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USING MULTIVARIATE ANALYSIS FOR SELECTING DESIRABLE HYBRIDS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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Abstract

Eighteen sunflower hybrids of diverse origin were evaluated for nine agronomic characters under field conditions at NARC, Islamabad. Data were recorded on days to flower initiation & completion and days to maturity were recorded on plot basis while Plant height (cm), Stem girth (mm) and Head diameter (cm) were recorded on 10 randomly selected plants in central two rows. Seed yield per plot in grams (Fresh weight). Seed yield per plot in grams (dry weight), Seed yield per plot on dry weight basis and then converted into kg ha^{-1}. The objectives were to estimate the genetic parameters, genetic diversity, correlation coefficient and path analysis. The highest seed yield 3409 kg ha^{-1} was produced by the hybrid "FSS 50" followed by FH-385 and Barracuda. All the characters had positive correlations with seed yield and 100 seed weight except head diameter where it was negatively correlated. Oil contents (-0.058) also had negative genotypic correlation. Therefore, it is suggested to break this negative correlation through conventional or novel breeding techniques to breed high yielding hybrids with higher oil contents. Positive direct effect was also observed with days to flower initiation, plant height, head diameter and oil contents on seed yield. Maximum positive direct effect (38.944) was observed with days to flower initiation followed by plant height (11.771). Cluster diagram based on Euclidean dissimilarity revealed 3 clusters at 50% linkage distance. Cluster-I had 9 genotypes, cluster-II had 6 and three in cluster-III had three genotypes. Hybrids in cluster-I had tall plants and were high yielding. Hybrids in cluster-II are desirable for large scale cultivation because plants of these were medium with larger heads, high yielder and late in maturity. These hybrids were also high in oil contents can be more desirable for large scale cultivation on the basis of high oil yield. The hybrids in cluster-III were earlier in maturity, shorter in stature, had more 100 seed weight but lower in seed yield.

Introduction

Pakistan is facing chronic deficiency of edible oil in the country, which is becoming more serious due to low and stagnant indigenous production, increased population and higher prices of edible oil in the world market. This deficiency (65%) of edible oil in the country is met through imports and local production that meets only 30-35% of the country's requirements (Anonymous 2009). Among oilseeds, sunflower is one of the important oil crop due to its higher yield potential, wider adaptability and shorter growth period. Sunflower has become an important cash crop of the country. It is cultivated on an area of 353,000 hectares annually. Its production is 554,000 tons with an average yield of 1569 Kg ha^{-1} during 2009-10 (Anonymous, 2010). Potential yield of this crop is 4000 Kg ha^{-1}. In Pakistan, the crop is grown with 100 percent imported seed of hybrids. The imported seed is expensive and has sometimes adaptability problems under local climatic conditions. Therefore, the imported hybrids tested under local climatic conditions for their adaptability, yield potential, maturity duration and reaction against different biotic and abiotic stresses before granting permission to grow on commercial scale.

The knowledge of genetic parameters is essential for understanding and manipulation in crop improvement programme. Seed and oil yield in sunflower are complex characters and are interrelated with number of other traits. 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 generations. Earlier in sunflower, Shankar *et al*., (2006), Arshad *et al*., (2007 & 2010) 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 (Ghafoor & Arshad, 2008 and Muhammad *et al*., 2009). Ghaffari, (2004); Sankar *et al*., (2004) and Ghafoor & Sultana (2009) also applied principal component analysis and reported considerable conformity with conventional methods, indicating its potential for use in cultivar development, selection of superior three way cross hybrids in sunflower and in lentil. Keeping in view the importance of this technique the present study was conducted to investigate the correlation coefficient, path analysis and principal components analysis for seed yield traits and to identify the best genotypes on the basis of result for future exploitation.

Materials and Methods

Eighteen sunflower hybrids of diverse origin were planted during spring season in a Randomized Complete Block Design (RCBD) with three replications at experimental area of NARC, Islamabad during 2009. Each hybrid was grown in 4 rows of 5 m length with row-to-row and plant-to-plant spacing of 75 and 25 cm, respectively. Sowing was done manually on ridges by dibbling 3-4 seeds per hill to a depth of 2-3 cm to maintain optimum plant population per plot. All other recommended cultural practices were adopted for healthy crop. Optimum fertilizers (120 Kg ha^{-1} Nitrogen, 60 Kg ha^{-1} Phosphorus) were applied to harvest potential of the hybrids. At maturity ten plants were selected randomly from each plot in the central two rows. Data were recorded on days to flower initiation (when about 5 percent of the buds per plot open to flower) & completion (when about 90 percent of the buds per plot open to flower) and days to maturity were recorded on plot basis while Plant height (cm), Stem girth (mm) and Head diameter (cm) were recorded on 10 randomly selected plants in central two rows. Seed yield per plot in grams (Fresh weight), Seed yield per plot in grams (dry weight), Seed yield per plot on dry weight basis and then converted into kg ha^{-1}.

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 were tested with the help of standard errors as suggested by Reeve & Rao (1981). Path coefficient was worked out with the methods used by Dewey & Lu (1959) with help of computer software written in QB45. The PCA was calculated using WARD's method from mean of the hybrids (Sneath & Sokal, 1973). The data collected and heritability (broad sense) were subjected to analysis of variance as outlined by Steel & Torrie (1980) for all the characters to observe the level of variation in the hybrids evaluated.

Results and Discussion

The results regarding statistical measures including mean, variance, standard deviation and heritability of nine characters are presented in Table 1. Significant differences were observed for all the characters except head diameter. Non-significant differences for replications revealed genetic consistency of the material evaluated under this study except days to flower initiation and stem girth. Broader acceptance of the results is mainly attributed towards insignificant influence of environments. Similarly, the narrow range between genotypic and phenotypic variance for almost all the characters emphasized the acceptance of results due to genotypic dependence rather than influenced by environmental fluctuations (Table 2). Partitioning of variance into additive fraction revealed high heritability for days to flower initiation, days to flower completion, days to maturity, plant height and seed yield (kg ha^{-1}), while the characters having low heritability were head diameter and seed yield (Table 1). Although seed yield is quite a dependent variable and highly unstable due to multiple factors, therefore low heritability is quite understandable, but in a character like head diameter, narrow heritability is likely attributed due to selection pressure for parental lines with similar background for head diameter (Table 1). The stable characters inherited by the inbred lines are likely to be utilized in hybrid development in sunflower. Khan *et al*., (2007) also reported similar results for these parameters in sunflower.

Correlation coefficient: The magnitudes of genotypic correlation coefficients were higher than both the phenotypic and environmental correlation coefficient in most of the character pairs indicating genuine association among genetic portion of the total variation (Table 2). Days to maturity (DM) had positive and highly significant correlations with days to flower initiation (0.943**) and days to flower completion (0.944**). It is obvious that all of these 3 phenological traits are inter-dependent and have a strong linear relationship, especially in autumn crops. Genotypic and phenotypic correlation coefficient of plant height (PH) had positive and significant association with days to flower initiation (0.754** and 0.698**), completion (0.772** and 0.691**) and maturity (0.774** and 0.701**), contributing phenological traits toward vegetative growth through photosynthesis. The stem girth one of the important traits contributing towards biomass, had positive and highly significant correlations with days to flower initiation (0.951** and 0.789**), completion (0.966** and 0.759**), maturity (0.954** and 0.788**) and plant height (0.805** and 0.618**). All of these traits discussed so far are one or the other way linked to vegetative phase, whereas others contribute for reproductive phase. Head diameter (HD) had low magnitude of positive association with DFI, DFC and DM, but it had negative association with plant height (-0.550*) and hundred seed weight (-0.683**). This was may be due the application of high input and heavy rainfall during cropping seasons which need to break this negative association through appropriate selection of parental line for hybrids development. However, Shanker *et al*., (2006) and Farhatullah *et al*., (2006) reported positive association among these traits.

Negative association of head diameter and plant height has been exploited by the sunflower breeders to avoid lodging and ultimately support seed yield (Nehru & Manjunath, 2003). Seed yield had significant genotypic correlation coefficient with days to maturity (0.580*) and stem girth (0.564*) indicating that long duration hybrids with better stem girth are likely to produce more seed yield and these important traits could be the selection criterion in sunflower breeding program. Habibullah *et al*., (2007) also reported significant positive genetic correlations of stem girth with seed yield in sunflower. Moreover, seed yield had positive association with all the traits but non-significant and negative association with head diameter (-0.058). Seed yield is the most important economic trait of any field crop that is inter-linked in various directions and it is the skill of breeder to combine multiple traits in a way to achieve the maximum yield potential, particularly under the threats of climate change (Razi & Assad, 1999). The negative linkages between important traits could be broken for economic benefit through conventional or novel breeding techniques to breed high yielding hybrids, short duration and height and higher with oil contents. Strong positive correlations of oil contents with stem girth (0.639**), head diameter (0.880**) and seed yield (0.689**) was observed while remaining traits had simple positive correlation with economically important traits. Although linear relationship between oil contents and seed yield is quite ridiculous and is the desire of breeders, hence all the hybrids included in the present study were improved and selected, therefore this type of relationship is understandable. Sridhar *et al*., (2005) and Vidhyavathi *et al*., (2005) also reported the similar relationships between these important traits in sunflower hybrids. It is observed on the basis of results that improvement for individual traits or group of economic traits could be possible if the parental lines are selected on the basis of their performance and genetic architectures.

Table 1. Name, source, origin and mean of eight characters for yield and its related components in 18 sunflower hybrids.

Hybrids	Source	Origin	DFI	DFC	DM	PH (cm)	STG (mm)	HD(cm)	SY (Kg ha^{1})	100SW (g)	OC (%)
Barracuda	United Distributors Pakistan Ltd., Karachi	USA	84	89	119	204	21.4	18.1	3261	4.77	42.7
Blazer CL	United Distributors Pakistan Ltd., Karachi	USA	88	92	120	210	24.2	20.0	2920	4.35	47.1
Sierra	United Distributors Pakistan Ltd., Karachi	USA	85	90	119	163	22.1	21.8	3025	4.00	46.3
US 666	Umar Seed and Agri Services, Bahawalpur	USA	82	89	115	172	22.3	19.8	2476	4.41	48.8
Ausigold 62	The Seed Company, Karachi	Australia	72	80	103	134	16.2	18.1	2821	6.72	47.4
Ausigold 61	The Seed Company, Karachi	Australia	73	81	105	157	16.0	18.8	2715	4.70	39.7
FSS 64	Farm Services Syndicate, Karachi	India	81	86	114	167	21.1	20.5	2607	4.49	42.9
FSS 50	Farm Services Syndicate, Karachi	India	84	89	119	190	25.6	18.9	3409	4.75	50.0
Sirena	Agri Farm Services, Multan	Italy	85	89	116	172	24.4	20.2	2868	4.65	47.4
Roshan	Agroman Chemicals & Seeds, Sahiwal	India	85	89	117	167	20.9	19.0	2636	4.19	46.6
FH-352	Oilseed Res. Institute, AARI, Faisalabad	Pakistan	82	87	117	161	21.9	20.6	3259	4.69	51.0
FH-385	Oilseed Res. Institute, AARI, Faisalabad	Pakistan	83	89	118	171	22.4	18.3	3267	5.06	46.4
NK-S-278	Syngenta Pakistan Limited, Multan	USA	88	93	121	191	24.1	16.9	2673	4.62	46.0
M-3271	Dagha Corporation, Karachi	USA	87	92	118	198	23.7	17.4	2725	4.30	44.8
VDH-487	ICI-Pakistan Limited, Lahore	Australia	76	82	105	156	17.1	18.4	2453	4.42	42.8
Ag Sun 5551	Seethi Seed Company, Sahiwal	S. Africa	79	85	116	177	21.5	18.4	2977	5.60	46.7
Hysun-33	ICI-Pakistan Limited, Lahore	Australia	80	86	115	176	20.3	17.8	2534	5.94	45.4
NX-00989	Syngenta Pakistan Limited, Multan	USA	83	88	115	192	23.5	15.8	2991	4.94	45.6
Character mean			82	87	115	176	21.6	18.8	2868	4.81	46.0
Character Range			72-88	80-93	103-121	134-210	16.0-25.6	15.8-21.8	2453-3409	4.00-6.72	39.7-51.0
MS (Varieties)			63.18**	43.26**	83.64**	1091.57**	22.78**	6.49ns	257161.40*	1.35**	22.57**
MS (Rep)			3.73*	1.73 ns	8.14ns	216.52 ns	11.86*	12.99ns	21591.11ns	0.03ns	9.26ns
MS (Error)			1.055	1.781	3.423	78.401	2.875	4.47	125510.2	0.304	5.468
Standard Error			0.593	0.77	1.068	5.112	0.979	1.221	204.54	0.318	1.35
Critical difference 1			1.695	2.202	3.053	14.611	2.798	3.489	584.602	0.91	3.859
Critical difference 2			2.268	2.946	4.085	19.549	3.744	4.668	782.169	1.218	5.163
Genotypic variance			20.707	13.825	26.739	337.723	6.636	.672	43883.74	0.349	5.7
Phenotypic variance			21.763	15.606	30.162	416.124	9.511	5.142	169393.9	0.653	11.168
Genotypic covariance			5.542	4.252	4.493	10.469	11.933	4.355	7.305	12.283	5.19
Phenotypic covariance			5.681	4.518	4.772	11.621	14.287	12.052	14.352	16.802	7.265
Coeff of heritability			0.952	0.886	0.887	0.812	0.698	0.131	0.259	0.534	0.51

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

* Indicates significance at the 0.05 level of probability.

** Indicates significance at the 0.01 level of probability.

Table 2. Genotypic (*rG*), phenotypic (*rP*) and environmental (*rE*) correlation coefficients among 8 characters in 18 sunflower hybrids.

Variables correlation		DFI	DFC	DM	PH (cm)	STG (mm)	HD (cm)	SY (kg)	100SW (g)
DFC	*rG*	1.005							
	rP	0.958**							
	rE	0.471*							
DM	*rG*	0.943**	0.944**						
	rP	0.897**	0.889**						
	rE	0.414	0.444						
PH (cm)	*rG*	0.754**	0.772**	0.774**					
	rP	0.698**	0.691**	0.701**					
	rE	0.376	0.252	0.305					
STG (mm)	*rG*	0.951**	0.966**	0.954**	0.805**				
	rP	0.789**	0.759**	0.788**	0.618**				
	rE	0.120	-0.001	0.206	0.054				
HD (cm)	*rG*	0.098	0.010	0.249	-0.550*	0.038			
	rP	0.073	0.072	-0.015	-0.173	0.028			
	rE	0.187	0.218	-0.318	0.015	0.033			
SY(Kg ha^{-1})	*rG*	0.299	0.374	0.580*	0.355	0.564*	-0.058		
	rP	0.198	0.106	0.305	0.204	0.297	0.144		
	rE	0.263	-0.253	0.092	0.111	0.120	0.193		
100SW (g)	*rG*	-0.656**	-0.643**	-0.499*	-0.363	-0.531*	-0.683**	0.173	
	rP	-0.514*	-0.463	-0.359	-0.339	-0.244	-0.263	-0.043	
	rE	-0.308	-0.089	-0.066	-0.338	0.213	-0.130	-0.184	
OC (%)	*rG*	0.408	0.401	0.435	0.011	0.639**	0.880**	0.687**	0.137
	rP	0.270	0.250	0.330	0.022	0.397	-0.064	0.180	0.051
	rE	-0.099	-0.084	0.161	0.050	0.041	-0.446	-0.115	-0.042

DFI: Days to flower initiation; DFC: Days to flower completion; DM: Days to Maturity; PH: Plant height (cm); STG: Stem. Girth (mm); HD: Head diameter (cm); SY: Seed yield (Kg ha^{-1}); 100SW; 100 Seed weight (g); OC%: Oil content %.
* Significant at 5% level
** Significant at 1% level

Path coefficient study: Due to independent nature of all the traits evaluated for correlation, there is a need to have better insight for the dependent variable that is seed yield in most of the field crops. The path coefficient analysis, however, being a more precise menthod which takes into account the mutual relationships among the independent variables and partitions their direct and indirect effects on the dependent variable (Joksimovic *et al*., 1999). Path coefficient analysis provides the horizon for estimating the exact contribution towards dependant variable. To have the true genetic picture, genotypic correlations were partitioned into direct and indirect effects through various yield contributing characters for selection criteria in sunflower breeding (Table 3). The direct effects of days to flower initiation, plant height, head diameter, 100-seed weight and oil contents were positive while the remaining characters exhibited negative direct effects. Maximum positive direct effect (38.94) was observed with days to flower initiation followed by plant height (11.771), oil contents (4.379) and head diameter (3.211). Earlier, Madhavilatha *et al*., (2004) and Farhatullah *et al*., (2006) also reported similar findings while studying on sunflower. The results of present study concluded that days to flower initiation, plant height and head diameter and oil contents are the traits, these contributed more in seed yield components, hence these traits should be given due consideration while selecting parental lines for potential hybrid development. Moreover, Singh & Labana, (1990); Visic, (1991) and Marinkovic, (1992) also reported positive direct effects of that flower initiation, plant height and head diameter with seed yield in sunflower. Whereas, Hidyatullah *et al*., (2008) reported promising results based on path analyses in tomato.

Table 3. Direct (highlighted) and indirect effects of eight traits on seed yield in sunflower hybrids.

Variables	DFI	DFC	DM	PH (cm)	Stem girth (mm)	HD (cm)	100SW (g)	OC (%)	SY (Kg ha^{-1})
DFI	(38.944)	-28.501	-6.786	8.870	-12.516	0.316	-1.813	1.786	0.299
DFC	39.146	(-28.354)	-6.808	9.086	-12.707	0.033	-1.778	1.756	0.374
DM	36.716	-26.818	(-7.198)	9.104	-12.548	0.801	-1.380	1.903	0.580
PH (cm)	29.345	-21.886	-5.567	(11.771)	-10.583	-1.768	-1.004	0.047	0.355
STG (mm)	37.053	-27.389	-6.866	9.470	(-13.155)	0.122	-1.468	2.797	0.564
HD (cm)	3.830	-0.290	-1.795	-6.479	-0.499	(3.211)	-1.889	3.852	-0.058
100SW (g)	-25.534	18.231	3.593	-4.275	6.985	-2.193	(2.765)	0.601	0.173
OC%	15.880	-11.370	-3.128	0.125	-8.403	2.825	0.379	(4.379)	0.687

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

Sridhar *et al*., (2005) observed that plant height, head diameter and 100-seed weight had positive direct effect on seed yield indicating that yield was a function of both growth and yield components. Moreover, 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. 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.

Cluster analysis indicates the extent of genetic diversity in the material that could be reflected towards the parental lines that is of practical use in plant breeding (Reddy *et al*., 2004 and Sultana & Ghafoor, 2008). The cluster diagram based on Euclidean dissimilarity using Ward's method revealed three clusters at 50% linkage distance (Fig. 1). The cluster-I consisted of 9 genotypes (Barracuda, NX-00989, FSS 50, FH-385, Ag sun 5551, Hysun-33, Blazer CL, NK-S-278 and M-3271), six in cluster-II (Sierra, FH-352, US-666, Roshan, Sirena and FSS-64) and three (Ausigold-62, Ausigold-61 and VDH-487) in cluster-III (Table 4). The hybrids in cluster-I had more plant height and high yielding (2973 Kg ha^{-1}), while the hybrids grouped in cluster-II were of medium plant height; medium maturity; larger head size and high yielding (2812 Kg ha^{-1}) with high oil contents (47.17%) that can be more desirable for large scale cultivation on the basis of high oil yield. The hybrids in cluster-III were earlier in maturity, short stature, more 100 seed weight and lower in seed yield. It was observed that hybrids grouped in different clusters on the basis of plant height and seed yield as a major part of variation, whereas other traits contributed less for clustering pattern. There is no clear indication of any relationship between hybrids and the origin except one where the hybrids of "The Seed Company" i.e., Ausigold-61 and Ausigold-2 grouped together in cluster-III. Anyhow the hybrids grouped in cluster III were early in maturity (104 days) and it is an important trait to incorporate sunflower in the rice based areas, although compromising seed yield at some admitted levels. It is concluded that among various hybrids, it was possible to have a better group of hybrids that can be identified through cluster analysis. Although the hybrids grouped in cluster-I were also high yielding (2973 Kg ha^{-1}), but taller in height that may cause lodging at maturity, hence, the hybrids in cluster II had more breeding value as compared to the members of other clusters (Table 4). Ghaffari (2004) also reported that PCA showed considerable conformity with conventional methods, indicating its potential in sunflower hybrids development. Results reported by Sultana & Ghafoor (2008) showed multivariate analysis as a valid system to deal with germplasm collection for utilization in breeding programme.

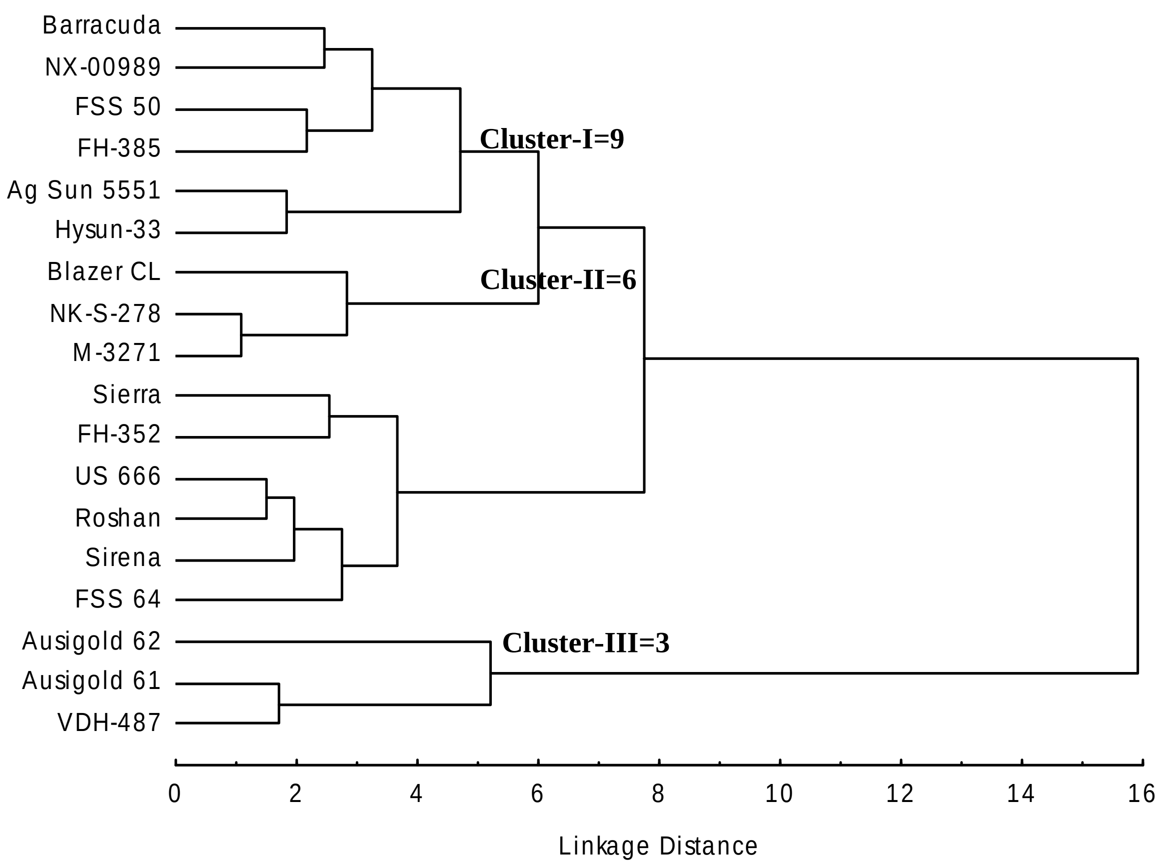

Fig. 1. Cluster diagram of 18 sunflower hybrids based on quantitative traits.

Table 4. Mean and standard deviation of 3 clusters for 9 variables in 18 sunflower hybrids.

Variables	Mean ± SD		
	Cluster-I (9)	Cluster-II (6)	Cluster-III (3)
Days to flower initiation	84.00 ± 3.24	83.33 ± 1.86	73.67 ± 2.08
Days to flower completion	89.22 ± 2.73	88.33 ± 1.51	81.00 ± 1.00
Days to maturity	117.89 ± 2.15	116.33 ± 1.75	104.33 ± 1.15
Plant height (cm)	189.89 ± 13.19	167.00 ± 4.52	149.00 ± 13.00
Stem girth (mm)	22.97 ± 1.68	22.12 ± 1.25	16.43 ± 0.59
Head diameter (cm)	17.96 ± 1.20	20.32 ± 0.93	18.43 ± 0.35
Seed yield (Kg ha^{-1})	2973 ± 297.25	2812 ± 294.69	2663 ± 189.43
100 Seed weight (g)	4.93 ± 0.54	4.41 ± 0.27	5.28 ± 1.25
Oil contents (%)	46.08 ± 1.96	47.17 ± 2.71	43.30 ± 3.87

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