17.	M-24-54	USA	Dagha Corporation, Karachi	74	79	105	168	17.3	3322	4.48	50.0
18.	PAC.ARG-405	Australia	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	80	87	112	181	19.8	2535	4.82	44.8
19.	AG.Sun-8251	S. Africa	Sethi Seed Co; Sahiwal	86	92	121	208	18.3	3391	4.70	47.5
20.	PAC.ARG-306	Australia	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	82	86	116	205	19.7	2921	4.72	49.0
21.	FH-259	Pakistan	Oilseeds Research Institute, Faisalabad	74	80	103	173	17.6	3042	3.30	44.0
22.	LG 54-15	France (EU)	Bari Seeds, Lahore	74	79	104	170	17.6	3406	5.11	45.4
23.	M-3260	USA	Dagha Corporation, Karachi	78	84	113	180	20.2	2811	5.54	47.9
24.	PAC.ARG-406	Australia	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	81	87	113	202	18.3	2523	4.84	47.7
25.	FH-331	Pakistan	Oilseeds Research Institute, Faisalabad	74	80	104	183	18.8	3161	3.78	47.1
26.	PAC.ARG-106	Australia	ICI Pakistan Seeds (Pvt.) Ltd; Lahore	82	87	113	190	18.9	2721	5.21	44.2
27.	NK-S-278	USA	Syngenta Pakistan Seeds (Pvt.) Ltd; Lahore	78	83	112	182	18.4	2655	4.37	47.6
28.	Ausi Gold-62	Australia	The Seed Company, Karachi	85	89	118	182	17.5	2325	4.73	49.0
29.	SSFH-444	India	Farm Services Syndicate, Karachi	79	86	117	179	19.4	2349	5.19	48.6
30.	Pan-7031	Argentina	Ali Akbar Seeds (pvt.) Ltd., Lahore	83	89	118	205	18.5	3332	4.80	48.1
31.	Ausi Gold-61	Australia	The Seed Company, Karachi	83	89	115	184	19.1	2175	5.26	46.7
32.	Pan-7351	Argentina	Ali Akbar Seeds (pvt.) Ltd., Lahore	78	86	112	192	20.1	3344	4.62	43.6
33.	FSS-64	India	Farm Services Syndicate, Karachi	83	90	117	196	18.0	2012	3.88	46.9
34.	JK-CHITRA	India	Ali Akbar Group, Lahore	76	81	115	189	20.2	2813	4.08	46.6
35.	FSS-50	India	Farm Services Syndicate, Karachi	79	85	118	195	20.2	2237	4.74	46.7
36.	FSS-63	India	Farm Services Syndicate, Karachi	87	92	122	209	17.8	3032	4.58	45.1
37.	Parsun-2	Pakistan	Oilseed Program, NARC, Islamabad	74	81	110	178	17.6	2473	6.20	40.9

Table 2. Characters range and analysis of variance for yield and its related components in 37 sunflower hybrids.

Variables	DFI	DFC	DM	PH	HD	SY (kg ha^{-1})	100 SW (g)	OC %
Character Range	73-88	79-93	103-122	146-212	17.3-20.2	2012-3495	3.23-6.20	40.9-50.8
F. ratio (V)	26.83**	38.54**	12.69**	15.88**	1.32^{ns}	5.84**	2.27**	3.37**
F. ratio (R)	1.74^{ns}	4.73*	7.22**	5.53**	13.29**	8.46**	3.03^{ns}	14.15**
Standard error	0.81	0.68	1.54	4.10	0.77	160.12	0.42	1.19
Critical difference 1	2.27	1.90	4.32	11.47	2.16	448.35	1.19	3.34
Critical difference 2	2.99	2.51	5.71	15.16	2.85	592.60	1.57	4.42
Genotypic variance	16.96	17.31	27.81	249.51	0.19	124108.9	0.23	3.38
Phenotypic variance	18.93	18.69	34.94	299.82	1.97	201021.9	0.77	7.65
Genotypic covariance	5.20	4.89	4.65	8.51	2.35	12.46	9.90	3.94
Phenotypic covariance	5.49	5.08	5.21	9.33	7.55	15.86	18.15	5.93

DFI: Days to flower initiation; **DFC:** Days to flower completion; **DM:** Days to Maturity; **PH:** Plant height (cm); **HD:** Head diameter (cm); **SY:** Seed yield (Kg ha^{-1}); **100SW;** 100 Seed weight (g)**; OC%:** Oil content %

Table 3. Range of variation in quantitative traits and predominance of qualitative descriptors status of the whole sunflower hybrids evaluated during 2008.

Evaluation traits	Mean ± SE	SD	σ^2	h^2	GA (% over means)
Days to flower initiation	79.26±0.41	4.32	18.56	0.90	8.63
Days to flower completion	85.10±0.41	4.30	18.47	0.93	8.27
Days to Maturity	113.41±0.56	5.94	35.24	0.80	7.37
Plant height (cm)	185.59±1.64	17.30	299.43	0.83	13.62
Head diameter (cm)	18.61±0.15	1.54	2.37	0.10	1.46
Seed yield (Kg ha^{-1})	282777±43.41	457.37	209190.76	0.62	0.18
100 Seed weight (g)	4.83±0.08	0.89	0.78	0.30	9.73
Oil content (%)	46.63±0.28	2.93	8.61	0.44	4.87

SE=Standard error, SD=Standard deviation, σ^2= Variance, h^2= Heritability, GA= Genetic Advance (% over means)

Table 4. Genotypic (*rG*), phenotypic (*rP*) and environmental (*rE*) correlation coefficients among 7 characters in 37 sunflower hybrids.

Variables		DFI	DFC	DM	PH (cm)	HD (cm)	SY (Kg ha^{-1})	100 SW
DFC	*rG*	0.992**						
	rP	0.933**						
	rE	0.339*						
DM	*rG*	0.916**	0.933**					
	rP	0.814**	0.834**					
	rE	0.278	0.273					
PH (cm)	*rG*	0.783**	0.779**	0.839**				
	rP	0.680**	0.705**	0.719**				
	rE	0.0312	0.192	0.197				
HD (cm)	*rG*	-0.207	-0.200	0.028	-0.016			
	rP	-0.091	-0.057	0.073	0.018			
	rE	-0.097	0.012	0.187	0.059			
SY (kg ha^{-1})	*rG*	-0.371*	-0.383*	-0.406*	-0.243	-0.296		
	rP	-0.251	-0.277	-0.260	-0.140	0.060		
	rE	0.128	0.075	0.087	0.1354	0.226		
100SW (g)	*rG*	0.031	0.088	0.115	0.028	0.480**	-0.071	
	rP	0.028	0.051	0.180	-0.014	0.128	-0.042	
	rE	0.045	0.020	0.326*	-0.079	0.263	-0.021	
OC%	*rG*	0.356*	0.293*	0.320	0.256	-0.094	-0.184	-0.314
	rP	0.272	0.209	0.300	0.235	0.047	-0.035	-0.049
	rE	0.197	0.109	0.328*	0.260	0.094	0.132	0.104

DFI: Days to flower initiation; **DFC:** Days to flower completion; **DM:** Days to Maturity; **PH:** Plant height (cm); **HD:** Head diameter (cm); **SY:** Seed yield (Kg ha^{-1}); **100SW;** 100 Seed weight (g)**; OC%:** Oil content %

Table 5. Direct (highlighted) and indirect effects of eight traits on seed yield in sunflower hybrids.

Variables	DFI	DFC	DM	PH	HD	100SW	OC%	SY
DFI	**0.161**	-1.056	0.662	0.156	0.171	-0.018	-0.126	-0.371
DFC	0.160	**-1.064**	0.674	0.155	0.165	-0.050	-0.103	-0.383
DM	-0.148	-0.993	**0.723**	0.167	0.023	-0.065	-0.113	-0.406
PH	-0.126	-0.829	0.606	**0.199**	0.013	-0.016	-0.091	-0.243
HD	0.033	0.213	-0.020	-0.003	**0.825**	0.273	0.033	-0.296
100 SW	-0.005	-0.094	0.083	0.006	0.396	**-0.568**	0.111	-0.071
OC%	-0.057	-0.311	0.231	0.051	0.078	0.178	**-0.353**	-0.184

Table 6. Principal components based on quantitative traits in 37 sunflower hybrids.

	PC_1	PC_2	PC_3
Eigen value	3.78	1.15	1.04
Proportion of variance	47.29	14.32	13.01
Cumulative variance	47.29	61.62	74.63
Traits	**Eigen vector**		
Days to flower initiation	0.955	0.007	-0.105
Days to flower completion	0.958	0.070	-0.071
Days to Maturity	0.949	0.077	0.075
Plant height (cm)	0.849	-0.030	-0.010
Head diameter (cm)	-0.053	-0.173	0.927
Seed yield (Kg ha^{-1})	-0.421	-0.107	-0.382
100 Seed weight (g)	0.070	0.849	0.114
Oil content (%)	0.386	-0.610	-0.036

Principal component analysis: The results regarding PCA revealed that three principal components with >1 eign value contributed three fourth of the total variation among all the hybrids (Table 6). It was observed PC_1 contributed 47.29%, whereas PC_2 and PC_3 contributed 14.23% and 13.01%, respectively of the total variation. The traits which contributed more positively to PC_1, were days to flower initiation (0.955), days to flower completion (0.958), days to maturity (0.949), plant height (0.849) and oil contents (0.386), while remaining traits in this PC_1 did not contributed rather their effects were distributed among other PCs. The populations in the PC_1 were more likely to be associated with late in maturity, taller plants and medium oil contents, whereas the populations with higher seed weight and low oil contents were contributing maximum for second PC. The selected hybrid on the basis of differential groups could be identified for yield potential and oil contents. Ghaffari (2004) also advised that PCA showed considerable conformity with conventional methods, indicating its potential for use in cultivar development programmes. The principal component 3 showed that head diameter (0.927) was more positively than any other character. It was observed that most of the yield contributing traits with higher direct effects (head diameter, maturity) and 100-seed weight were scattered throughout all the factors and thus the best hybrids could be among various population groups that is quite evident due to diverse nature of inbred lines involved in various hybrids.

The characters contributed positively to first three principal components could be given consideration while selecting the best hybrids without losing yield potential. First two components contributing more than sixty percent variance were plotted graphically as scattered diagram to observe the relationship among various hybrids (Fig. 2). Although important yield contributing traits were scattered amongst three PCs, hence the best hybrids could be identified in the upper left half of the graph that could be due to complex nature of gene expression for yield potential in sunflower. Sultana and Ghafoor

(2009) considered PCA as powerful technique for data reduction that removes interrelationships among components and this technique has been reported effective for selection of desirable clusters of promising genotypes by Muhammad *et al*., (2009) and Nisar *et al*., (2008 and 2009). Results reported by Sultana & Ghafoor (2008) showed multivariate analysis as a valid system to deal with germplasm collection. Smith *et al*., (1995) conducted average linkage cluster and principal component analyses and reported the utility of these results in preservation and utilization of germplasm. Ghafoor & Arshad (2008) studied genetic diversity in black gram germplasm accessions and reported cluster and principal component analyses for quantitative traits.

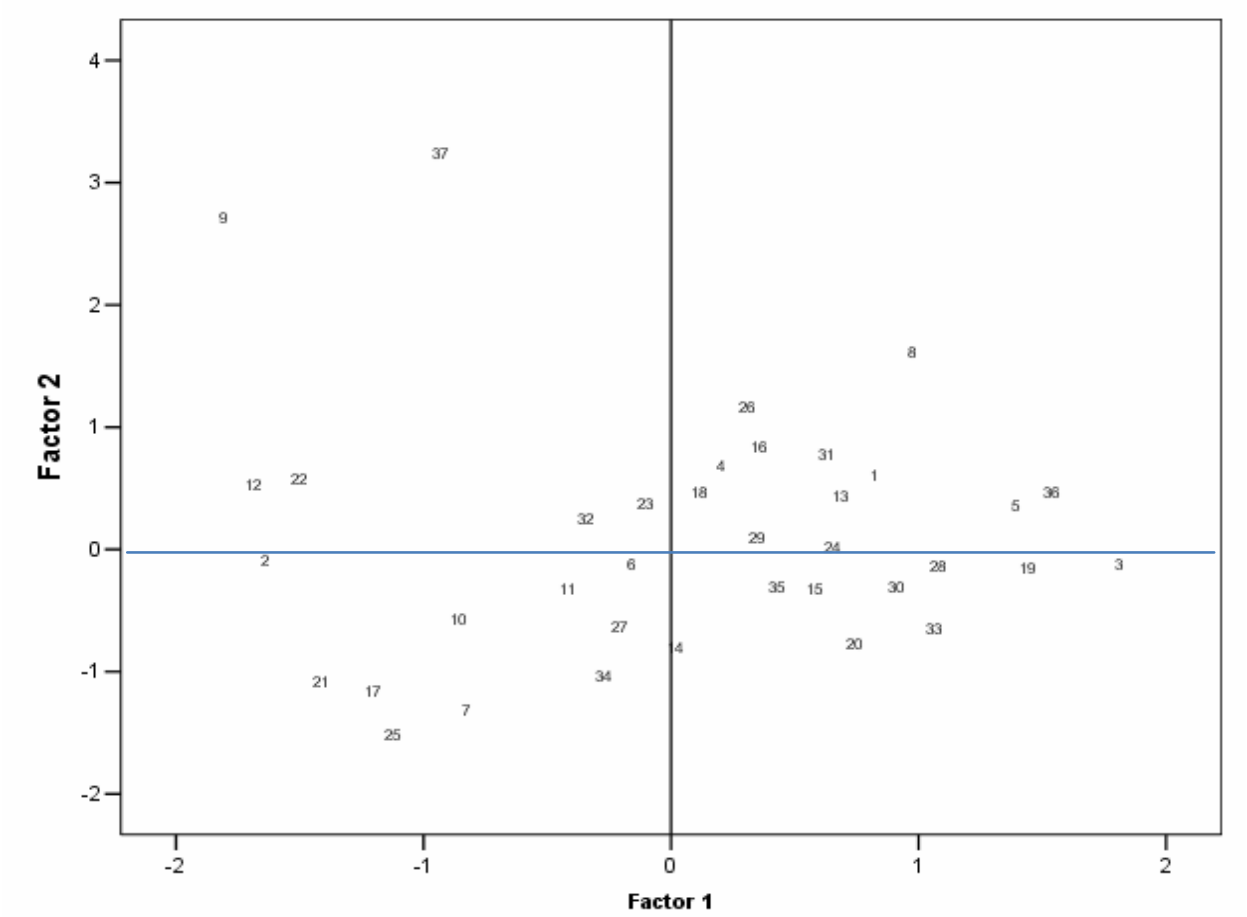

Fig. 2. Scattered diagram for 37 sunflower genotypes based on eight traits. Each digit indicates the serial wise hybrids name as presented in Table-1.

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