Studii şi Cercetări	Biologie	14	46 - 50	Universitatea din Bacău	Martie 2008

PATH COEFFICIENT ANALYSIS IN SAFFLOWER (*Chartamus tinctorius* L.) LINES.

V. Alba, G.B. Polignano, M. Galante, G. Carrozzo, E. Alba

Keywords: *Safflower, Path analysis, Oil Yield, Breeding.*

INTRODUCTION

In the last decades, the high energy demand in the industrialized world, as much in the domestic use, and the derived problems of fossil fuels widespread use, have led to a relevant interest in the development of renewable energy sources of limitless duration and smaller environmental impact than the traditional ones. In this contest, the E.U. adopted a communication, in 2001, on alternative fuels for road transport, which is responsible for about 21% of the harmful greenhouse gas emissions, identifying three fuels: natural gas, hydrogen and biofuels.

This decision marked the beginning of a new era caused by the important expectations in energy crops. The EU commitment of achieving a biofuel consumption of 5.75% of the total diesel fuel consumption by 2010 will involve an important increase in crop cultivation for producing biofuels. But biofuels from wood, wastes and agricultural crops are currently more expensive respect to that from plant oils, which represent a relevant renewable natural resource, just useful in several food and no-food economic sectors (Carriero et al., 2004). On the other hand, concerning environmental impacts, a potential positive aspect of oilseed plants is their contribution to the establishment of new cultivation systems, i.e. as alternatives to monoculture of wheat (Alba et al 1986). In particular, oilseed crops, especially safflower as winter growing season species, are to consider an important alternative in dry hilly areas of southern Italy, where the progressive abandoning of agriculture has left the soil hydro-geologically vulnerable and it would not be unrealistic to foresee, in a not too distant future, a significant increase in safflower production in those regions (Corleto et al., 1997; Corleto, 2005).

In the past, farmers discarded the cultivation of safflower because the E.U. did not included it, among oil seeds plants, for compensatory payment, while soybean, sunflower, rapeseed and turnip rape were the only oilseed crop to receive compensatory payments. Presently, biofuels from safflower as important renewable source represents a promising alternative energy for its use in compression-ignition engines (Bergman and Flynn, 2001). Moreover, starting on 26th June 2003, the E.U. has reformed its story on the farm subsidy regime, which significantly distorted international trade and harmed developing country, and decoupled subsidies to production. For these reasons, the increase of production in oil yield by using good selected safflower varieties for southern environmental, would be an important goal. But, it is well known that yield, more in general, is a complex character strongly conditioned by genotype x environment interactions and by complex associations with other bio-morphological characters (Alba and Greco 1979; Alba et al 1982). That is, 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 number of head/plant to improve yield) disregarding the indirect effects of the character under selection upon other traits, whose breeding values are somehow associated with that of the selected character. Therefore, a successful breeding program relies on a good knowledge about all the influences of the main morpho-biological characters on yield; such a goal may be obtained using path coefficient analysis, namely a standardized partial regression analysis which permits the partition of the influence of casual factors into direct and indirect effects, thus indicating the real association among the investigated characters. The method has been widely employed by breeders (Dewey and Lu 1959; Liang and Riedl 1964; Porceddu, 1966; Alba e Greco 1979; Shim et al., 2001, Malleshappa et al., 2003). This study attempts to contribute in defining the influence of the main bio-morphological characters upon oil yield on a sample of safflower lines.

MATERIALS AND METHODS

A total of twenty-eight lines of safflower, the majority of which were in advanced breeding stages developed by researchers of Basilicata and Bari University, were grown in a randomized complete block design with 3 replications during two seasons: 2005-2006 and 2006-2007 in Aradeo (LE) (Apulia region-Italy). The experimental field was characterized by deep soils with a silty-clay texture, well supplied with K_2O an deficient in N and P_2O_5. The climate is Mediterranean with rainfall being concentrated in the period from November to March. The total annual rainfall ranges from 450-600 mm.. The annual mean temperature is about 15°C, whereas absolute temperature values are between 42°C (maximum) and –2°C (minimum). During the cropping cycle (November-July) in both years, total annual rainfall and temperature values were within the range of pluriannual values. The plot size was 4 m^2 (4 rows x 2 m) with a row spacing of 50 cm and 20 cm between plants. Planting date were between 5^{th} and 8^{th} November in both years. Fertilization consisted of Diammonium Phosphate and was applied in order to supply 9 kg N ha^{-1} and 23 kg P ha^{-1}. Two-three seeds were planted per hill and thinned to one when plants were about 10 cm developed. Weed growth was manually performed. Each plot value was based upon the mean of 16 plants of the 2 central rows. The characters investigated in this study were: days to flowering (d), plant height (cm), main branches with head (nr.) seed yield (q/ha), 1.000 seed weight (g), oil content of the seed (% d.m.), oil yield (q/ha). Estimate of line (r_l) and environmental (r_e) correlation coefficients were computed on all combinations of the 7 characters, and only texture has been utilized for the computation of the path coefficients, because estimates of genetic correlation are subject to large sampling errors and result therefore seldom very precise (Falconer 1964). Path coefficients analysis were computed with the solution of simultaneous equations through the method of least squares as shown by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of the correlations.

The line (r_l) and environmental (r_e) correlation for all possible combinations among the investigated characters is reported in Table 1. The characters most strongly associated with oil yield were, as expected, seed yield (r_l = 0,954**) and oil content (r_l = 0,774**); whereas the remaining traits were not significantly correlated with oil yield. These findings were obtained in the separate analysis of two years, confirming the validity of a pooled analysis. Days to flowering exhibited a high significant positive association (r_l = 0.660**) with the plant height, while on the other hand it resulted significantly negative correlated (r_l = -0,656**) with 1.000 seed weight. The reasons 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, safflower yield potential is affected by the over long cropping cycle and by the occurrence of part of the reproductive stages in June (from anthesis until seed filling), when weather conditions are generally severe, the evapotranspirative demand increases, rainfall is sharply reduced and the photosynthesis rate heavily declines due to the increase in dead leaves (Corleto 2005).

Rather interesting was the positive associations (r_l = 0,555*) between seed yield and oil content, while none of the remaining characters, excluding oil yield, showed a significant association with oil content in the seeds.

Path-analysis

Each path-analysis involved the assumption, based upon the priori evidence, of a precise cause-effect situation between the characters. 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 casual characters 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 casual characters. Considering the direct action of seed yield (P EG = 0,758) and oil content (P FG = 0,353) on oil yield, it is worth nothing 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 associations (r_l = 0.555) with seed yield.

Tables 3 and 4 show direct and indirect action of four main bio-morphological factors upon yield components. Regarding seed yield as the effect of the casual variables, a rather similar picture was given by path values and correlation coefficients. Plant height was exposed as the trait mainly influencing seed yield negatively (P BE= -0.557), followed by branches with head (P CE = -0.292); indirect influences in both cases were low and negligible. The negative correlation (r_l = -0.173) between days to flowering and seed yield was determined by a mild positive direct effect (P AE = 0.120) and a valuable indirect action (P AB = -0.368) via plant height. Oil content resulted affected by all characters both directly and indirectly. The most relevant direct influence (P AF = 0.984) was due to days to flowering followed by plant height (P BF = -0.680), 1000 seed weight (P DF = 0.374) and branches with head (P CF = -0.307). Such values, with the exception of the one referred to branches with head, did not agree with correlation values because of strong indirect influences opposing and counterbalancing the direct effect. The negative value obtained for path and correlation values between branches with head and seed or oil yield, would probably be explained by the influence of other characters, such as percentage of empty seed and sterile portion of the heads, not taken into account. It obviously results that unfavourable environmental conditions during flowering and grain filling period, could cause a great amount of aborted, or partially filled achens. The number of branches with head and the angle that branches form to the main stem are variable characteristics, considerably affected by genotype x environment interaction and cultivating techniques, such as planting date, population size, soil moisture and fertilization (Ricardo and Knowles 1964, Abel 1976, Tanaka et al. 1997). Increasing density of plant will decrease the angle, and low densities will increase it. Of course, not all the branches in a plant form the same degree of angles with the main stem. Under low temperature and long daylight conditions safflower trends to produce more branches. Most branching occurs on the upper part of the plant; few on the middle and basal part. Additionally, low density planting under high soil fertility conditions promotes branching with large heads. At low plant densities, more flower heads with larger size are produced.. Normally, fall-sown cultivar has more branches with head than spring-sown; denser population leads to less branches with small head; adequate water and nutrients can obviously increase the number of branches with large head. Many authors, both earlier and later of the nineteenth century, have written about the cultivation of safflower for flower gardens, and the important rule of the branches (Kiptum 1998; Uher 2005). It is advisable to include this character among the most important traits that have to be studied specially when new foreign genotypes need to be tested under unfavourable conditions. Concluding, the results obtained by path coefficients showed that: seed yield strongly influenced oil yield, while oil content had a milder action. The last two traits were negatively affected by plant height and branches with head, while days to flowering exerted a strong direct effect upon oil content. Considering the direct action of seed yield (P EG = 0,758) and oil content (P FG = 0,353) upon oil yield, it is worth nothing the stronger influence of the former, thus indicating a major validity for a selection based upon seed yield. Moreover, the high influence of the residual factors (P XE = 0.858 and P XF = 0.742) should be taken into account because of the presence of unsurveyed factors like experimental errors.

Table 1. Line (r_l) and environmental (r_e) correlations among oil yield and six characters in safflower

Characters		Plant height (cm)	Branches with head (nr.)	Seed yield (q/ha)	1000 seed weight (g)	Oil content (% d.m.)	Oil Yield (q/ha)
Days to flowering (d)	r_l	0.660**	-0.288	-0.173	-0.656**	0.379	-0.026
	r_e	- 0.024	0.018	0.080	-0.063	0.216*	-0.027
Plant height (cm)	r_l		-0.242	-0.410	-0.228	-0.041	-0.340
	r_e		-0.203*	-0.555	-0.028	-0.051	-0.059
Branches with head (nr.)	r_l			-0.189	0.169	-0.363	-0.257
	r_e			0.361**	-0.065	0.039	0.317**
Seed Yield (q/ha)	r_l				0.014	0.555*	0.954**
	r_e				0.107	0.060	0.951**
1000 seed weight (g)	r_l					-0.169	-0.013
	r_e					-0.150	0.056
Oil content (% d.m.)	r_l						0.774**
	r_e						0.344**

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

Table. 2 Path coefficient analysis of the direct and indirect effects of seed yield and oil content upon oil yield in safflower

Varietal correlations with oil yield	Direct effects	Effects trough the characters. Indirect effects via:	
		Seed yield (g)	Oil content (% d.m.)
Seed yield (q/ha) (0.954**)	0.758	1	0.196
Oil content (% d.m.) (0.774**)	0.353	0.421	1

Table 3. Path coefficient analysis of the direct and indirect effects of four characters upon yield in safflower

Varietal correlations with seed yield	Direct effects	Effects trough the characters Indirect effects via:			
		Days to flowering (d)	Plant height (cm)	Branch with head (nr.)	1000 seed weight (g)
Days to flowering (d) (-0.173)	0.120	1	-0.368	0.084	-0.010
Plant height (cm) (-0.410)	-0.557	0.079	1	0.071	-0.003
Branches with head (nr.) (-0.189)	-0.292	-0.035	0.135	1	0.003
1000 seed weight (g) (0.014)	0.015	-0.079	0.127	-0.049	1

Table 4. Path coefficient analysis of the direct and indirect effects of four characters upon oil content in safflower

Varietal correlations with oil content	Direct effects	Effects trough the characters. Indirect effects via:			
		Days to flowering (d)	Plant height (cm)	Branch with head (nr.)	1000 seed weight (g)
Days to flowering (d) (-0.379)	0.984	1	-0.449	0.088	-0.245
Plant height (cm) (-0.041)	-0.680	0.649	1	0.074	-0.085
Branches with head (nr.) (-0.363)	-0.307	-0.283	0.165	1	0.063
1000 seed weight (g) (-0.169)	0.374	-0.646	0.155	-0.0	1

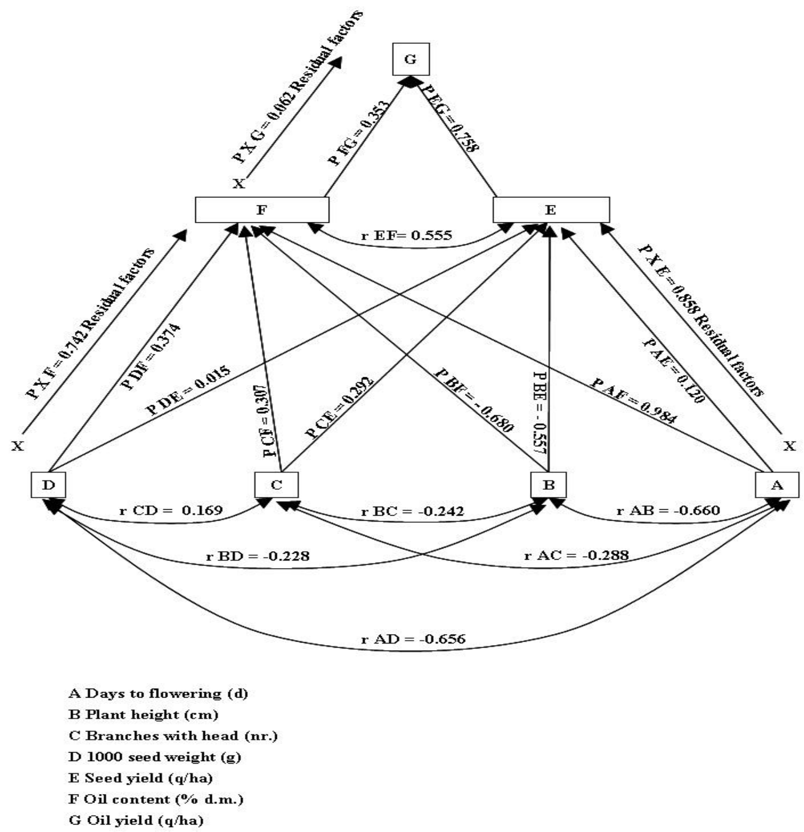

Fig. 1 Path diagram and coefficients of four morpho-biological characters affecting oil yield components

ABSTRACT

Twenty-eight lines of safflower (*Chartamus tinctorius* L.) were evaluated during two seasons: 2005-2006 and 2006-2007 in Aradeo LE (Apulia region) to study the interrelationships among seven characters such as: oil yield components (seed yield and oil content) days to flowering, plant height, 1000 seed weight and branches with head. To analyse the cause-effect relationship upon the oil yield components (seed yield and oil content) and four morpho-biological characters a path coefficient analysis was performed. The results obtained showed that: seed yield strongly influenced oil yield, while oil content had a milder action. The last two traits were negatively affected by plant height and branches with head, while days to flowering exerted a strong direct effect upon oil content. Considering the direct action of seed yield and oil content upon oil yield, it is worth nothing the stronger influence of the former, thus indicating a strategy of a selection based upon seed yield.

REFERENCES

1. ABEL G.H., 1976 - Effects of irrigation regimes, plant dates, nitrogen levels, and row spacing on safflower cultivars. Agronomy Journal. 68, 448-451.
2. ALBA E., GRECO I., 1979 - An a nalysis of association of the factors influencing seed yield in sunflower. The Sunflower Newsletter, 3, 2, 13-15.
3. ALBA E., GRECO I., ALTINI R., 1982 - Individuazione di caratteri secondari che influenzano altri caratteri agronomicamente importanti tramite i "path coefficient". Annali Facolta' di Agraria di Bari Vol. XXXII, 613-623.
4. ALBA E., LO CASCIO B., VENTURI G., 1986 - Miglioramento quantitativo e qualitativo delle produzioni oleifere mediante interventi genetici ed agrotecnici del progetto "Oleaginose del MAF. Subprogetto: Cartamo. In: Atti Convegno Nazionale "Una coltura alternativa: Cartamo". 9th June, Metaponto (MT-Italy), 11-17.
5. BERGMAN J.W., FLYNN C.R., 2001 - High oleic saffower as a diesel fuel extender. A potential new marked for Montana safflower. Proceeding of 5th International safflower conference, (Eds. Bergman J.W. and Mundel H.H.), Williston, North Dakota, Sidney, Montana, USA, 23rd-27th July, 179-184.
6. CARRIERO F., D'AMBROSIO, C., IANNACONEO S., STIGLIANI L., SUMMERERE S., CELLINI F., 2004 - Applicazioni delle biotecnologie vegetali per la produzione di oli con profili applicativi speciali Agroindustria 2, 3, 127-140.
7. CORLETO A., ALBA E., POLIGNANO G.B., VONGHIA G., 1997 - Safflower: a multipurpose species with unexploited potential and world adaptability. The Research in Italy. Proceeding of 4th International Safflower Conference. Bari (Italy), 23-31
8. CORLETO. A., 2005 - Seed yield potential in farm introduction of safflower as an alternative oil crop in southern Italy. Sesame and safflower Newsletter 20, 87-91.
9. FALCONER D.S., 1964 - Introduction to quantitative genetics. 3rd Edition, (Ed. Oliver and Boyd), Edimburgh and London, 312-329.
10. KIPTUM B.K., 1998 - Marketing of cut flower. HCDA Horticulture News, 20, 6-7.
11. LIANG G.H.L., RIEDL W.A., 1964 - Agronomic traits influencing forage and seed yield in Alfa-alfa. Crop Science, 4, 394-396.
12. MALLESHAPPA S.M., HIREMATH I., RAVIKUMAR R. I., 2003 - Negative associations between important traits in safflower (*Chartamus tinctorius* L.). Sesame and Safflower Newsletter, 18, 80-84.
13. PORCEDDU E., 1966 - Analisi delle correlazioni tra fattori delle produzioni in erba medica con metodo dei "path coefficient". Genetica Agraria, 20, 121-133.
14. SHIM K.B., KANG C.W.S. W., KIM D.H., LEE B.H., 2001 - Heritabilities, genetic correlations and Path coefficients of some agronomic traits in different cultural environments in sesame. Sesame and Safflower Newsletter, 16, 16-22.
15. TANAKA D.L., RIVELAND N.R., BERGMAN J.W., SCHNEITER A.A., 1997 - Safflower plant development stages. Proceeding of 4th International Conference, Bari (Italy), 179-180.
16. UHER J., 2005 - Safflower in world floriculture. A rewiew. Sesame and Safflower newsletter, 20, 76-80.

AUTHORS' ADDRESS

ALBA V. - Department of Agro-Forestry and Environmental Biology and Chemistry, section of Genetics and Breeding, University of Bari, Italy.

POLIGNANO G.B. - Institute of Plant Genetics, C. N. R., Bari, Italy.

GALANTE M. - Department of Biology, Plant protection and Agro-Forestry Biotechnology, University of Basilicata, Potenza, Italy.

ALBA E. - Department of Biology, Plant protection and Agro-Forestry Biotechnology, University of Basilicata, Potenza, Italy.

CARROZZO G. - Department of Biological and Environmental Science and technologies, University of Lecce, Italy. Corresponding authors: giambattista.polignano@igv.cnr.it. totitoti@katamail.com; Fax: 0039 0805587566.