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Developing a Selection Criterion Using Correlation and Path Coefficient Analysis in Sunflower (*Helianthus Annuus* L.)

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Abstract: In breeding programs, it is imperative to recognize the genetic variations and levels of association between traits that directly or indirectly affect the yield. Achene yield and related traits in forty-nine sunflower genotypes were studied for genetic variability, correlations and path coefficient analysis. The phenotypic coefficient of variation (PCV) were higher than the genotypic coefficient of variation (GCV) for the all the studied traits in sunflower. The most active association of achene yield was found with achene/head, 100-achene weight and plant height. However, oil contents had a negative association with achene filling percentage, 100-achene weight, number of leaves and stem diameter. The maximum direct influence on achene yield were exerted by head diameter followed by achene filling percentage, 100 achene weight, achene/head and number of leaves. In contrast, plant height, days to maturity and stem diameter had the negative direct impact on yield. The genetic correlations were higher than phenotypic correlations which suggest that

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environmental influences were very low. Our results showed that achene/head, 100 achene weight, plant height and head diameter are important plant traits which should be considered while planning any breeding program for higher achene yield in sunflower.

Keywords: genetic variability, correlation, path coefficient, sunflower, achene yield

Introduction

Achene yield in sunflower (*Helianthus annuus* L.) is a complex polygenic character influenced by physiological, morphological and environmental factors (Razzaq *et al.*, 2017; Zia *et al.*, 2013). The ultimate objective of any breeder is to increase seed yield and oil contents (Vrânceanu *et al.*, 2005). The manifestation of genetic variability is a pre-requisite in the breeding material for the selection of genotypes with desirable traits and further plant improvement (Ali *et al.*, 2009; Riaz *et al.*, 2017). To quantify the extent of variability for the inherited traits is an important tool in plant breeding. It produces high-value knowledge by estimating the genetic parameters and generates an efficient selection. Also, more accuracy and heritability can be estimated through the study of the relationship between genotypic and phenotypic variances. Therefore the extrapolations of average phenotypic and genotypic variances are very useful to check the effectiveness of different traits associations (Resende and Duarte, 2007). Accuracy and heritability are also essential to study the impact of environmental stresses on several yield-related traits for active selection (Cruz, 2004). The explorations for more adapted genotypes from genetic variances must be constant throughout the breeding programs for research progress.

The accomplishment of breeding programs mainly depends on the variation present for yield and yield components as well as the nature of the hereditary material (Nehru and Manjunath, 2003). The extent of the relationship between phenological, seed yield and oil traits would ultimately enhance their selection efficiency for the above traits. Therefore, it is essential to size the mutual associations between agronomic traits to define the component traits which may be capitalized as reliable selection criteria for genetic improvements of yield and other essential traits (Memon *et al.*, 2014).

The value of the net effect of a relationship between two traits is known as correlation. The familiarity about correlation and path coefficients can play a significant role in the genetic improvement of various traits during a selection procedure. Correlation coefficients conclude the traits that directly affect to the achene produce. Correlation and path coefficient analyses have been used by many researchers to check the relationship among seed yield and other related components (Kaya *et al*., 2009; Machikowa and Saetang, 2008; Mijić *et al*., 2009).

Correlation analysis explains the interactions of morphological traits with achene yield per plant. It may be partitioned into genetic and phenotypic correlations. When the genetic association is higher than phenotypic, environmental effects are not playing an important role (Ashok *et al*., 2000). Correlation studies also help to improve different traits simultaneously (Sujatha and Nadaf, 2013). However, the drawback is that it only measures the relationship among the traits. There is another analysis, i. e. path coefficient analysis which measures the direct and indirect influences of traits on achene yield (Marinković, 1992). Correlation and path coefficients analyses assist in identifying the traits, valuable as selection criteria to enhance achene yield of sunflower.

This study was aimed to discover genetic variation and association among different achene yield contributing traits in sunflower genotypes for developing new varieties with better combinations of these traits.

Material and methods

The research study was conducted at the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan during 2014–15. Forty-nine genotypes of sunflower were sown in a randomized block design (RBD) with three replications.

The sowing of sunflower genotypes was done keeping row-to-row 0.75 m and plant-to-plant 0.25 m distance. The length of each planting row was 5 m in length. Planting of seeds was done by using a dibbler. All the cultural and agronomic practices were maintained to have good crop stand. Monthly average minimum and maximum temperature and monthly total rainfall of 2014–15 during the crop period have been shown in Figure 1.

The data were collected on the following pre-harvest and post-harvest plant traits including DM (days to maturity), PH (plant height), SD (stem diameter), HD (head diameter), NOL (number of leaves per plant), APH (number of achene/head), AYP (achene yield per plant), 100AW (100-achene weight), FA (achene filling percentage and oil contents). The mean values of the evaluated trait in this study are given in Table 1.

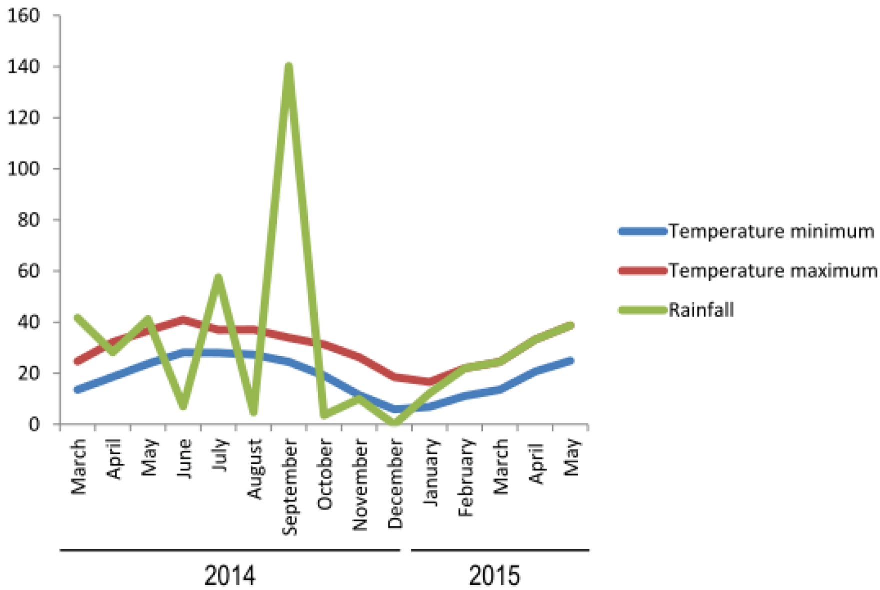

Figure 1: Metrological conditions prevailing during the crop season (2014–15).

Statistical analysis

The genotypic (GCV) and phenotypic (PCV) coefficients of variation of the studied traits were calculated as follows:

PCV = σ2ph/XG x100 and GCV = σ2G/XGx100

Where: XG = Grand mean

Genetic advance (GA) was estimated proposed by Johnson *et al.* (1955) and Falconer (1989). Heritability in the broad sense (h2) was estimated according to Burton and Dewane (1953) which is given as,

h2 (B.S.) = (Vg/Vp) × 100

Where,

Vg = the genotypic variance

Vp = the phenotypic variance

h2 (B.S.) = heritability (Broad sense)

The data collected were subjected to correlation analysis to determine the association among different traits at a genotypic and phenotypic level among the characters as proposed Kwon and Torrie (1964) and path coefficients were calculated following Dewey and Lu (1957) to study direct and indirect effects of

Table 1: Mean values for quantitative traits of sunflower (*Helianthus annus* L.) genotypes.

Genotypes	DM	PH	SD	HD	NOL	APH	AYP	100AW	FA	OC
AR501	77.43	130.5	5.21	16.13	14.6	370.6	14.4	5.08	42.66	32.08
AR502	86.7	158.83	5.14	14.26	14.36	366.33	14.86	5.47	52.61	30.80
AR503	86.91	140.53	6.43	17.93	14.46	407.83	21.16	6.23	45.62	31.94
AR504	86.27	155.83	5.81	15.61	13	397.2	27	6.48	26.86	34.23
AR505	85.82	173.83	7.53	18.63	21.93	533.83	26.66	7.39	24.53	32.05
AR506	85.28	146.73	6.73	17.05	18.2	453.5	24.13	7.33	48.79	31.92
AR507	83.46	173.43	7.32	18.48	20.43	496.1	22.43	8.388	29.83	30.59
AR508	76.89	118.8	4.64	13.48	16.93	115.4	12.8	3.10	51.67	33.62
AR509	81.72	115.96	4.58	15.56	15.76	321.83	15.4	8.62	30.00	31.82
AR510	78.78	118.36	4.98	17.46	19.33	398.96	14.23	6.89	55.33	32.20
AR511	80.69	122.73	5.33	17.63	15.43	387.53	14.26	6.09	42.66	33.85
AR512	82.55	107.43	5.47	16.93	15.26	460.46	17.3	7.762	70.33	33.34
AR513	79.19	126.36	5.91	17.95	15.56	349.66	16.13	6.66	66.00	30.53
AR514	89.13	85.96	5.86	16.51	13.16	316.03	14.36	7.691	55.00	33.06
AR515	80.63	149.3	5.65	16.93	13.53	243.46	12.4	7.96	58.29	30.09
AR516	79.48	148.4	6.32	15.68	14.43	423.66	19.43	6.39	25.00	30.65
AR517	78.69	140.06	5.48	15.91	16.66	333.06	18.66	9.25	40.00	32.05
AR518	78.57	123.86	6.58	16.35	13.96	404.33	18.4	7.92	49.66	32.04
AR519	81.14	136.16	6.04	17.59	16.83	585.56	27.26	7.58	64.33	30.74
AR520	83.41	150.83	7.38	17.44	20.93	464.86	20.2	7.104	65.66	33.48
AR521	80.86	144.5	6.87	15.17	19.16	358.06	17.36	5.61	64.66	32.95
AR522	84.61	143.53	4.94	16.7	12.96	378.86	17.06	6.03	45.29	31.97
AR523	80.57	155.46	6.33	17.68	15.53	437.5	36.7	10.23	67.66	32.08
AR524	87.76	156.2	5.66	16.96	16.26	363.03	33.93	10.73	52.33	32.31
AR525	81.87	148.33	5.92	16.99	19.0	376.86	13.56	6.68	74.66	32.99

(*continued*)

Table 1: (*continued*)

Genotypes	DM	PH	SD	HD	NOL	APH	AYP	100AW	FA	OC
AR526	78.86	156.36	5.76	17.4	19.33	404.5	15.86	5.88	75.00	32.08
AR527	87.25	123.63	4.84	13.15	20.36	424.2	13.4	7.20	68.33	30.66
AR528	85.08	148.73	6.38	17.75	20.23	397.66	11.7	6.12	65.33	34.04
AR529	89.59	144.5	4.93	16.58	14.0	281.33	23.23	4.85	61.78	31.18
AR530	80.88	149.86	4.60	14.22	20.33	464.66	16.16	6.45	52.66	32.47
AR531	85.47	147.13	5.26	15.01	14.36	395.53	23.53	7.99	39.66	32.39
AR532	87.74	154.5	6.55	17.37	18.5	475.8	23.1	7.39	59.66	32.47
AR533	76.86	154.63	6.38	15.68	19.13	465.9	26.96	8.57	56.00	30.73
AR534	87.51	142.36	6.26	17.05	19.53	442.8	24.66	5.42	57.33	31.83
AR535	77.58	124.4	7.55	14.12	19.33	427.16	20.7	8.42	74.00	30.36
AR536	87.03	174.1	7.29	21.78	19.66	337.9	17.73	4.93	43.80	32.24
AR537	80.25	178.96	7.25	18.78	21.06	382.1	24.63	8.94	73.00	31.63
AR538	85.50	131.6	5.11	16.70	18.93	336.5	28.33	9.17	64.33	30.98
AR539	85.48	120.4	4.74	15.56	13.03	412.6	28.36	6.98	47.66	32.08
AR540	85.76	160.73	6.04	16.22	18.43	362.06	14.23	5.72	71.00	29.94
AR541	80.92	149.23	6.91	17.53	18.5	330.06	12.3	5.11	62.67	30.19
AR542	86.97	149.33	6.27	16.41	17.36	406.3	12.13	6.39	62.33	31.91
AR543	90.2	112.03	3.61	14.46	13.0	226.1	4.93	4.43	24.66	33.34
AR544	86.97	111.4	6.45	18.53	13.4	357.9	20.2	6.55	53.66	32.97
AR545	76.76	113.5	6.40	16.6	14.93	282.63	9.76	8.38	45.33	31.22
AR546	86.34	124.2	5.73	15.9	18.33	348.3	12.56	6.90	72.33	32.47
AR547	86.73	153.16	5.87	15.68	18.23	396.5	19.43	6.71	53.33	33.79
AR548	78.23	143.53	6.13	16.37	16.16	401.86	25.2	5.53	54.66	30.25
AR549	81.39	160.1	6.65	17.81	17.4	491.9	25.86	6.97	65.33	31.87

DM = days to maturity, PH = plant height, SD = stem diameter, HD = head diameter, NOL = number of leaves, APH = achene/head, AYP = achene yield/plant, 100AW = 100-achene weight, FA = achene filling percentage, OC = oil contents morphological traits on achene yield. Achene yield/plant was kept as a resultant trait and yield contributing traits as causal variables.

Results

Genetic variability

Genetic variability is an important tool for the enhancement of achene yield in sunflower. The variation reflects the diverse geographic origin and distribution of genotypes. The study of components of variation including genetic and phenotypic variability, h2 and GA reveal the heritable portion of overall variation in genetic material. Finally, such a considerable range of variation provides an excellent opportunity for seed yield improvement. PCV and GCV, h2, and genetic advance expressed as per cent of the mean (GAM) revealed significant variation among sunflower genotypes for the ten traits (Table 2).

Table 2: Estimation of mean and different genetic parameters in sunflower.

Traits	Mean	PCV	GCV	h2 (BS)	GA	GAM (%)
DM	16.782	20.95	12.871	37.742	2.734	16.289
PH	385.136	24.806	15.285	37.966	74.721	19.401
SD	19.222	36.36	27.304	56.387	8.119	42.236
HD	6.873	26.062	16.115	38.23	1.411	20.525
NOL	53.804	28.831	20.481	50.467	16.127	29.973
APH	31.53	13.112	8.311	40.179	3.422	10.853
AYP	82.504	10.545	3.559	11.393	2.042	2.475
100AW	140.04	17.206	11.123	41.789	20.743	14.812
FA	6.113	31.495	18.394	34.111	1.353	22.131
OC	16.511	13.715	5.11	13.88	0.648	3.922

PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, h2 (BS) = broad sense heritability, GA = genetic advance, GAM = genetic advance as percent of mean. DM = days to maturity, PH = plant height, SD = stem diameter, HD = head diameter, NOL = number of leaves, APH = achene/head, AYP = achene yield/plant, 100AW = 100-achene weight, OC = oil contents

The PCV and GCV were highest for stem diameter and filled seed percentage and moderate for some leaves, head diameter, plant height and days to maturity. GCV and PCV were high for achene and oil yield and moderate for plant height, stem diameter, head diameter, 100 achene weight and oil content. h2 estimates were high for all the characters studied, except for oil contents but achene yield per plant and oil contents had moderate h2. Stem diameter and number of leaves exhibited high heritability and moderate genetic advance. GAM ranged from 2.47 to 42.23 for the traits under study. These results suggested the greater effectiveness of selection and improvements expected for these traits in the future breeding programs as estimated from GAM.

Correlations

Study of the actual association between achene yield and its related traits helps to reveal their importance in sunflower breeding programs. The strongest positive associations of achene yield were observed with achene per head ($r = 0.575$, 0.386) followed by 100 achene weight ($r = 0.524$, 0.373) plant height ($r = 0.414$, 0.262) and head diameter ($r = 0.259$, 0.168) both at genetic and phenotypic levels respectively (Table 3). In addition, stem diameter ($r = 0.165$) was significant positively correlated with achene yield only at the phenotypic level.

Plant height revealed significant and positive association with number of leaves ($r = 0.498$, 0.442), achene per head ($r = 0.383$, 0.295) and head diameter ($r = 0.382$, 0.262) both at genetic and phenotypic levels. However, the strongest correlation was found between number of leaves and plant height at both levels. Oil contents were positive and significantly correlated with days to maturity ($r = 0.623$) while negatively correlated with achene filling percentage ($r = -0.852$) and 100 achene weight ($r = -0.552$), number of leaves ($r = -0.488$) and stem diameter ($r = -0.201$) only at genotypic levels. Concomitantly, stem diameter and head diameter, 100 achene weight and achene/head had significant positive associations both at genetic and phenotypic levels. In addition, achene filling percentage was strongly associated with number of leaves at the genetic level.

For the development of new cultivars with the greater genetic potential to increase achene yield is ultimate objective by implementing continuous selection, improving, maintaining and enhancing other related components. Our results suggest that achene/head, achene weight, plant height and head diameter are important yield-related traits and could be considered as selection criteria to increase achene yield in sunflower.

Table 3: Genotypic (rg) and Phenotypic (rp) correlation coefficients of studied traits for achene yield/plant (g) in sunflower.

Traits	r	DM	PH	SD	HD	NOL	APH	100AW	FA	OC	AYP
DM	rg	1	0.108	0.062	0.032	−0.146	−0.016	−0.339	−0.189	0.623**	0.115
	rp	1	−0.011	−0.009	0.137	−0.147	0.003	0.033	−0.073	0.089	0.011
PH	rg		1	0.146	0.382*	0.498**	0.383*	0.042	0.009	0.109	0.414**
	rp		1	0.136	0.262*	0.442**	0.295*	0.077	0.028	0.043	0.262*
SD	rg			1	0.492**	0.160	0.258	0.136	0.123	−0.201*	0.201
	rp			1	0.439**	0.203	0.167	0.058	0.099	0.019	0.165*
HD	rg				1	0.216	0.323*	0.169	0.062	0.026	0.259*
	rp				1	0.181*	0.140*	0.030	0.076	−0.019	0.168*
NOL	rg					1	0.424**	0.100	0.389**	−0.488**	0.061
	rp					1	0.274*	0.069	0.269*	−0.053	0.048
APH	rg						1	0.376*	0.074	−0.216	0.575**
	rp						1	0.248*	0.079	−0.093	0.386**
100AW	rg							1	0.087	−0.552**	0.524**
	rp							1	0.019	−0.033	0.373**
FA	rg								1	−0.852**	−0.002
	rp								1	−0.045	0.003
OC	rg									1	−0.038
	rp									1	−0.043

***** = significant at 0.05 probability level ****** = highly significant at 0.01 probability levelDM = days to maturity, PH = plant height, SD = stem diameter, HD = head diameter, NOL = number of leaves, APH = achene/head, 100AW = 100-achene weight, FA = achene filling percentage, OC = oil contents, AYP = achene yield/plant,

Path coefficient analysis

Path coefficient analysis (Table 4) showed that head diameter (0.68) had maximum positive direct effect followed by achene filling percentage (0.67), 100 achene weight (0.62), achene/head (0.30) and the number of leaves (0.16). These results explained that head diameter is directly contributing to achene yield per plant and this effect is mainly through achene filling percentage and 100 achene weight. Head diameter had a positive indirect impact through stem diameter, plant height, days to maturity, number of leaves and 100-achene weight. Increase in these traits will ultimately cause some increase in achene yield of sunflower. The maximum adverse direct effect was found in days to maturity (–0.66) followed by stem diameter (–0.47), oil contents (–0.41) and plant height (–0.06). Notably, plant height had the least negative direct effect which suggests that achene yield would be less affected as compared to other traits.

Table 4: Direct (bold diagonal) and indirect effects of various characters on achene yield/plant of sunflower genotypes.

Traits	DM	PH	SD	HD	NOL	APH	100AW	FA	OC	r_g
DM	**−0.66**	0.04	−2.24	1.13	0.14	0.45	1.01	−0.06	0.46	0.29*
PH	−0.44	**−0.06**	−1.42	2.17	−0.29	−0.16	−0.11	0.01	−0.07	−0.37
SD	−1.07	0.06	**−0.47**	2.61	0.20	−0.05	0.37	0.19	0.05	0.96**
HD	−0.27	0.05	−1.43	**0.68**	0.06	−0.01	0.20	−0.22	0.09	0.13
NOL	−0.55	−0.11	−1.82	0.95	**0.16**	−0.29	−0.18	−0.12	0.03	−0.96
APH	−0.97	−0.03	0.27	−0.13	−0.16	**0.30**	−0.51	−0.11	−0.26	−0.60
100AW	−1.06	−0.01	−0.87	0.86	−0.04	−0.25	**0.62**	0.02	−0.12	−0.86
FA	0.05	0.01	−0.42	−0.90	−0.03	−0.05	0.02	**0.67**	0.019	−0.64
OC	0.73	0.01	0.17	−0.58	−0.05	0.19	0.18	−0.03	**−0.41**	0.25*

***** = significant at 0.05 probability level ****** = highly significant at 0.01 probability levelDM = days to maturity, PH = plant height, SD = stem diameter, HD = head diameter, NOL = number of leaves, APH = achene/head, FA = achene filling percentage, 100AW = 100-achene weight, OC = oil contents, AYP = achene yield/plant

Stem diameter showed an indirect positive impact on achene yield through head diameter while negative via days to maturity. However, oil contents had negative direct effects while positive indirect effects through days to maturity, head diameter, stem diameter, achene/head and achene filling percentage on achene yield.

Discussion

The significant higher PCV and GCV for traits including stem diameter and achene filling percentage (Table 2) proposed that these traits be under the influence of genetic architecture. Therefore, pure selection can be dependent on these traits for further improvement. In addition, a greater influence of PCV over GCV indicates that there is involvement of environmental factors, which influence maturity; hence selection for this trait should be delayed to study the extent of environmental factors. These results are following previous studies (Khan *et al.*, 2007; Rani *et al.*, 2017; Sujatha and Chikkadevaiah, 2002). h2 estimates reveal the heritable portion of variability present in morphological traits. The h2 information gives a clue to plant breeder to decide the course of the screening process by following under a given situation. However, h2 estimates coupled with GA would be more reliable (Johnson *et al.*, 1955) and valuable in framing the screening procedure. The moderate h2 for oil contents and achene yield have also been reported by Mijić *et al.* (2009).

The highly heritable traits with high or moderate GA could be further improved with individual plant selection. Traits with higher h2 and low GA indicated little scope for further increase via individual plant selection. Our results suggested the superior efficiency of selection and enhancement be expected for these traits as the genetic variations are mostly due to additive gene action (Jocković *et al.*, 2018; Mijić *et al.*, 2009; Rani *et al.*, 2017; Yankov and Tahsin, 2015).

The genetic and phenotypic correlation coefficients among achene yield and contributing traits (Table 3) showed that most of the traits have higher genetic correlation coefficients than corresponding phenotypic correlation coefficients because the relationship was affected by the environment at the phenotypic level, indicated the low phenotypic correlation coefficients (Ghias *et al.*, 2018; Omikunle, 2003). Existing knowledge about relationships between traits helps in appropriate selection process due to a greater share in crop improvement (Gonçalves *et al.*, 2017). Previous studies have reported head diameter as a good selection criterion for achene yield improvement in sunflower (Chambó *et al.*, 2017; Rigon *et al.*, 2014; Zia-Ullah *et al.*, 2013; Yasin and Singh, 2010; Singh and Chander, 2018). Positive association of plant height determines more plant height with more number of leaves giving higher carbon fixation and accumulation of more dry matter. Also, there is an increase in stem diameter, head diameter, 100 seed weight which are responsible for higher yield (Nirmala *et al.*, 1999; Singh and Chander, 2018). Oil contents in sunflower genotypes mainly depend on genetic potential and environmental conditions. Early maturing or harvesting, the achene weight and other traits may have a negative impact on oil contents and achene yield (Hladni *et al.*, 2008; Miklič *et al.*, 2012). Increase in head diameter that produces more number of flowers attract pollinators and ultimately increase of achene per head lead to higher yield in sunflower.

Path analysis suggested head diameter is consistent selection criteria for increasing achene yield in sunflower. A strong direct positive effect of head diameter has also been reported by various other authors (Yasin and Singh, 2010; Jocković *et al.*, 2015; Ghias *et al.*, 2018). The maximum positive direct effect of head diameter and high positive correlation with achene yield (Figure 2) suggested that breeding on this trait can be useful for achene yield improvement in sunflower.

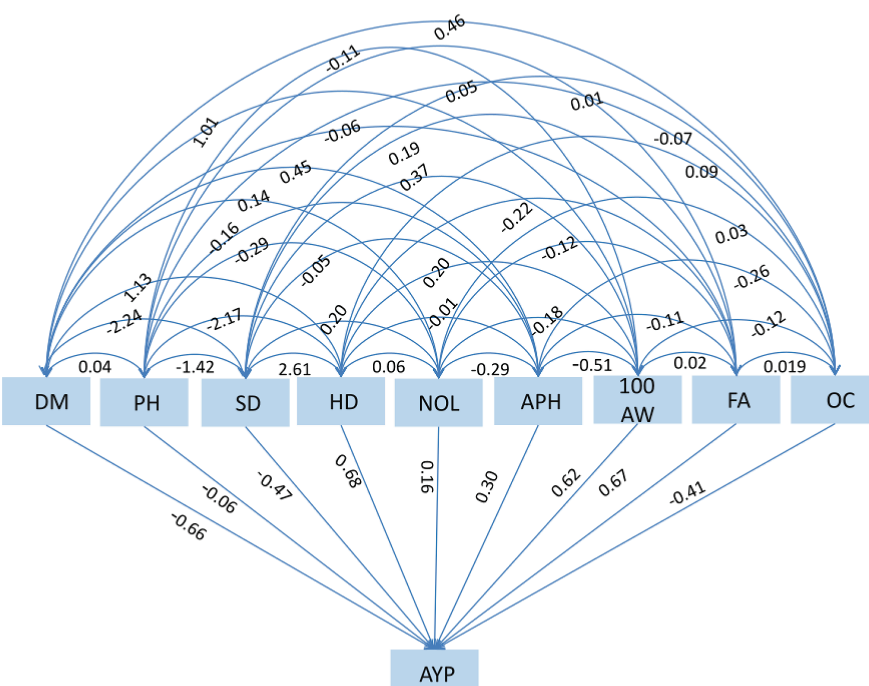

Figure 2: Genotypic path diagram showing the relationship of various traits on achene yield/plant of sunflower.
AYP = Achene yield/plant, DM = Days to maturity, PH = Plant height, SD = Stem diameter, HD = Head diameter, NOL = Number of leaves, APH = Achene/head, 100AW = 100-achene weight, FA = achene filling percentage OC = Oil contents.

Conclusions

The studied breeding material had enough genetic variability for all the traits. Genetic correlations and path analysis indicated that head diameter, stem diameter, achene/head, 100 achene weight and the number of leaves showed more positive influences over achene yield and can be used in the selection for better achene yield. Head diameter, achene filling percentage, 100-achene weight, achene per head and the number of leaves had shown the strongest direct positive effects on achene yield. Positive direct influences of these traits were associated with significant and positive correlations with achene yield. It can be concluded that these traits can be useful as selection criteria for achieving improved achene yield of sunflower.

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