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Path Analysis of the Coefficients of Sunflower (*Helianthus annuus* L.) Hybrids

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ABSTRACT

Correlation and path analysis were studied for yield, yield components and some morphological traits in nine sunflower hybrids i.e. Gulshan (check- 1), Peshawar- 93 (check- 2), Ts- 1 x Tr- 14 (tall), Ts- 7 x Tr- 14 (tall), Ts- 7 x Tr- 14 (medium), Ts- 7 x Tr- 14 (dwarf), Ts- 7 x Tr- 857 (medium), Ts- 7 x Tr- 857 (dwarf) and Ts- 11 x Tr- 857 (dwarf), at Agriculture Research Institute Tarnab. The grain yield was positively ($p < 0.01$) correlated with plant height, head diameter and oil content both at genotypic and phenotypic levels. Seeds head^{-1} showed significant and positive association with grain yield at both genotypic and phenotypic levels. Plant population m^{-2} showed significant positive relationship at genotypic level. The plant population m^{-2}, days to maturity, plant height, head diameter, seeds head^{-1}, 1000 -seed weight and oil content showed positive direct effect on grain yield. However, leaves plant^{-1} and days to flowering had negative direct effects on grain yield. The most prominent characters that affected the grain yield in sunflower were head diameter, seeds head^{-1} and 1000 -seed weight, which may be directly considered in sunflower improvement programs.

Key Words: *Helianthus annuus* L.; Correlation; Path analysis; Yield; Yield components

INTRODUCTION

Path-coefficient analysis is simply a standardised partial regression coefficient and as such measures the direct and indirect effect for one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effect (Dewey & Lu, 1959). Using path-coefficient analysis, it is easy to determine, which yield component is influencing the yield substantially. Having this information, selection can then be based on that criterion thus making great progress possible through selection in limited time. The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components-one component being the path coefficient (or standardized regression partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable through other predictor variables (Dewey & Lu, 1959). In agriculture, path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey & Lu, 1959; Duarte & Adams, 1972; Sidwell *et al*., 1976; Puri *et al*., 1982; Kang *et al*., 1983; Milligan *et al*., 1990).

Sunflower, despite its superiority in all aspects among oilseeds, has not attained its target productivity. This may be due to the inadequacy of hybrids, lack of varieties with high yield potential, improper seed filling, or lack of self fertile lines. Sunflower (*Helianthus annuus* L.), a non-traditional oil seed crop in Pakistan, belongs to family Compositae (Weiss, 1983). In Pakistan, average yield of sunflower is 1810 kg (ha^{-1}), which is very low as compared to the yield in other agriculturally advanced countries. The major constraints in increasing yield of sunflower and other non-traditional oilseed crops in Pakistan are: non-availability of hybrid seeds, drying facilities, modern production technology, and short duration varieties. In addition, high cost of foreign imported hybrid seed and storage, limited use of marginal lands, lack of rhizobium inoculum, low prices of farmer produce and high harvesting cost are factors hindering the farmers to adopt non-conventional oilseed crops. To alleviate these problems, to increase yield unit area^{-1} and to construct better hybrids, research on breeding high yielding cultivars is essential. Yield components are critical for over all yield improvement because they contribute towards yield. Therefore, before improving the yield components, it must be ascertained that, which of the postulated components have positive and significant relationship with grain yield. To separate correlation coefficients into components of direct and indirect effects, the path-coefficient analysis provides an excellent tool as it can measure the direct and indirect effects of interrelated components of a complex trait like yield (Alba *et al*., 1982; Chaudhary, 1993; Punia & Gill, 1994).

The objective of the study was to obtain and interpret information on the nature of interrelationships between sunflower grain yield and yield-related traits that have been organized as predictor variables such as head diameter, seeds head^{-1}, 1000-seed weight and oil contents.

MATERIALS AND METHODS

Nine sunflower (*Helianthus annuus* L.) hybrids, Gulshan (check- 1), Peshawar- 93 (check- 2), Ts- 1 x Tr- 14 (tall), Ts- 7 x Tr- 14 (tall), Ts- 7 x Tr- 14 (medium), Ts- 7 x Tr- 14 (dwarf), Ts- 7 x Tr- 857 (medium), Ts- 7 x Tr- 857 (dwarf) and Ts- 11 x Tr- 857(dwarf), were field evaluated at NWFP Agricultural University Peshawar. These hybrids were planted in a randomized complete block design (RCBD) with four replications in the field (5 x 30 m^2), excluding border area. Each replication was further subdivided into nine subplots of equal dimensions (5 x 6.75 m^2), excluding borders for nine hybrids. Each subplot was again divided into four rows for each hybrid. A path of one meter was kept between replications to facilitate moving about for recording the observations and also to keep each block distinct from its immediate neighbour. Rows were 0.75 m apart with plant-to-plant distance of 0.25 m with in rows.

Standard agronomic practices were followed from time to time during the growing season of the crop. Nitrogen in the form of urea and P_2O_5 in the form of triple super phosphate (TSP) were applied at the rate of 100 and 60 kg ha^{-1}, respectively. Half of the nitrogen was applied at the time of seedbed preparation, while the other half with first irrigation.

Data were recorded on plant population m^{-2}, days to 50% flowering, days to physiological maturity, number of leaves $plant^{-1}$, plant height (cm), head diameter (cm), number of grains $head^{-1}$, 1000 grain weight (g), oil content and grain yield $plant^{-1}$ (g).

The data were statistically analysed using MStat-C. Least significant difference (LSD) test was used for mean separation among genotypes. Genotypic and phenotypic variances and covariance were computed out for all possible combinations of characters (Singh & Chaudary, 1977).

Genotypic correlations were computed from genotypic variances and covariance, Phenotypic correlations by using phenotypic variances and covariance and environmental correlations by using environmental variances and covariance. The genotypic and phenotypic correlations so computed were tested for significance (Gomes & Gomes, 1984). The path coefficient analysis was carried out for genotypic correlations (Dewey & Lu, 1959).

RESULTS AND DISCUSSION

Correlations. Significant and positive correlations at genotypic, phenotypic and environmental levels were recorded for head diameter with seeds $head^{-1}$, oil content and grain yield $plant^{-1}$, plant height with oil content and grain yield $plant^{-1}$, days to maturity with plant height and oil content, days to flowering with days to maturity and plant height, and amongst leaves $plant^{-1}$ and head diameter and seeds $head^{-1}$ and grain yield $plant^{-1}$(Table I).

At genotypic and phenotypic levels, the relationship of plant population m^{-2} with oil content was positive and highly significant. However, the relationship of the same component with yield was significant. The rest of correlations were positive but non-significant. Correlation between plant population m^{-2}, plant height, head diameter, seeds $head^{-1}$, oil content and grain yield $plant^{-1}$ was also positive and significant (Table I). Such results have also been reported by Benjamin *et al*. (1982), Sheriff *et al*. (1983), Rana *et al*. (1991), Badwal *et al*. (1993) and Pathak *et al*. (1983).

Relationship of leaves $plant^{-1}$, days to flowering, days to maturity, 1000-seed weight, with grain yield $plant^{-1}$ was positive but non significant. These results are in agreement with the work of Sheriff *et al*. (1983), Rao (1987) and Zhang *et al*. (1992). Only at environmental level, the relationship of leaves $plant^{-1}$ with days to flowering, days to maturity, plant height, oil content, days to flowering with head diameter, seeds $head^{-1}$, grain yield $plant^{-1}$, days to maturity with head diameter, seeds $head^{-1}$, days to maturity, plant height with head diameter, seeds $head^{-1}$ and seeds $head^{-1}$ and oil content was positive and significant (Table I). The rest of the correlations were either negative or non-significant.

Path analysis. The estimates of direct and indirect effects are presented in Table II.

Plant population m^{-2} vs. grain yield $plant^{-1}$. Plant population m^{-2} has positive direct effect on grain yield $plant^{-1}$, while it has a positive indirect effect on grain yield $plant^{-1}$ via days to maturity, plant height, head diameter, seeds $head^{-1}$, 1000-seed weight and oil content while negative indirect effect via leaves $plant^{-1}$ and days to flowering. The components of variance and broad sense heritability estimates show that the variance observed for plant population m^{-2} is genetic in nature because the environmental components are lower than the genetic components and the character is considered highly heritable.

Correlation between plant population m^{-2} and grain yield $plant^{-1}$ was positive and significant. Furthermore, this trait also showed positive direct effect on grain yield $plant^{-1}$. As the direct effect of this character is positive and the genotypic correlation between these two characters is also positive thus indicating true relationship and signifies the direct selection of this character in breeding programme.

Leaves $plant^{-1}$ vs. grain yield $plant^{-1}$. Leaves $plant^{-1}$ showed negative direct effect on grain yield $plant^{-1}$, while positive indirect effect via plant population m^{-2}, days to flowering, head diameter, seeds $head^{-1}$ and 1000-seed weight and negative indirect effect through days to maturity, plant height and oil content. Our results indicate that environmental variance for leaves $plant^{-1}$ are higher than heritability indicating a large influence of environment on this trait.

Relationship of leaves $plant^{-1}$ with grain yield $plant^{-1}$ was positive but non significant. These results tally the work of Sheriff *et al*. (1983). So far, the path analysis of this character is concerned; the results indicate that it has negative direct effect upon grain yield. As the direct effect is negative and correlation coefficient between leaves $plant^{-1}$ and grain yield $plant^{-1}$ is positive, showing that some indirect effects seems to be the cause of correlation. In this situation, one should consider all the indirect causal factors, which effects grain yield positively during selection. Such views have also been proposed by Rao (1987).

Days to flowering vs. grain yield $plant^{-1}$. Days to flowering had negative direct effect on grain yield $plant^{-1}$. It has positive indirect effect through plant population m^{-2}, leaves $plant^{-1}$, days

Table I. Correlation coefficients among ten characters of Sunflower hybrids during 1998 at A.R.I Tarnab

Characters		Leaves plant^{-1}	Days to flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seeds head^{-1}	1000-Seed weight (gm)	Oil content (%)	Yield plant^{-1} (g)
Plant population m^{-2}	G	0.300	0.251	0.209	0.302	0.106	0.037	0.262	0.515**	0.415*
	Prof. Shafiq Ahmad	0.200	0.300	0.273	0.283	0.017	0.038	0.162	0.415**	0.328
	E	-0.030	0.944**	0.818**	0.185	-0.769**	0.051	-0.322	-0.062	-0.833**
Leaves plant^{-1}	G		-0.363*	-0.498**	-0.426**	0.584**	0.524**	0.396*	-0.060	0.240
	Prof. Shafiq Ahmad		-0.219	-0.293	-0.267	0.582**	0.540**	0.140	0.059	0.257
	E		0.728**	0.762**	0.850**	0.657**	0.758**	-0.740**	0.485**	0.835**
Days to flowering	G			0.995**	0.690**	0.020	-0.003	-0.737**	0.369*	0.107
	Prof. Shafiq Ahmad			0.974**	0.689**	0.053	0.034	-0.723**	0.352*	0.124
	E			0.666**	0.679**	0.708**	0.649**	-0.782**	0.269	0.791**
Days to maturity	G				0.704**	-0.111	-0.095	-0.717**	0.313	0.048
	Prof. Shafiq Ahmad				0.701**	-0.057	-0.036	-0.700**	0.311	0.072
	E				0.689**	0.741**	0.672**	-0.633**	0.324	0.796**
Plant height	G					0.045	-0.081	-0.204	0.403*	0.461**
	Prof. Shafiq Ahmad					0.077	-0.037	-0.237	0.389*	0.469**
	E					0.762**	0.744**	-0.721**	0.367*	0.828**
Head diameter	G						0.586**	-0.082	0.594**	0.632**
	Prof. Shafiq Ahmad						0.604**	-0.154	0.578**	0.633**
	E						0.858**	-0.365*	0.521**	0.793**
Seeds head^{-1}	G							-0.115	0.178	0.379*
	Prof. Shafiq Ahmad							-0.184	0.221	0.390*
	E							-0.709**	0.556**	0.816**
1000-Seed weight	G								-0.112	0.234
	Prof. Shafiq Ahmad								-0.166	0.175
	E								-0.442**	-0.716**
Oil content	G									0.757**
	Prof. Shafiq Ahmad									0.700**
	E									0.250

* Significant at 5% level, ** Significant at 1% level, G Genotypic correlation, P Phenotypic correlation, E Environmental correlation

Table II. Total Direct and Indirect Effects of Yield and Yield components on Grain yield of Sunflower Hybrids during Kharif 1998 at A.R.I. Tarnab

Characters	Plant population m^2	Leaves plant^{-1}	Days to flowering	Days to maturity	Plant height (cm)	Head diameter(cm)	Seeds head^{-1}	1000-Seed weight (gm)	Oil content (%)	Total
Plant population m^2	0.05522	-0.12336	-0.05641	0.14382	0.01165	0.08049	0.01052	0.21732	0.07574	0.415
Leaves plant^{-1}	0.01657	-0.41120	0.08158	-0.34269	-0.01644	0.44349	0.14905	0.32847	-0.00882	0.240
Days to flowering	0.01386	0.14927	-0.22473	0.68469	0.02662	0.01519	-0.00085	-0.61131	0.05427	0.107
Days to maturity	0.01154	0.20478	-0.22361	0.68814	0.02716	-0.08429	-0.02702	-0.59472	0.04603	0.048
Plant height	0.01668	0.17517	-0.15506	0.48445	0.03858	0.03417	-0.02304	-0.16921	0.05927	0.461
Head diameter	0.00585	-0.24014	-0.00449	-0.07638	0.00174	0.75940	0.16669	-0.06802	0.08735	0.632
Seeds head^{-1}	0.00204	-0.21547	0.00067	-0.06537	-0.00312	0.44501	0.28445	-0.09539	0.02618	0.379
1000-Seed weight	0.01447	-0.16284	0.16562	-0.49339	-0.00787	-0.06227	-0.03271	0.82946	-0.01647	0.234
Oil content	0.02844	0.02467	-0.08293	0.21539	0.01555	0.45108	0.05063	-0.09289	0.14706	0.757

Diagonal values shows direct effect

to maturity, plant height, head diameter and oil content, while negative indirect effect via seeds head^{-1} and 1000-seed weight. In the present study, the broad sense heritability for days to flowering is higher than environmental variance showing that this trait is more dependable for improvement through selection.

Days to flowering had positive but non-significant correlation with grain yield plant^{-1}. Quite identical results were obtained by Oka and Campos (1974). In the present study, days to flowering shows negative direct effect upon grain yield plant^{-1}, while correlation coefficient is positive, showing that some indirect effects seems to be the cause of correlation. In such a case indirect factors, which effect grain yield positively should be given consideration?

Days to physiological maturity vs. grain yield plant^{-1}. Days to maturity has positive direct effect on grain yield plant^{-1}, while positive indirect effect via plant population m^{-2}, leaves plant^{-1}, plant height and oil content and negative indirect effect through days to flowering, head diameter, seeds head^{-1} and 1000-seed weight. The results of the present study indicate that broad sense heritability for days to maturity is greater than environmental variance and this trait is not largely influenced by environment and is genetic in nature.

The genotypic correlation between days to maturity and grain yield plant^{-1} was positive but non-significant. The results confirm the work of Singh *et al*. (1977), while deviate from those of Naeem and Farhatullah (1986), Rao (1987), Muhammad *et al*. (1992) and Ashok *et al*. (2000). The difference may be due to variations in experimental material and environmental factors specially soil texture. The direct effect as well as the genotypic correlation is positive, therefore direct selection of this trait is recommended in the hybrid improvement programme in sunflower.

Plant height vs. grain yield plant^{-1}. Plant height has positive direct effect on grain yield lant^{-1}, while positive indirect effect via plant population m^{-2}, leaves plant^{-1}, days to maturity, head diameter and oil content, while negative indirect effect through days to flowering, seeds head^{-1} and 1000-seed weight. The results show that plant height is largely influenced by environmental factor as the broad sense heritability is lower than the environmental variance.

Plant height had highly significant correlation with grain yield plant^{-1}. This observation is supported by the results obtained by Fick *et al*. (1974), Pathak *et al*. (1983), Yusuf *et al*. (1985) Chaudhary and Anand (1993), Punia and Gill (1994) and Ashok *et al*. (2000). Data regarding path coefficient analysis revealed that plant height produced positive direct effect on grain yield plant^{-1}. The genotypic between the two characters is also positive thus indicating true association among these traits.

Head diameter vs. grain yield plant^{-1}. Head diameter has high positive direct effect on grain yield plant^{-1}, while positive indirect effects via plant population m^{-2}, plant height, seeds head^{-1} and oil content and negative indirect effect through leaves plant^{-1}, days to flowering, days to maturity, and 1000-seed weight. Our results indicated that the value of broad-sense heritability for head diameter was higher than environmental variance showing that this trait is more dependable for improvement through selection.

Correlation between head diameter and grain yield plant^{-1} was positive and highly significant. The result is in agreement with those reported by Sheriff *et al*. (1983), Yusuf *et al*. (1985), Badwal *et al*. (1993), Chaudhary and Anand (1993) and Punia and Gill (1994). It is also evident from the data that this character showed positive direct effect on grain yield plan^{-1}t. Similar results were reported by Visic (1991), Punia and Gill (1994) and Ashok *et al*. (2000). As in the present study the direct effect of this character on grain yield per plant is positive and the genotypic correlation between these two characters is also positive thus indicating true relationship and signifies direct selection of this character in breeding programme.

Seeds head^{-1} vs. grain yield plant^{-1}. Seeds head^{-1} has positive direct effect on grain yield plant^{-1} and positive indirect effect through plant population m^{-2}, days to flowering, head diameter and oil content, while negative indirect effects via leaves plant^{-1}, days to maturity, plant height and 1000-seed weight. The components of variance estimates showed that environmental component for number of seeds head^{-1} was high than broad sense heritability and is therefore largely influenced by environment.

Number of seeds head^{-1} showed positive and significant correlation with grain yield plant^{-1}. This observation is supported by the results obtained by Kotecha (1980), Beard and Geng (1982), Pathak *et al*. (1983), Sheriff *et al*. (1983) and Punia and Gill (1994). The direct effect of number of seeds head^{-1} is positive, which is in agreement with the results obtained by Alvarez *et al*. (1992) and Punia and Gill (1994). As the correlation coefficient is positive and the direct effect is also positive thus showing true relationship with grain yield plant^{-1} and direct selection is effective in the present situation.

1000-Seed weight vs. grain yield plant^{-1}. The direct effect of 1000-seed weight on grain yield is positive, while it also shows positive indirect effect through plant population m^{-2} and days to flowering and negative indirect effect through leaves plant^{-1}, days to maturity, plant height, head diameter, seeds head^{-1} and oil content. The result showed that the value of environmental variance is greater than heritability showing that 1000-seed weight is more affected by environment.

Correlation between 1000-seed weight and grain yield plant^{-1} is positive but non-significant. Such results were also obtained by Shabana (1974) and Rao (1987). The direct effect of 1000-seed weight was positive and high. The result is in conformity with results obtained by Alba *et al*. (1982), Sadaqat and Khalid (1987) and Punia and Gill (1984). As the direct effect as well as genotypic correlation is positive therefore, this character shows direct association with grain yield and needs due consideration during selection procedures.

Oil content vs. grain yield plant^{-1}. The direct effect of oil content on grain yield plant^{-1} is positive, while it showed positive indirect effect via plant population m^{-2}, leaves plant^{-1}, days to maturity, plant height, head diameter and seeds head^{-1}, while negative indirect effect through days to flowering and 1000-seed weight. The value of broad sense heritability for oil content was higher than environmental variance showing that this trait is more dependable for improvement through selection.

Oil content had highly significant positive correlation with grain yield plant^{-1}. The results are in agreement with those reported by Fick *et al*. (1974), Beard and Geng (1982), Rao (1987) and Chaudhary and Anand (1993). The direct effect of oil content was positive. The result was in agreement with the work of Sadaqat and Khalid (1987), while Alba *et al*. (1982) and Rao (1987) found negative direct effect of oil content on grain yield. As the direct effect as well as the genotypic correlation is positive the correlation explains true relationship with grain yield and a direct selection through this trait will be effective.

Grain yield plant^{-1}. Grain yield is directly and positively affected by plant population m^{-2}, days to maturity, plant height, head diameter, seeds head^{-1}, 1000-seed weight and oil content, while negatively indirectly affected by leaves plant and days to flowering.

Direct effects. Plant population m^{-2}, plant height, head diameter, seeds head^{-1}, 1000-seed weight and oil content showed positive direct effect on grain yield plant^{-1}, while leaves plant^{-1}, days to flowering, leaves plant^{-1} and days to flowering had negative direct effect upon grain yield. In the present study days to flowering and leaves plant^{-1} show negative direct effect upon grain yield plant^{-1} and the correlation coefficient between days to flowering and leaves plant^{-1} with grain yield plant^{-1} is positive, showing that some indirect effects seem to be the cause of correlation. In such a case indirect factors, which affect grain yield positively, should be given consideration.

The most important direct positive contribution to the yield development was made by capitulum's diameter in the present and earlier projects (Visic, 1991; Punia & Gill, 1994). Similarly the direct effect as well as positive genotypic correlation of 1000 grain weight with grain yield and needs due consideration during selection procedures. In general due considerations may be given in selection to all the indirect causal factors, which effect grain yield positively. Such views have also been proposed by Rao (1987).

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