Genetic Diversity for Seed Yield and its Components Using Principal Component and Cluster Analysis in Sunflower (*Helianthus annuus* L.)

Fida Hussain[1]*, Muhammad Rafiq[1], Maria Ghias[1], Rizwana Qamar[1], Muhammad Khurram Razzaq[1], Amir Hameed[2], Sajida Habib[1] and Hafiz Saad Bin Mustafa[1]

[1]Directorate of Oilseeds, Ayub agricultural Research Institute, Faisalabad (Pakistan)
[2]Statistical Section, Ayub agricultural Research Institute, Faisalabad (Pakistan)
*Corresponding author's email: fida1385@gmail.com, saadpbg@gmail.com

Abstract: Development of sunflower hybrids with better performance in current scenario of climate change is a dire need of present time. Currently, almost all the hybrids grown by Pakistani farmers are of exotic in their origin. This study was intended to evaluate the locally developed sunflower hybrids for seed yield and its components. Twenty-eight sunflower hybrids were grown in randomized complete block design (RCBD) with three replication during Spring 2015. The data was recorded for days to 50% flowering, plant height, stem diameter, leaves per plant, head diameter, 100 kernel weight, kernel per head, kernel weight per head, days to maturity, oil percentage and seed yield. The data was evaluated by using cluster and principle components analysis (PCA). Principle component (PC) analysis revealed that out of 10 PCs, first 2 PCs has the Eigen value larger than one. 73.7% variability was assessed among the sunflower hybrids for yield related traits, contributed by these two principle components. PC 1 contributed the maximum (59.7%) towards diversity and all the traits in it showed positive factor loading. Plant height, stem diameter and days to 50% flowering being the most important characters in PC 2. Cluster analysis grouped 28 sunflower hybrids into three diversified classes. Cluster 1 and 2 comprises of 7 and 8 hybrids respectively, while the third cluster embraces 13 sunflower hybrids. All the traits except 100 kernel weight in the cluster 1 had highest values hence, contributing maximum in seed yields. Selection could be made from cluster 2 for 100 kernel weights. Cluster 3 had the minimum values for days to 50% flowering, leaves per plant and 100 kernel weight. Selection may be avoided in these parameters from this cluster. For achieving higher 100 kernel weight cluster 1 and 2 may be combined and likewise for accomplishing higher oil contents cluster 1 may be combined with cluster 3. Out of 28 sunflower hybrids, FH-516 proved its worth by producing seed yield at par with Hysun-33.
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Keywords: Bi-plot, Cluster analysis, Principle component analysis, Sunflower hybrids and Seed yield.

1. Introduction:

Pakistan is an agricultural country in which agriculture contributes 20.9 % of the Gross Domestic Product (GDP) and is a spring of livelihood for 43.5 % of countryside inhabitants (GOP, 2014-15). High yielding crops with improved stability are indispensable for food security which makes the farming systems less susceptible to climate change. Edible oil is one of the most imperative commodities for everyday life of Pakistani public which is regrettably facing extreme dearth since last several decades. The situation is going worse with every year due to declining local production, climbing population pressure and rising prices in the world market. Pakistan has to import 65-70% of its edible oil from the international market annually. During 2013-14 the edible oil import bill of Pakistan was Rs. 246.895 billion (US$ 2.50 billion), to fulfill the requirement (GOP, 2014-15).

Sunflower (*Helianthus annuus* L) is one of the major oilseed crops adaptive to a varied ecological condition (Martin *et al*, 2012). It has proved its worth as substantial industrial crop because of its vast industrial uses (Putt, 1997; Martinez *et al.,* 2004; Byrareddy, 2008 and Hu *et al*., 2010,). The oil percentage in sunflower hybrids is found to have between 38.0 % - 54.4%, (Keshta *et al*. 2008). Oil contents and seed yield depends on genotypes and environmental conditions in which these are grownup (Marinkovic *et al*., 2003). In Pakistan sunflower is the leading oilseed cash crop, with greater yield potential, wider adaptability and shorter growth period (Raheela *et al*, 2012). It is cultivated on an area of 384 thousand acres and produced 190 thousand tonnes with average seed yield 1303 kg/ha (GOP, 2014-15).

Sunflower oil is very high on quality matrix among vegetable oils, as it comprises of five basic nutrients for human diet (Demirer *et al*., 2004). Its oil plays a significant role in human nourishment (Robert and Selma, 1967). Sunflower seeds offer proteins, fiber, vitamins, minerals, and phytochemicals. Sunflower seeds are the richest source of vitamin E,

which lower the risk of stroke (Dutta *et al*., 2003). Sunflower seeds contain 31% selenium and 25% copper of the daily value which work with other antioxidants to guard cells from impairment that may cause heart ailment. Magnesium is a hard-to-get nutrient found in sunflower seeds that possibly will lessen the menace for developing type II diabetes (Fung *et al*., 2003) and heart disease (Abbott *et al*, 2003). Its benefits for human health and skin care has been proved by many scientists in their research due to which it is used as natural alternative of skin care products (Eichenfield *et al*., 2009). It is also applied to premature infants to reduce mortality due to infections in hospitals (Lawn *et al*., 2013; Salam *et al*., 2013).

Study of genetic divergence is the procedure through which variant individuals or clusters of individuals or populations are recognized (Mudassar *et al*., 2013). Principal Component Analysis (PCA) is one of the statistical tools to assess and evaluate genetic diversity. Plant breeders can apply this multivariate tool to investigate clear pattern of diversity existing in the different genotypes. The results of PCA will be of greater benefit to identify the parents for improving various traits or characters or component and it can also be exploited in planning and execution of future breeding program (Mustafa *et al.,* 2015 and Venujayakanth *et al.,* 2017). Cluster analysis has been suggested for categorizing entries of germplasm collections based on degree of similarity and dissimilarity (Mustafa *et al.,* 2015). Principle component analysis (PCA) and cluster analysis is an apposite method generally applies for calculation of genetic diversity, for investigating genetic traits and revealed significant consistency regarding conventional breeding procedures. (Mohammadi and Prasanna 2003; Shankar *et al*., 2006; Arshad *et al*., 2007; Hidyatullah *et al*., 2008; Rehman *et al*., 2013; Ghaffoor 2009). Keeping in view the importance of this method the current study was conducted to explore principal components analysis for seed yield and its related traits to classify the best hybrids on the basis of harvested seed yield.

2. Material and Methods:

Twenty-eight sunflower hybrids viz., FH-425, FH-465, FH-516, FH-545, FH-552, FH-557, FH-558, FH-572, FH-593, FH-606, FH-607, FH-608, FH-609, FH-610, FH-611, FH-612, FH-613, FH-614, FH-615, FH-616, FH-617, FH-618, FH-619, FH-620, FH-621, FH-622 including two check hybrids i.e. FH-331 (Pakistan) and Hysun-33(Australia) respectively, were planted in randomized complete block design (RCBD) with three replications, at experimental farm of Oilseeds Research Institute (ORI), Faisalabad (Pakistan) during Spring 2015. The area is located at 31.4041° N and 73.0487° E. All the recommended agronomic practices were carried out during the crop season. Data was recorded for ten plants selected from central two rows for days to 50% flowering, plant height (cm), stem diameter (mm), leaves per plant, head diameter (cm), 100 kernel weight (g), kernel per head, kernel weight per head (g), days to maturity, oil percentage and seed yield (kg/ha). Oil% was determined through Soxhlet apparatus at Hi-tech Oilseeds Laboratory (ORI), Faisalabad (Pakistan).

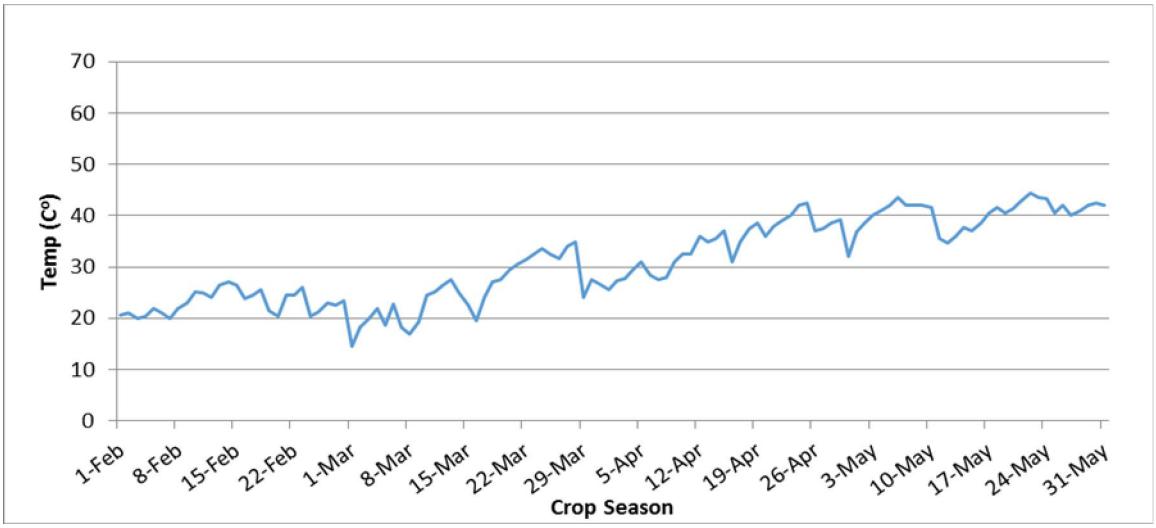

Fig. 1: Data for temperature during the crop season (Feb-May, 2015).

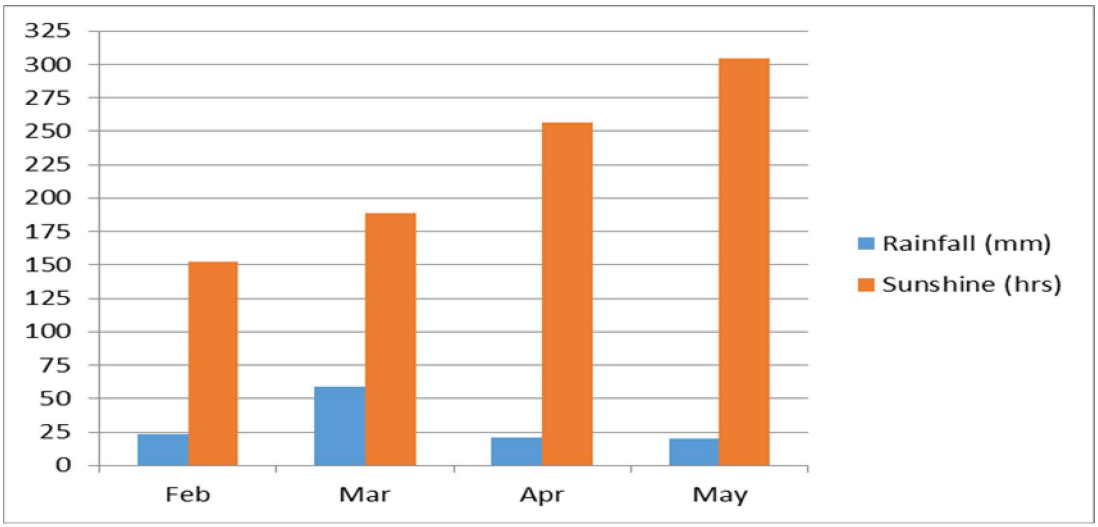

Fig. 2: Data for rainfall and sunshine hour's statistics, Feb-May, 2015

Table 1: Mean data for different morphological and yield parameters of sunflower hybrids.

S. No	Hybrids	Origin	Source	Days to 50% flowering	Stem diameter (cm)	Plant height (cm)	Leaves / plant	Head Diameter (cm)	100 kernels wt.(g)	Karnels /head	Kernels wt./ head	Days to maturity	Oil%	Seed yield (kg/ha)
1	FH-331	Pakistan	ORI, FSD	65	2.62	160.7	27.73	13.7	3.88	1085	44	115	41	1691
2	FH-572	Pakistan	ORI, FSD	62	2.34	147.7	22.6	12.67	4.11	651	34	108	39	918
3	FH-425	Pakistan	ORI, FSD	68	3.01	150.7	26.93	13.67	4.04	691	27	108	38	870
4	FH-607	Pakistan	ORI, FSD	62	2.67	157.7	22.6	12.53	3.66	762	28	109	38	1288
5	FH-608	Pakistan	ORI, FSD	66	2.78	152.7	24.4	13.93	3.75	750	32	106	37	1159
6	FH-617	Pakistan	ORI, FSD	64	2.56	163.7	24.53	14.4	4.45	646	27	108	38	998
7	FH-618	Pakistan	ORI, FSD	63	2.57	157.7	23.2	13.27	4.73	475	21	110	38	1063
8	FH-516	Pakistan	ORI, FSD	77	2.71	180.7	27.8	15.47	4.35	1014	37	130	42	1916
9	FH-609	Pakistan	ORI, FSD	65	2.83	162.0	23.93	12.87	4.71	487	26	114	39	1208
10	FH-610	Pakistan	ORI, FSD	72	3.24	174.3	27.27	14.27	3.82	1061	37	125	40	1771
11	FH-619	Pakistan	ORI, FSD	64	2.69	158.3	23.6	14.2	4.34	448	26	116	37	1127
12	FH-616	Pakistan	ORI, FSD	64	2.50	162.3	24.73	14	4.38	496	27	114	39	1337
13	FH-606	Pakistan	ORI, FSD	63	2.56	157.0	23.13	12.87	3.71	638	27	110	38	1031
14	FH-545	Pakistan	ORI, FSD	65	2.77	159.7	22.93	13.93	3.9	783	35	119	40	1369
15	FH-615	Pakistan	ORI, FSD	65	2.76	159.3	24.93	13.4	4.13	629	33	117	39	1240
16	FH-620	Pakistan	ORI, FSD	63	2.70	160.0	20	13.33	4.68	606	27	110	37	1208
17	FH-558	Pakistan	ORI, FSD	68	2.71	163.7	27.67	14.07	4.08	1029	44	119	40	1417
18	FH-611	Pakistan	ORI, FSD	65	2.68	160.0	22.6	12.93	4.55	567	26	115	38	966
19	FH-614	Pakistan	ORI, FSD	67	2.87	165.7	24.87	12.93	3.82	636	27	108	36	902
20	FH-621	Pakistan	ORI, FSD	71	3.07	172.0	25.87	14.27	3.49	936	39	123	40	1594
21	FH-552	Pakistan	ORI, FSD	62	2.43	157.0	21.13	12.4	4.02	771	39	109	37	1063
22	Hys-33	Australia	ICI, PAK	77	3.28	180.3	29.6	14.13	4.39	850	35	130	42	2061
23	FH-622	Pakistan	ORI, FSD	69	2.63	163.7	25.73	13	4.1	637	25	110	37	934
24	FH-613	Pakistan	ORI, FSD	66	2.70	163.0	21.27	13.13	2.59	787	27	110	38	1014
25	FH-612	Pakistan	ORI, FSD	66	2.80	163.7	23.93	13.53	2.6	808	39	112	39	1208
26	FH-557	Pakistan	ORI, FSD	64	2.44	156.0	24.73	13.53	1.3	765	36	114	39	1143
27	FH-465	Pakistan	ORI, FSD	63	2.64	155.0	22.55	12.47	4.1	637	25	113	37	910
28	FH-593	Pakistan	ORI, FSD	70	3.19	167.7	24.82	14.07	4.08	1029	44	121	40	1417

Statistical analysis: Data collected from experimental material was subject to analyze statistically by using the statistical software packages of SPSS version 19 and Statistica version 5.0 (Sneath and Sokal, 1973). Cluster analysis was performed using K-means clustering while tree diagram based on eucladian distances was developed by Ward's method. The first two principal components were plotted against each other to find out the patterns of variability among genotypes using SPSS version 19. Association among treatments were assessed using least significant difference (LSD) test at P=0.05 for yield and yield components. Mathematical analysis and simple statistics was calculated by using principal component analysis by utilizing computer software 'Past' for Windows.

3. Results and Discussion:

Spring season crop of sunflower grows well in the areas of central and northern Punjab (Pakistan). The sowing was one month earlier in Southern Punjab due to high temperature during lateral stage of seed development. The data in **Figure 1** revealed that the crop was sown at temperature (20°C -25°C), during vegetative growth stage of crop temperature was (20°C -32°C), and flower initiation & seed development completed at temperatures (30°C 38°C) while crop was matured at temperatures about 40°C.

The weather data in **Figure 2** showed that Feb and March are usual months of rains in Punjab, Pakistan. Crop got nutritional benefits from rains and also secured the crop from aphid attack at initial growth stage. Sunshine hours gradually increased from Feb (150) to May (305).

Table 2: Mean values for seed yield of sunflower hybrids.

Rank	Hybrid Name	Mean Seed Yield kg/ha	Group
1	Hys-33	2000.0	A
2	FH-516	1983.3	AB
3	FH-610	1833.3	ABC
4	FH-331	1750.0	ABCD
5	FH-621	1650.0	BCDE
6	FH-593	1590.0	CDEF
7	FH-558	1466.7	DEFG
8	FH-545	1416.7	DEFGH
9	FH-616	1383.3	EFGHI
10	FH-607	1333.3	EFGHIJ
12	FH-615	1283.3	FGHIJK
13	FH-572	1250.0	FGHIJKL
14	FH-609	1250.0	FGHIJKL
15	FH-620	1250.0	FGHIJKL
16	FH-612	1216.7	GHIJKLM
17	FH-608	1200.0	GHIJKLM
18	FH-557	1183.3	GHIJKLM
19	FH-617	1166.7	GHIJKLM
20	FH-619	1166.7	GHIJKLM
21	FH-552	1100.0	HIJKLM
22	FH-618	1100.0	HIJKLM
23	FH-465	1079.7	HIJKLM
24	FH-606	1066.7	IJKLM
25	FH-613	1050.0	IJKLM
26	FH-611	1000.0	JKLM
27	FH-622	966.7	KLM
28	FH-614	933.3	LM
$LSD_{0.05}$ = 174		C.V (%) = 350	

The data in **Table 2** showed the mean values of seed yield of sunflower hybrids. The maximum average seed yield from all studied hybrids was attained by the Hysun 33(2000 kg ha^{-1}) followed by FH-516 (1983 kg ha^{-1}). The minimum seed yield was attained by the hybrid FH-614 (933 kg ha^{-1}). The coefficient of variation for seed yield was 350%. According to LSD test the hybrids under investigation showed significant variation on the bases of seed yield. Hence, they were grouped differently in **Table 2**. The presence of variances among the experimental hybrids showed the wide range of variability in

parental material which will be used to strengthen future sunflower hybrid development program, in order to enhance the seed yield. At 5% level, the hybrids which had not significant seed yield difference were marked with the same later.

The Multivariate statistical technique is extensively used tools in investigation of genetic diversity (Mustafa *et al.,* 2015). According to Mohammadi and Prasanna, 2003, most frequently used approaches are cluster analysis (CA) and principal component analysis (PCA), Multivariate study has been used for estimation of genetic diversity in various crops such as wheat (Hailu *et al*., 2006), sorghum (Ayana and Becele, 1999) and sunflower (Kholghi *et al*., 2011).

Principal Component Analysis of different traits in sunflower hybrids: Principle component analysis (PCA) is really a reliable tool for successfully selection of parents in breeding program of any crop (Nazir *et al*. 2013, Mustafa *et al.,* 2015 and Venujayakanth *et al.,* 2017). It also offers an opportunity for the exploitation of appropriate germplasm in crop development for specific plant characters (Pecetti and Damania 1996).

Table 3: Principle component analysis of different morphological traits in sunflower.

	PC1	**PC2**
Eigen values	6.57	1.54
Proportion of total variance %	59.7	14.0
Cumulative variance %	59.7	73.7

Table: 4 Factor loading by various traits in sunflower hybrids.

Variable	**PC1**	**PC2**	**PC3**	**PC4**
D50%	0.347	0.187	-0.299	0.99
Stem diameter	0.262	0.215	-0.601	-0.436
Plant height	0.328	0.216	-0.159	0.071
Leaves per plant	0.310	0.66	-0.063	0.235
Head diameter	0.296	0.109	0.150	0.562
100 seed weight	0.001	0.638	0.503	-0.469
Kernels per head	0.299	-0.411	-0.040	-0.295
Seed weight per head	0.256	-0.505	0.208	-0.332
Days to maturity	0.352	0.114	0.116	-0.002
Oil %	0.336	-0.110	0.368	0.049
Yield per hectare	0.358	0.011	0.227	-0.069

Table 3 showed that two principle components (PCs) had more than 1 Eigen values out of 10 principle components. These principle components contributed 73.7% variability among the sunflower hybrids assessed for yield related traits and remaining 26.3% variability was due to other components. The PC 1 contributed the maximum towards diversity (59.7%) and followed by PC 2 (14.0%). Nazir *et al*. (2013) reviewing numerous yield related traits assessed that the contribution of first two PCs is important in the total variation. According to **Table 4** all the traits in PC 1 showed positive factor loading. PC 2 was related to variability among sunflower hybrid due to plant height, stem diameter and days to 50% flowering with their positive loading while Kernels per head, kernel weight per head and oil contents showed negative loading in PC-2. Diversity among sunflower genotypes was mainly due to 100 seed weight in the PC-2 followed by plant height and stem diameters. Principle Components analysis recognized the extent of variability for different traits amongst the material studied which could be manifested in designing a hybrid development program intended to improve seeds per head, head diameter, oil contents and eventually the seed yield of sunflower hybrids, as it is generally considered that more the variability, maximum the heterotic effects (Nazir *et al*. 2013). The individual variables distance with respect to PC-1 and PC-2 presented the influence of these variables in the dissimilarity of hybrids studied.

Table 5. Cluster membership of sunflower hybrids.

Cluster 1	07	FH-331, FH-610, FH-621, FH-558, FH-593, FH-516 and Hysun-33.
Cluster 2	08	FH-425, FH-572, FH-614, FH-465, FH-622, FH-617, FH-606 and FH-611.
Cluster 3	13	FH-607, FH-545, FH-608, FH-557, FH-612, FH-552, FH-613, FH- 618, FH-619, FH-609, FH-616, FH-615 and FH-620.

A PC biplot (**Fig.3)** presented that variables and hybrids are super imposed on the plot as vectors. The distance of each variable with respect to PC-1 and PC-2 exhibited the influence of these variables in the variation of hybrids studied. Nazir *et al*., (2013) also presented the similar kind of results. The biplot showed that stem diameter, Kernels per head, kernel weight per head, days to maturity and seed yield, contributed maximum diversity among the sunflower hybrids under study.

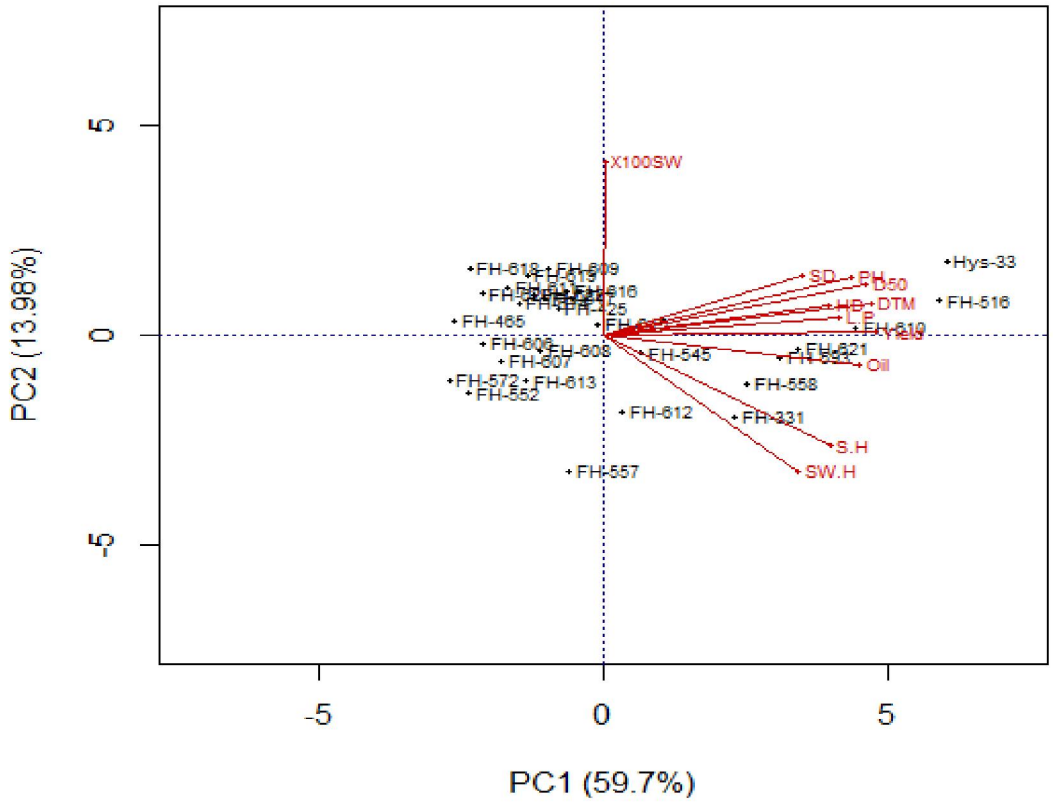

Fig. 3: Biplot between PC-1 and PC-2 presenting contribution of different parameters in variability of hybrids.

Cluster analysis: Twenty eight sunflower hybrids were grouped into 3 clusters based on different traits **(Table 6)**. The cluster analysis **(Fig. 4)** showed that cluster 1 includes 07 hybrids; cluster 2 consists of 08 while cluster 3 had 13 sunflower hybrids. The hybrids in cluster 1 showed highest values for almost all the traits studied except the 100 seed weight. This clearly indicated that selection can be made for all these traits in this cluster except 100 seed weight. The cluster 2 had maximum value for the trait 100 kernel weight and average values for days taken to 50% flowering and leaves per plant. This cluster has the least values for plant height, head diameter, kernels per head, kernel weight per head, oil percentage and seed yield. Selection for these traits could not be favorable from hybrids of this cluster. This provides simple criteria for selection on the basis of 100 seed weight. The hybrids from Cluster 3 has the least values for days taken to 50% flowering, leaves per plant and 100 kernel weight. Selection should be avoided on the bases of these parameters from this cluster. All the other yield contributing factors are in average for this cluster. Hybrids in cluster 1 produced maximum seed yield, average seed yield was given from cluster 3 hybrids and minimum seed yield was achieved from hybrids of cluster 2 showed in **(Table 6)**.

Table 6: Clustering of different traits of sunflower hybrids under study.

Variable	Cluster 1	Cluster 2	Cluster 3
D50%	71.43	65.125	64.23
Stem diameter	2.97	2.661	2.66
Plant height	171.33	157.91	159.18
Leaves per plant	27.25	24.118	23.18
Head diameter	14.28	13.118	13.39
100 seed weight	4.01	4.110	3.75
Seeds per head	1000.57	637.87	659.00
Seed weight per head	40.00	27.25	30.46
Days to maturity	123.29	110.0	112.31
Oil %	40.71	37.62	38.23
Yield per hectare	1695.29	941.12	1186.6

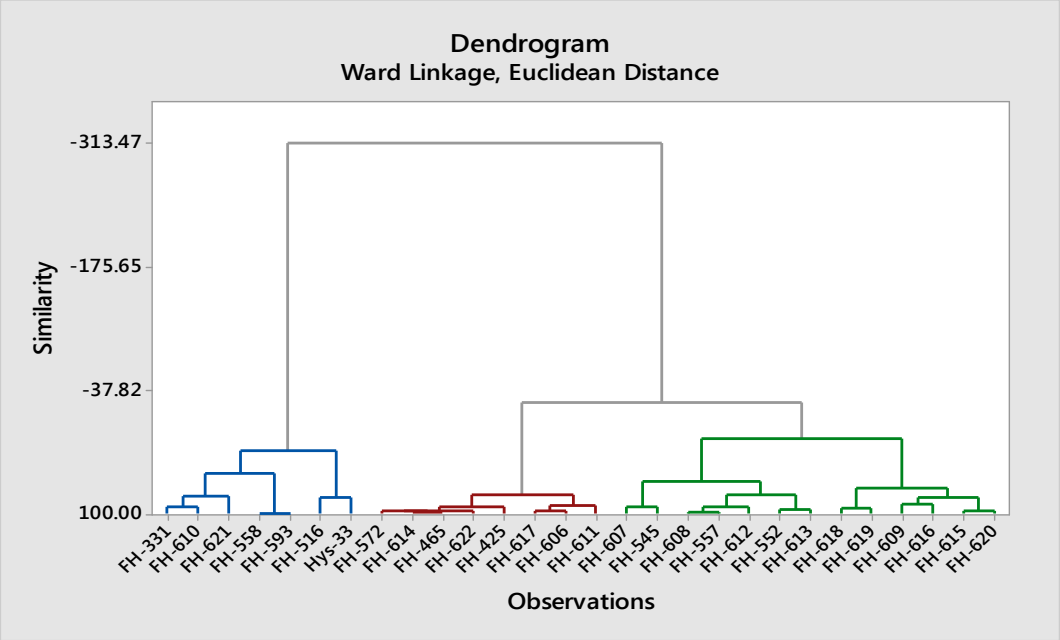

Fig. 4: Tree diagram of 28 sunflower hybrids based on yield and yield related traits.

The scientists Rabbani *et al*. (1998) and Amurrio *et al*. (1995) found absence of association among different clusters established on agronomic traits and origin of genotypes in mustard (*Brassica juncea*) and peas (*Pisum sativum*) respectively. Likewise, wide variations in clusters have been reported by Nazir *et al*., (2013). The occurrence of extensive variability among the clusters is of great genetic value in discovery of hybrids for best all round presentation.

4. Conclusion:

Useful evidences were generated from PC and cluster analysis may be supportive in planning a successful hybrid development program aimed to develop sunflower hybrids possessing a high degree of stability with better seed yields. FH-516 locally developed sunflower hybrid, produced seed yield at par with international sunflower hybrid Hysun-33. So, it must be promoted as commercial sunflower hybrid to combat the current situation of edible oil in the country.

Corresponding Author:
Fida Hussain,
Directorate of Oilseeds,
Ayub Agricultural Research Institute, Faisalabad (Pakistan).
Phone: +92-41-9200770
Email: fida1385@gmail.com

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