

A PATH COEFFICIENT ANALYSIS OF SOME YIELD COMPONENTS IN SUNFLOWER

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INTRODUCTION

The amount of information contained in any correlation coefficient sometimes gives inadequate results, especially when the breeder applies an indirect selection upon yield (e.g. selection on head diameter to improve yield) disregarding the indirect effects of the character under selection upon the other traits, whose breeding values are somehow associated with that of the selected character.

Therefore a successful breeding programme relies on a good knowledge about all the influences of the main bio-morphological characters on yield; such a goal may be attained using path coefficient analysis, namely a standardized partial regression analysis which permits to partition the influence of the causal factors into direct and indirect effects, thus indicating the real association among the investigated traits.

The method, developed by Wright (1921, 1923) further discussed by Li (1956) and Wright (1960) has been widely employed by breeders (Dewey & Lu, 1959; Liang & Riedl, 1964; Porceddu, 1966; Bhatt, 1973).

Nevertheless many studies have been conducted in sunflower to investigate correlations between oil yield components and other characters (Skorič, 1974; Kloczowski, 1974; McWilliam & English, 1978) but little research has been done with the use of path analysis (Alba & Greco, 1979).

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This study attempts to contribute in defining the influence of the main bio-morphological characters upon oil yield on a sample of 17 cultivars of sunflower.

MATERIALS AND METHODS

The experiments consisted of 2 field trials with 17 cultivars (16 hybrids + 1 open pollinated variety) and were conducted as part of the F.A.O. Research Network on Sunflower.

Plants were grown during 1978 in 2 localities (Bari and Pisa) under normal agronomic conditions; the experimental design utilized was a randomized block with four replications in each location.

Plots were 8.7 m × 3.6 m (6 rows of 29 plants) with plants spaced 30 cm within each row. Each plot value is based upon the mean of 100 plants of the 4 central rows.

The characters investigated in this study were: days to flowering (d), plant height (cm), head diameter (cm), seed yield (q/ha), 1,000-seed weight (g), oil content of the seed (%), oil yield (q/ha).

Varietal (r_v) and environmental (r_e) correlation coefficients were computed on all combinations of the 7 characters, according to the formulae:

$$r_v = \frac{\text{Cov}_{(v)1, j}}{\sqrt{V_{(v)1} \times V_{(v)j}}} \quad r_e = \frac{\text{Cov}_{(e)1, j}}{\sqrt{V_{(e)1} \times V_{(e)j}}}$$

where $\text{Cov}_{(v)}$, $V_{(v)1}$, $V_{(v)j}$ are the covariance and mean square of the varieties and $\text{Cov}_{(e)}$, $V_{(e)1}$, $V_{(e)j}$ are the covariance and mean square of the error.

Path coefficients were computed with the solution of simultaneous equations through the method of least squares as shown by Dewey & Lu (1959).

RESULTS AND DISCUSSION

ANALYSIS OF THE CORRELATIONS

Table 1 reports the varietal (r_v) and environmental (r_e) correlations for all possible combinations among the investigated traits;

of August are generally severe. This is probably the cause of the contrast between our results and those obtained by other researchers operating in different environmental conditions.

Rather interesting was the positive association ($r_v = 0.555$) between seed yield and oil

Table 1

Varietal (r_v) and environmental (r_e) correlations among oil yield and six characters in sunflower.

Character	Plant height (cm)	Head diameter (cm)	Seed yield (q/ha)	1 000 seed weight (g)	Oil content (%)	Oil yield (q/ha)
Days to flowering <i>Days to flowering</i>	r_v 0.660 **	-0.288	-0.173	-0.656 **	0.379	-0.026
	r_e -0.011	0.018	-0.080	-0.063	0.216 *	-0.027
Plant height	r_v	-0.242	-0.410	-0.228	-0.041	-0.340
	r_e	-0.203 *	-0.055	-0.028	-0.051	-0.059
Head diameter	r_v		-0.189	0.169	-0.363	-0.257
	r_e		0.361 **	-0.065	0.039	0.317 **
Seed yield	r_v			0.014	0.555 *	0.954 **
	r_e			0.107	0.060	0.951 **
1,000 seed weight	r_v				-0.169	-0.013
	r_e				-0.150	0.056
Oil content	r_v					0.774 **
	r_e					0.344 **

*, ** significant at the 5% and 1% point respectively.

in this study only r_v has been utilized for the computation of path coefficients. In fact estimates of genetic correlations are subject to large sampling errors and result therefore seldom very precise (Falconer, 1964).

The characters most strongly associated with oil yield were, as expected, seed yield ($r_v = 0.954$) and oil content ($r_v = 0.774$), whereas the remaining traits were not correlated significantly with oil yield. These findings were obtained in the separate analysis of the locations, confirming the validity of a pooled analysis.

A significant positive association ($r_v = 0.660$) was exhibited by days to flowering with plant height; the former trait showed also a significant negative correlation ($r_v = 0.656$) with 1,000-seed weight.

The reason probably should be sought in the presence of stressing environmental conditions during the grain filling period, thus limiting in the late genotypes the synthesis and accumulation of a regular amount of reserve products in each seed. In fact weather conditions during the last part of July and the beginning

content, while none of the remaining characters, excluding oil yield, showed a significant association with oil content in the seed.

PATH ANALYSIS

Each path analysis involves the assumption, based upon *a priori* evidence, of a precise cause-effect situation between the variables. The model presented in Figure 1 was a direct consequence of the fact that oil yield originated from the product between seed yield and oil content, whereas the remaining characters influenced oil yield through seed yield and oil content. This assumption did not imply the quantification of a simultaneous action of the causal variables upon oil yield via seed yield and oil content; in fact the mathematical solution of such a model with path-coefficients was not possible.

In the path diagram, single-arrowed lines indicate unilateral direct effect as expressed by path coefficients, while double-arrowed lines denote mutual association among the causal variables.

Considering the direct action of seed yield ($P = 0.758$) and oil content ($P = 0.353$) on oil

- (1) - Days to flowering
- (2) - Plant height
- (3) - Head diameter
- (4) - 1000-seed weight
- (5) - Seed yield
- (6) - Oil content
- (7) - Oil yield

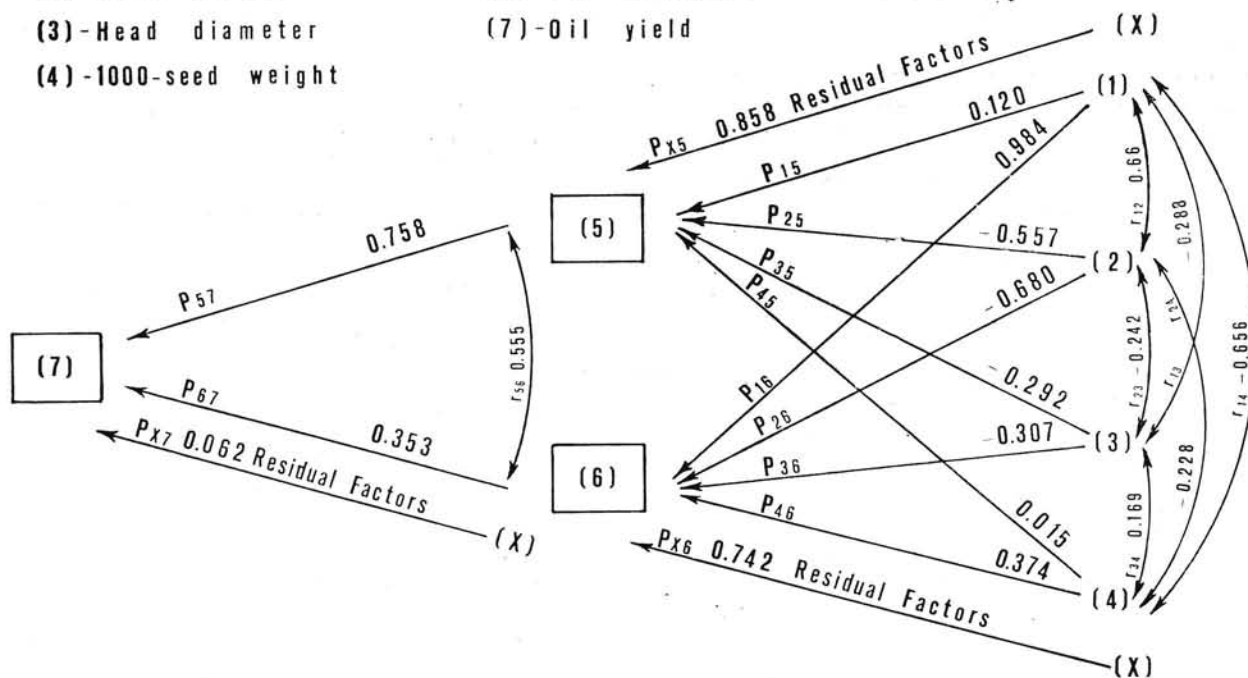


Fig. 1 — Path diagram and coefficients of characters influencing oil yield components (average of two locations)

yield, it is worth noting the stronger influence of the former, thus indicating a major validity for a selection based upon seed yield. Table 2 reports direct and indirect influences of the two yield components upon oil yield: oil content had a sizeable positive indirect effect due to the large positive association ($r_v = 0.555$) with seed yield.

Table 2

Path coefficient analysis of the direct and indirect effect of seed yield and oil content upon oil yield in sunflower

Varietal correlations with oil yield	Direct effects	Effects through the characters	
		indirect effects via	
		seed yield	oil content
Seed yield (0.954 **)	0.758	1	0.196
Oil content (0.774 **)	0.353	0.421	1

*, ** significant at the 5% and 1% point respectively.

Tables 3 and 4 show direct and indirect action of 4 main bio-morphological factors upon yield components.

Regarding seed yield as the effect of the causal variables, a rather similar picture was given by path values and correlation coefficients. Plant height was exposed as the trait

Table 3

Path coefficient analysis of the direct and indirect effect of four characters upon seed yield in sunflower

Varietal correlations with seed yield	Direct effects	Effects through the characters			
		indirect effects via			
		days to flowering	plant height	head diameter	1,000 seed weight
Days to flowering (-0.173)	0.120	1	-0.368	0.084	-0.010
Plant height (-0.410)	-0.557	0.079	1	0.071	-0.003
Head diameter (-0.189)	-0.292	-0.035	0.135	1	0.003
1 000 seed weight (0.014)	0.015	-0.079	0.127	-0.049	1

mainly influencing yield negatively ($P = -0.557$), followed by head diameter ($P = -0.292$); indirect influences in both cases were low and negligible. The negative correlation ($r_v = -0.173$) days to flowering-seed yield was determined by a mild positive direct effect ($P = 0.120$) and a valuable indirect action (-0.368) via plant height.

Oil content resulted affected by all characters both directly and indirectly. The most

Table 4

Path coefficient analysis of the direct and indirect influence of four characters upon oil content in sunflower

Varietal correlations with oil content	Direct effects	Effects through the characters			
		indirect effects via			
		days to flowering	plant height	head diameter	1 000 seed weight
Days to flowering (0.379)	0.984	1	-0.449	0.088	-0.245
Plant height (-0.041)	-0.680	0.649	1	0.074	-0.085
Head diameter (-0.363)	-0.307	-0.283	0.165	1	0.063
1 000 seed weight (-0.169)	0.374	-0.646	0.155	-0.052	1

relevant direct influence ($P = 0.984$) was due to days to flowering, followed by plant height ($P = -0.680$), 1,000-seed weight ($P = 0.374$) and head diameter ($P = -0.307$). Such values, with the exception of the one referred to head diameter, did not agree with correlation values, because of strong indirect influences opposing and counterbalancing the direct effect.

The negative values obtained for path and correlation values between head diameter and seed or oil yield would probably be explained by the influence of other characters, such as percentage of empty seeds and sterile portion of the head, not taken into account. It results obviously that unfavourable environmental conditions during flowering and grain filling period, could cause, respectively, a large sterile area in the head and a great amount of aborted, or partially filled achenes.

It is then advisable to include these characters among the investigated traits, especially when foreign genotypes are tested under unfavourable conditions.

Moreover the high influence of residual factors ($P_x 5 = 0.858$; $P_x 6 = 0.742$), could be accounted for by the presence of such unsurveyed factors, besides experimental errors.

CONCLUSIONS

A path coefficient analysis was performed in sunflower to study the cause-effect relationship upon the oil yield components (seed yield and oil content) of 4 bio-morphological characters: days to flowering, plant height, head diameter, 1,000-seed weight.

Data refer to an analysis of 17 cultivars examined in two F.A.O. trials carried out in two

regions of the central and southern part of Italy, in 1978.

Seed yield strongly influenced oil yield, while oil content showed a milder action. The last two traits were negatively affected by plant height and head diameter, while days to flowering exerted a strong direct effect upon oil content.

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L'ANALYSE DU «PATH COEFFICIENT» DE QUELQUES COMPOSANTS DU RENDEMENT CHEZ LE TOURNESOL

Résumé

Les données se rapportent à l'analyse de 16 hybrides et d'une variété, provenant du réseau international F.A.O., essayés en 1978 en deux localités différentes d'Italie. L'analyse du "path coefficient" a été effectuée pour étudier les relations cause - effet entre les composants du rendement en huile (rendement en grains et teneur en huile) et quatre caractères morphologiques: le nombre de jours jusqu'à la floraison, la hauteur des plantes, le diamètre des capitules et le poids de 1000 grains.

Le rendement en grains est le caractère qui exerce la plus forte influence sur la production d'huile, pendant que la teneur en huile manifeste une action plus faible sur celle-ci. Le rendement en huile et la teneur en huile des grains sont affectés négativement par la hauteur des plantes et le diamètre des capitules, tandis que le nombre de jours jusqu'à la floraison exerce un effet direct remarquable sur la teneur en huile.

ANALISIS DEL "PATH-COEFFICIENT"
DE UNOS COMPONENTES
DE LA PRODUCCION DE GIRASOL

Resúmen

Los datos se refieren al análisis de 16 híbridos y una variedad, de la Red Internacional F.A.O., experimentados en el año 1978 en dos localidades diferentes

de Italia. Se efectuó el análisis "path-coefficient" para el estudio de las relaciones causa-efecto entre los componentes de la producción de aceite (la producción de semillas y el contenido en aceite) y cuatro caracteres morfo-biológicos: el número de días hasta la floración, la altura de las plantas, el diámetro del capítulo y el peso de 1 000 granos.

La producción de semillas es el carácter que más acusadamente influye en la producción de aceite, mientras que el contenido de aceite manifiesta una acción más reducida sobre la misma. La producción de aceite y el contenido en aceite de las semillas están afectados negativamente por la altura de las plantas y el diámetro del capítulo, mientras el número de días hasta la floración ejerce un potente efecto directo sobre el contenido en aceite.