HELIA, **22**, Nr. 31, p.p. 35-42, (1999)　　UDC 633.854.78:631.524.84

PATH COEFFICIENT ANALYSIS OF SOME OIL YIELD COMPONENTS IN SUNFLOWER (*Helianthus annuus* L.)

Jovan Joksimović, Jovanka Atlagić and Dragan Škorić

Institute of Field and Vegetable Crops, M. Gorkog 30, 21000 Novi Sad, Yugoslavia

Received: April 05, 1999
Accepted: September 15, 1999

SUMMARY

Eight sunflower inbred lines and 15 F_1 hybrids (line x tester) have been analyzed for correlations between several yield components (oil yield, protein yield, kernel yield, grain yield, dry mass of the aboveground plant parts, leaf area and harvest index). The path coefficient analysis was employed to partition the direct and indirect effects of the studied characteristics on oil yield per plant. Highly significant positive correlations were found between oil yield on one side and all the characters under study on the other. Protein yield exhibited a highly significant positive direct effect on oil yield. Grain yield and kernel yield had positive direct effects on oil yield per plant, whereas the dry matter mass of the vegetative plant part, harvest index and leaf area had negative direct effects on oil yield.

Key words: **sunflower, inbred lines, hybrids, correlation coefficient, path coefficient analysis, oil yield**

INTRODUCTION

Oil yield per unit area is the ultimate target in growing high-oil sunflower genotypes. Oil yield is affected by numerous other plant characteristics, most important being plant number per unit area, number of grains per plant, hectoliter mass, 1000-grain mass, husk content, oil content in grain and grain yield. These characteristics are the final components of grain yield, i.e., oil yield. Grain yield, i.e., kernel yield play a decisive role in oil yield performance (Škorić, 1974; Djakov, 1986). In high-oil sunflower hybrids, there exists a close functional relationship (r=0.99) between oil yield and kernel yield.

Many authors have used the simple correlation analysis to study relationships between grain yield, i.e., oil yield on one side and the other characteristics of the sunflower plant on the other (Fick *et al.*, 1974; Škorić, 1974; Green, 1980, etc.). Since the simple correlation coefficients could not fully explain the relationships among characters, the path coefficient analysis has been introduced for a more successful breeding work. The path coefficient analysis, by partitioning direct and indirect effects, helped breeders determine the impact of independent variables on the dependent one. This statistical model has been extensively used by sunflower researchers (Alba *et al.*, 1979; Ivanov *et al.*, 1980; Lakshmanrao *et al.*, 1985; Marinković, 1992; Punia and Gill, 1994, etc.).

We studied mutual relationships between several yield components and physiological parameters on one side and oil yield on the other, as well as the direct and indirect effects of these components and parameters on oil yield.

MATERIAL AND METHOD

The experimental object were eight sunflower inbred lines of different genetic origins and 15 F_1 hybrids (line x tester). A two-year experiment with the F_1 hybrids and their parent lines was established after the system of random blocks in four replications at the experiment field of the Institute of Field and Vegetable Crops in Novi Sad. The seeding was done manually, with 70 cm distance between rows and 25-30 cm distance in the row. The basic sample for analyses comprised 40 plants (10 plants per replication). We analyzed the following characteristics:

1. Leaf area (cm^2/plant) at the stage of full flower (A=0.75 x petiole length x maximum petiole width);
2. Dry matter mass of the vegetative parts (g/plant) - determined by the conventional laboratory method, by drying samples to constant mass in a dryer at 105°C;
3. Grain yield (g/plant) - determined in laboratory after harvest, on 11% moisture basis;
4. Kernel yield (g/plant) - determined by the conventional laboratory method, from the ratio seed yield vs. kernel percentage in grain;
5. Oil yield (g/plant) - determined from the ratio grain yield vs. oil content in seed previously obtained by the method of nuclear-magnetic resonance;
6. Protein yield (g/plant) - determined from the ratio grain yield vs. protein content in seed previously obtained by the "Trebor" method;
7. Harvest index (%) - determined from the ratio grain yield vs. total biomass of the aboveground plant parts.

Mutual relationships of the examined characteristics and their direct and indirect effects on oil yield were analyzed by the path coefficient analysis, the method developed by Wright (1921) and applied by Dewey and Lu (1952). Significance of simple correlation coefficients was tested after the method of Snedecor (1959) (according to Hadživuković, 1991). Significance of direct effects was tested by the method of Ivanović (1984).

RESULTS AND DISCUSSION

Highly significant positive correlations were found between oil yield per plant and protein yield (0.991**), kernel yield (0.987**), grain yield (0.984**), dry matter mass of vegetative parts (0.824**), leaf area (0.770**) and harvest index (0.534**) (Table 1).

Table 1: Simple correlation coefficients of six components of oil yield per sunflower plant

Characteristic	Dry matter mass of veg. parts	Grain yield	Kernel yield	Protein yield	Harvest index	Oil yield
	X2	**X3**	**X4**	**X5**	**X6**	**Y**
Leaf area **X1**	0.809**	0.807**	0.807**	0.777**	0.196	0.770**
Dry matter mass of veg. parts **X2**		0.859**	0.855**	0.805**	0.023	0.824**
Grain yield **X3**			0.997**	0.986**	0.522*	0.984**
Kernel yield **X4**				0.987**	0.519*	0.987**
Protein yield **X5**					0.577**	0.991**
Harvest index **X6**						0.534**
Significance level (n=23-2) at 0.05=0.413, at 0.01=0.526						

Numerous authors had found significant negative correlations between the contents of oil and proteins in seed. Djakov (1986), however, proved experimentally the absence of antagonism between the processes of oil and protein synthesis in sunflower grains. This explains the high positive correlation between protein yield and oil yield obtained in this study. Negative correlations between the contents of oil and proteins in sunflower inbred lines of different origins (Spain, Argentina, Russia, local populations from eastern Serbia) were obtained in a study of Stanojević *et al.*, 1992. However, the authors also reported positive correlations found between several lines from Bulgaria and the domestic high-protein variety "Kolos". Jovanović (1995) found low positive correlations between the contents of oil and proteins in seed of sunflower lines in the S_6 generation. All this shows that success in establishing correlations between characteristics depends to a large measure on plant material used.

Oil content is highly dependent on the husk:kernel ratio (Morozov, 1947; Nikolić-Vig *et al.*, 1971). The highly significant positive correlations between kernel yield, grain yield and oil yield established in this study confirm the previous findings of Djakov (1986) who concluded that the yields of grains and kernels are decisive factors in oil yield formation. Kernel yield, grain yield and oil yield are the final yield components and they are mutually highly significantly positively correlated (Škorić, 1974; Marinković, 1992).

The highly significant positive effect of harvest index on oil yield established in this study supports the statement of Djakov (1982) that the breeding for increased harvest index remains the most effective method of breeding for high yield.

Highly significant positive correlations were found between all independent variables except between harvest index and grain yield (+0.522) and harvest index and kernel yield (+0.519); these two correlations were significantly positive. Harvest index and leaf area and harvest index and dry matter mass of vegetative parts were non-significantly positively correlated - +0.196 and +0.023, respectively (Table 1). Škorić and Marinković (1981) pointed out that the reduction in plant height brings a proportional decrease in the sunflower requirement for assimilates. These extra assimilates are used for grain forming, therefore, for yield increase.

Since the values of simple correlation coefficients did not provide clear connections between the examined characteristics on one side and oil yield on the other, we used the path coefficient analysis in order to establish the intensity of effects of the independent variables on the dependent one. The analysis helped us to partition direct from indirect effects of individual characteristics on oil yield per plant, i.e., it helped us identify those characteristics which could be used as selection criteria in sunflower breeding.

Table 2: Analysis of direct and indirect effects of six characters on oil yield per sunflower plant

Characteristic	Direct effect	Indirect effect *via*						Total
		Leaf area (cm^2)	Dry matter mass of veg. parts (g)	Grain yield (g)	Kernel yield (g)	Protein yield (g)	Harvest index (g)	
Leaf area (cm^2)	-0.090	1	-0.325	+0.424	+0.258	+0.561	-0.058	0.770
Dry matter mass of veg. parts (g)	-0.401	-0.073	1	+0.451	+0.274	+0.580	-0.007	0.824
Grain yield (g)	+0.526	-0.073	-0.344	1	+0.319	+0.711	-0.155	0.984
Kernel yield (g)	+0.320	-0.073	-0.434	+0.524	1	+0.712	-0.154	0.987
Protein yield (g)	+0.721	-0.074	-0.323	+0.518	+0.316	1	-0.171	0.991
Harvest index (%)	-0.297	-0.018	-0.009	+0.275	+0.166	+0.417	1	0.534

Residual effect = 0.101
Coefficient of determination = 0.990

When simple correlation coefficients were considered alone, it appeared that protein yield is solely responsible for oil yield forming in sunflower. When the relationship between the two characteristics was analyzed on the basis of direct and indirect effects, the importance of the direct effect of protein yield was further emphasized. The direct effect of protein yield was highly significantly positive (+0.721) (Table 2). No similar data could be found in the literature, but an explanation of Djakov (1986) implies that such a relationship is possible. Protein synthesis precedes oil synthesis, it is completed sooner and it is less prone to various stresses. Under favorable agroecological conditions, it is possible to realize high yields of both, oil and proteins. Alternatively, the highly significant positive effect of protein yield on oil yield may be due to the high indirect effects of grain yield and kernel yield, +0.518 and +0.316, respectively (Figure 1).

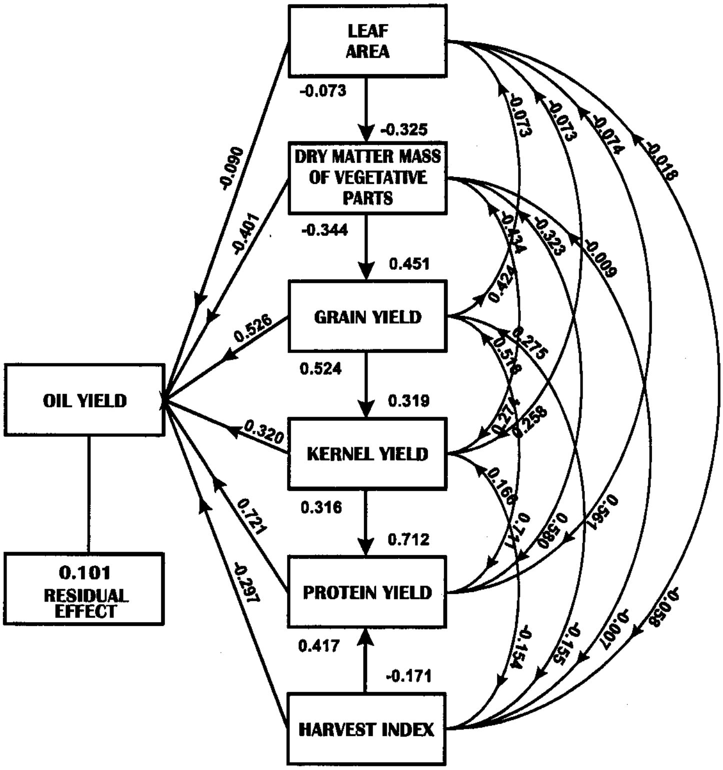

Figure 1: Path diagram of oil yield in sunflower

Grain yield and kernel yield also exhibited positive direct effects on oil yield per plant. The path coefficient analysis showed that the positive direct effect of grain yield on oil yield per plant (+0.526) was masked by the negative indirect effects of dry matter mass of vegetative parts, harvest index and leaf area, -0.344, -0.155 and -0.073, respectively. The total positive effect of grain yield is a result of the positive indirect effects of protein yield and kernel yield, +0.711 and +0.319, respectively (Figure 1).

By partitioning the simple correlation coefficient between kernel yield and oil yield into direct and indirect effects, it was concluded that its total positive effect was a result of the positive indirect effects of protein yield and grain yield, +0.712 and +0.524, respectively. The positive direct effect of kernel yield (+0.320) was masked by the negative indirect effects of dry matter mass of vegetative parts, harvest index and leaf area, -0.434, -0.154 and -0.073, respectively (Figure 1).

Negative direct effects on oil yield were exhibited by leaf area, dry matter mass of vegetative parts and harvest index, -0.090, -0.401 and -0.297, respectively (Table 2). The corresponding correlation coefficients (0.770**, 0.824** and 0.534**, respectively) were positive and highly significant (Table 1). The analysis of the calculated components showed that the negative direct effect of leaf area on oil yield was expressed through the negative indirect effects of dry matter mass of vegetative parts and harvest index, -0.325 and -0.058, respectively. The total positive effect of leaf area on oil yield per plant was a result of the positive indirect effects of protein yield, grain yield and kernel yield, +0.561, +0.424 and +0.258, respectively.

The highest indirect effects of leaf area, dry matter mass of vegetative parts, grain yield, kernel yield and harvest index, +0.561, +0.580, +0.711, +0.712 and +0.417, respectively, were realized *via* protein yield.

The coefficient of determination was 0.990. It means that 0.990 of the total variation, represented as 1, was due to the action of the independent variables. The residual factor in the path coefficient analysis, which amounted to 0.010, represents the unexplainable effects on the dependent variable and it may be due to error or other variables that were not the subject of this study.

CONCLUSION

Significant differences became evident when we compared the correlation coefficient values of six independent variables against the dependent one. Comparable differences were also found among the direct effects of the independent variables on the dependent one. Judging on the basis of the correlation coefficient values alone, it appeared that all six characteristics had highly significant effects on oil yield per plant. The path coefficient analysis, however, being a more precise method which takes into account the mutual relationships among the independent variables and partitions their direct and indirect effects on the dependent variable, showed that protein yield was the only characteristic that exhibited a highly significant direct effect on oil yield. Therefore, protein yield and oil yield, being positively correlated with all characteristics examined in this study, may be used as additional criteria for the assessment of sunflower breeding materials.

REFERENCES

Alba, E., A. Benvenuti, R. Tuberosa and G.P. Vannozzi, 1979. A path coefficient analysis of some yield components in sunflower. Helia, 2: 25-29.

Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal, 51: 515-518.

Djakov, A.B., 1982. The systems of investigation of interrelation of the components in the process of inheritance of productiveness (in Russian). Geterozis: 17-38, Minsk.

Djakov, A.B., 1986. Related variability of trait complex in the course of sunflower selection (in Russian). Selskohozjastvenaja biologija, 1: 77-83.

Fick, G.N., D.C. Zimmer and D.C. Zimmerman, 1974. Correlation of seed oil content in sunflower with other plant and seed characteristics. Crop Science, 14: 755-757.

Green, V.E., 1980. Correlation and path coefficient analysis of the components of yield in sunflower cultivars, *Helianthus annuus* L. Proc. of 9th Internat. Conf. of Sunflower, pp. 12-21, 8-13 June, Terremolinos-Malage, Espana.

Hadživuković, S., 1991. Statistički metodi. Poljoprivredni fakultet u Novom Sadu.

Ivanov, P. and Y. Stoyanova, 1980. Studies on the genotypic and phenotypic variability and some correlation in sunflower (*Helianthus annuus* L.). Proc. of the 9th Inter. Conf. of Sunflower, pp. 336-342, 8-13 June, Torremolinos-Malaga, Espana.

Ivanović, M., 1984. Primena metoda path coefficient analysis u genetičko-selekcionim istraživanjima. Arhiv za polj. nauke, 45(106): 471-478.

Jovanović, D., 1995. Variabilnost sadržaja proteina i nekih komponenti prinosa semena kod samooplodnih linija suncokreta. Magistarski rad, Poljoprivredni fakultet u Novom Sadu.

Lakshmanrao, N.G., K.G. Shaambulingappa and P. Kusumakumari, 1985. Studies on path-coefficient analysis in sunflower. Proc. of the 11th Inter. Sunfl. Conf., pp. 733-735, 10-13 March, Mar del plata, Argentina.

Marinković, R., 1992. Path-coefficient analysis of some yield components of sunflower. Euphytica, 60: 201-205.

Morozov, V.K., 1947. Selekcija podsolnečnika v SSSR (knjiga), Moskva.

Nikolić-Vig, V., D. Škorić and S. Bedov, 1971. Varijabilnost procenta ulja i ljuske u semenu suncokreta sortnih populacija Peredovika i VNIIMK-a 8931 i njihova heritabilnost. Savremena poljoprivreda, 19(3): 23-32.

Punia, M.S. and H.S. Gill, 1994. Correlations and path-coefficient analysis for seed yield traits in sunflower (*Helianthus annuus* L). Helia, 17(20): 7-12.

Stanojević D., S. Nedeljković and D. Jovanović, 1992. Oil and protin concetration in seed of diverse high-protein inbred lines of sunflower. Proc. of the 13th Inter. Sunfl. Conf., pp. 1263-1268, 7-11 September, Pisa, Italy.

Škorić, D., 1974. Correlation among the most important characters of sunflower in F_1 generation. Proc. of the 6th Inter. Sunfl. Conf., pp. 283-289, 22-24 July, Bucharest.

Škorić, D. and R. Marinković, 1981. Sunflower hybrid ideotype for pricipal sunflower-growing regions of Yugoslavia. Proc. of Eucarpia Symposium: Sunflower breeding, pp. 33-34, Prague.

Wright, S., 1921. Correlation and causation. J. Agric. Res., I, 20: 557-585.

ANÁLISIS DEL COEFICIENTE DE CAMINO DE CIERTOS COMPONENTES DE RENDIMIENTO DE OLEO EN EL GIRASOL (*Helianthus annuus* L.)

RESUMEN

Para 8 líneas inbred y 15 híbridos F_1 (línea x tester) fueron análizadas las correlaciónes entre ciertos componentes de rendimiento (rendimiento de oleo, rendimiento de proteinas, rendimiento de nucleo, rendimiento de grano, masa seca de las partes de planta sobre el suelo, superficie de hoja y indice de cosecha). El análisis del coeficiente de camino fué utilizado para separar las influencias, directas e indirectas, de las características investigadas sobre el rendimiento de oleo por planta. Fueron constatadas las correlaciónes positivas muy significativas entre el rendimiento de oleo y otras características investigadas. El rendimiento de proteinas manifesto una influencia positiva muy significativa sobre el rendimiento de oleo. El rendimiento de grano y el rendimiento de nucleo tenian una influencia positiva directa sobre el rendimiento de oleo por planta, mientras la masa seca de las partes de planta sobre el suelo, el indice de cosecha y la superficie de hoja tenian una influencia directa negativa sobre el rendimiiento de oleo.

ANALYSE DU COEFFICIENT DU PARCOURS DE CERTAINES COMPOSANTES DU RENDEMENT EN HUILE DANS LE TOURNESOL

RÉSUMÉ

Huit lignes inbred et 15 hybrides F_1 (ligne et tester) ont été analysés pour que soient déterminées les corrélations entre certaines composantes du rendement (rendement d'huile, rendement en protéines, rendement en akènes, rendement en graines, poids des parties aériennes séchées de la plante, surface des feuilles et index de récolte). L'analyse du coefficient de parcours a été utilisée pour séparer les effets directs et indirects des caractéristiques observées sur le rendement d'huile par plante. Des corrélations positives très significatives ont été établies entre le rendement en huile et le reste des caractéristiques étudiées. Le rendement en protéines a montré un effet direct positif très significatif sur le rendement en huile. Le rendement en graines et en akènes a eu un effet direct positif sur le rendement en huile par plante alors que le poids des parties aériennes de la plante, l'index de récolte et la surface des feuilles ont eu un effet direct négatif sur le rendement en huile.