HELIA, **23**, Nr. 32, p.p. 105-114, (2000) UDC 633.854.78:631.524.5:631.58

CORRELATIONS AND PATH ANALYSIS OF PHYSIO-MORPHOLOGICAL CHARACTERS OF SUNFLOWER (*Helianthus annuus* L.) AS RELATED TO BREEDING METHOD

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Received: March 05, 1999
Accepted: July 10, 2000

SUMMARY

The interrelationships of 12 physio-morphological traits of 144 sunflower genotypes including 66 germplasm accessions, 75 inbred lines and three checks were investigated using a 12 x 12 simple lattice design at the University of Agricultural Sciences, Bangalore, India. The study revealed that there were significant positive correlations between seed yield per plant and plant height, number of filled seeds, head diameter, stem girth, 100 seed weight, and harvest index on one side and oil yield per plant on the other. Percent autogamy was negatively correlated with seed yield per plant and other yield-contributing traits. Days to maturity and oil content were significantly associated with seed yield per plant only in the inbred lines. The breeding method followed in developing the genotypes has less influence in altering the magnitude and direction of correlation. Genotypic path analysis revealed that number of filled seeds and 100 seed weight had significant positive direct effects on seed yield per plant. Seed yield per plant followed by oil content had the highest direct positive influence on oil yield per plant. These traits were also the main channels to direct other components to influence the seed and oil yields per plant accordingly.

Key words: **correlation coefficient, germplasm, inbred lines, path coefficient, sunflower (*Helianthus annuus* L.)**

INTRODUCTION

In biological sciences one usually encounters a group of variables which are correlated due to complex interactions that are uncontrolled and obscured (Wright, 1921). The degree of association among such variables can be determined through

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correlation analysis. Correlations between characters signify the importance of such genetic causes as pleiotropic action of genes, linkages, improvement brought by selection through related characters and natural selection (Ginzburg and Nikoro, 1933; Harlan, 1939).

Although the nature and degree of association among various characters can be estimated by correlation analysis, determining the direct influence of one character on another along each separate path or indirectly via others is worthwhile. Path analysis, a biometrical technique developed by Wright (1921) and later elaborated by Dewey and Lu (1957) provides such information. If correlation between a dependent and an independent character arises due to the direct effect of the later, it reflects the true relationship between the two. Selection can, therefore, be done for the independent character to improve the dependent character.

Boosting oil yield per unit area is the goal in breeding of oil-type sunflower. Oil yield is a function of both seed yield and oil content. However, oil content is less variable than seed yield. Hence, seed and oil yields are functionally more interrelated (Škorić, 1992). Seed yield is a combination of many characters, which are polygenic in nature and difficult to make direct selection for. It is, therefore, desirable to attempt to understand the interrelationships of such a complex trait as seed yield with its less complex but associated component traits, so that indirect selection may be possible.

Although different types of character-associations have been reported in sunflower (Giriraj *et al.*, 1987; Jayarame Gowda, 1994; Doddamani *et al.*, 1997) information pertaining to the effect of breeding method on the association of component traits is meager. Hence, the present study was initiated to determine and compare the pattern and magnitude of associations of 10 physio-morphological characters with seed and oil yields per plant for germplasm accessions and inbred lines separately. In addition, using path analysis, the relative importance of some traits was determined.

MATERIALS AND METHODS

The experiment consisted of 144 sunflower genotypes with 66 germplasm accessions, 75 inbred lines (maintainer, restorer and non-converted inbred lines) introduced from 24 countries and three checks was conducted during the rainy season of 1997 in 12 x 12 simple lattice design at the experimental site of the University of Agricultural Sciences, GKVK, Bangalore, India. Each genotype was grown in two rows of 3 m length with 60 and 30 cm inter- and intra-row spacing, respectively. All the recommended agronomic practices for the region were followed to raise the crop.

From each genotype, five plants were randomly selected and covered with cloth bags on the same day the first ray florets opened and remained covered untill harvest to observe percent seed set, which was used later to calculate percent autogamy. All the other characters were recorded from another five plants left for open pollination. The characters considered were days to 50 percent flowering, days to maturity, plant height, stem girth, head diameter, seed yield per plant, 100 seed weight, number of filled seeds, harvest index, percent autogamy, oil content and oil yield per plant. Seed set and percent autogamy were calculated using the formula given by George and Shein (1980). Oil content, expressed as percent, was determined by a nuclear magnetic resonance (NMR) spectrometer.

In all cases, mean values of the five plants from each replication were subjected to computation using MSTAC and SPAR1 softwares. Correlation and path coefficient analyses were done separately for the germplasm accessions and inbred lines (including the three checks in each case). An analysis of variance and genotypic correlation coefficient were computed following Cochran and Cox (1957) and Weber and Moorthy (1952), respectively. Coefficient calculated for the respective associations in the inbred lines and germplasm accessions were tested for homogeneity using χ^2 test (Steel and Torrie, 1980). Path coefficient analysis was carried out as suggested by Wright (1921) and Dewey and Lu (1957).

RESULTS AND DISCUSSION

Univariate analysis of variance for each of the 12 characters studied showed significant differences among the genotypes ($P<0.001$) (ANOVA not presented).

Invariably, seed yield per plant was positively correlated with plant height, stem girth, head diameter, 100 seed weight, number of filled seeds, harvest index and oil yield per plant but negatively with autogamy. The correlation of seed yield per plant with days to maturity and oil content was positive and significant, but only among the inbred lines (Table 1).

Correlation coefficients observed between plant height and stem and head diameters with seed yield per plant were higher in magnitude for the germplasm than the inbred lines. On the other hand, the inbred lines showed good association between seed yield per plant and 100 seed weight, number of seeds per head, harvest index, percent autogamy and oil content.

The poor associations of seed yield per plant with days to flowering and maturity suggests that duration of photosynthetic activity is not a limitation in sunflower. Therefore, reducing the length of growing period without affecting final yield should be possible in sunflower breeding. Jayarame Gowda (1994), Patil *et al.* (1996) and Doddamani *et al.* (1997) also reported poor association between seed yield and days to flowering. Rao *et al.* (1987) reported a negative association of seed yield with days to maturity.

Development of superior self-compatible hybrids/varieties is a goal in sunflower breeding programs. In spite of this, however, seed yield and most of its components were found to be negatively correlated with percent autogamy. Jayarame Gowda (1994) and Patil *et al.* (1996) also reported similar results. Thus, the breeding of

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Table 1: Genotypic correlation coefficients of 12 quantitative characters for the germplasm accessions (n = 69) and inbred lines (n =78) of sunflower

Character		DF	DM	PH	SG	HD	SY	HSW	NFS	HI	AP	OC	OY
DF (GA)		1	0.844**	0.719**	0.455**	0.151	0.108	-0.141	0.258**	-0.679**	0.474**	0.042	0.112
	(IL)	1	0.912**	0.607**	0.418**	0.086	0.060	-0.184	0.134	-0.436**	0.419**	0.082	0.084
DM (GA)			1	0.706**	0.516**	0.262**	0.169	0.001	0.216*	-0.521**	0.359**	0.235*	0.234*
	(IL)		1	0.681**	0.516**	0.225*	0.245*	0.023	0.279**	0.260**	0.311**	0.152	0.264**
PH (GA)				1	0.783**	0.633**	0.613**	0.400**	0.499**	-0.277**	0.117	0.001	0.546**
	(IL)			1	0.609**	0.490**	0.586**	0.330**	0.587**	0.057	0.133	0.269**	0.612**
SG (GA)					1	0.805**	0.815**	0.420**	0.602**	-0.186	-0.195	0.028	0.724**
	(IL)				1	0.798**	0.713**	0.635**	0.615**	0.184	-0.129	0.024	0.676**
HD (GA)						1	0.921**	0.399**	0.802**	0.244*	-0.474**	0.136	0.874**
	(IL)					1	0.789**	0.795**	0.634**	0.334**	-0.260**	-0.099	0.733**
SY (GA)							1	0.621**	0.892**	0.539**	-0.347**	0.041	0.910**
	(IL)						1	0.638**	0.876**	0.656**	-0.240*	0.249*	0.984**
TSW (GA)								1	-0.021	0.454**	-0.531**	-0.173	0.472**
	(IL)							1	0.280**	0.316**	-0.492**	-0.116	0.583**
NFS (GA)									1	0.231*	-0.186	0.188	0.886**
	(IL)								1	0.673**	-0.118	0.331**	0.878**
HI (GA)										1	-0.455**	0.105	0.505**
	(IL)									1	-0.458**	0.034	0.617**
AP (GA)											1	0.041	-0.273**
-	(IL)										1	-0.066	-0.233*
OC (GA)												1	0.431**
	(IL)											1	0.405**
OY (GA)													1
	(IL)												1

GA=germplasm accessions; IL=inbred lines; * and ** =significant at 5 and 1 percent level, respectively;
DF=Days to flowering, DM=Days to maturity, PH=Plant height (cm), SG=Stem girth (cm), HD=Head diameter (cm), SY=Seed yield (g/plant), HSW=100 seed weight (g), NFS=Number of filled seed, HI=Harvest index (g), AP=Autogamy (%), OC=Oil content (%) and OY=Oil yield (g/plant)

high yielding genotypes with high self-compatibility would be rather difficult and hence requires a compromise between these traits. Repeated intermating with simultaneous selection for both characters could break the negative association so that high level of self-fertility coupled with high seed yield could be realized.

Harvest index was noticed to be significantly and positively correlated with seed yield per plant, which is in agreement with earlier findings of Giriraj *et al.* (1987) and Haile (1994). Increasing harvest index has been the main breakthrough in cereals and millet yield improvement (Austin, 1989). This could also be an unexploited avenue for yield improvement in sunflower. High harvest index could be associated with a low total photosynthate production, which ultimately negatively affect both seed and foliage formation and development. Therefore, during selection for a high harvest index, the efficiency of total biomass production has to be taken into consideration. In sunflower, Škorić (1992) has proposed to improve harvest index by reducing plant height that has an additional indirect benefit of developing varieties that are resistant to lodging.

The positive significant correlation observed between plant height and seed yield per plant is justifiable and is in agreement with results reported by Patil *et al.* (1996) and Doddamani *et al.* (1997). Tall plants supporting many leaves could increase total biomass production through increased carbon fixation that can ultimately be partitioned to reproductive organs. Thus, the number of internodes, which are sites of leaf initiation, should remain constant during breeding for shorter plant types.

Oil content exhibited positive and significant associations with the number of filled seeds, seed yield per plant, plant height and oil yield per plant among the inbred lines and only with days to maturity among the germplasm accessions. Other researchers also reported a positive association of oil content with seed and oil yields (Patil *et al.*, 1996; Jayarame Gowda, 1994) and with plant height and number of seeds per head (Patil *et al.*, 1996). In this study, generally association of oil content with most of the characters was either non-significant or the few significant correlations were of lower magnitude suggesting that indirect selection for oil content would be rather a difficult proposition.

Those traits, which were significantly associated with seed yield per plant and/or oil content ultimately showed associations with oil yield per plant suggesting that improvement in seed yield per plant and/or oil content improves oil yield per plant at the same time. This relationship is not unexpected since oil yield has a multiplicative effect of oil content and seed yield.

Homogeneity test between correlation coefficients of the respective association showed that only 11 of the 66 total correlation coefficients were statistically different at 0.05 level of probability between inbreds and germplasm accessions (data not shown). Of these, five were associations with harvest index, three with head diameter, two with seed yield and one with stem girth. This indicates that these characters, with their order of importance, were altered during the genotypes breeding process. The remaining 55 correlation coefficients were not significant and can be represented using a pooled coefficient for the inbreds and germplasms. This shows that the correlated response of characters in the germplasm is maintained during inbreeding. Hence, the breeding method followed had less influence in altering the magnitude and direction of association. A breeding method particularly designed to break a correlated response of characters could be an exception to this generalization.

Path analysis was carried out to determine the relative importance of five selected characters on oil yield per plant and revealed the strong correlations observed among these characters and seed yield per plant that were found to be contributed indirectly by other traits but not by themselves. In both the germplasm accessions and inbred lines, direct effect was maximum for number of seed followed by 100 seed weight. The maximum indirect effects of the other characters were observed to be through number of filled seeds and 100 seed weight, while both of these characters were the major direct contributor to seed yield per plant (Table 2). This result is in agreement with the findings of Jayarame Gowda (1994) and Patil *et al.* (1996).

Table 2: Direct and indirect effects of some components on seed yield per plant for the germplasm accession (GA) and inbred lines (IL) of sunflower (germplasm n = 78; inbred lines n=69)

Character		Plant height (cm)	Stem girth (cm)	Head diameter (cm)	100 seed weight (g)	Number of filled seeds	Correlation coefficient
Plant height (GA)		**-0.301**	0.289	-0.327	0.328	0.625	0.613
	(IL)	**0.011**	-0.016	-0.071	0.176	0.486	0.586
Stem girth (GA)		-0.235	**0.369**	-0.416	0.344	0.753	0.815
	(IL)	0.007	**-0.027**	-0.116	0.339	0.509	0.713
Head diameter (GA)		-0.190	0.297	**-0.517**	0.327	1.004	0.921
	(IL)	0.005	-0.021	**-0.145**	0.425	0.525	0.789
100 seed weight (GA)		-0.120	0.155	-0.206	**0.820**	-0.027	0.621
	(IL)	0.004	-0.017	-0.115	**0.534**	0.232	0.638
Number of filled seeds (GA)		-0.150	0.222	-0.415	-0.018	**1.252**	0.892
	(IL)	0.006	-0.017	-0.092	0.150	**0.829**	0.876

Residual for germplasm accessions= 0.2666; residual for inbred lines = 0.0607; the main diagonals (bold) are direct effects

In both genepools, the direct effect of head diameter and indirect effects of other characters via it were negative. Shivaram (1986) reported a negative direct effect, while Patil *et al.* (1996) reported a low positive direct effect for head diameter. Chaudhary and Anand (1993) observed the direct influence of head diameter on seed yield was high and positive. Based on the magnitude of correlation coefficient (which happened to be positive and high), indirect selection for high seed yield per plant using this trait will thus be misleading as its direct effect turned out to be negative and high. The high and positive indirect effect of head diameter on seed yield per plant through number of filled seeds and 100 seed weight nullify the direct negative effect making the total correlation positive and high. According to Pustavoit (1966) (cf Škorić, 1992), increases in head size simultaneously increases the husk percentage and the incidence of empty seeds and, hence, may reduce kernel yield per plant and oil concentration in the seed. Morozov (1947) (cf Škorić, 1992), considered head shape to be more important than head size as it determines the number of disc florets as well as of filled seeds in the center.

In spite of the high and positive correlation of plant height with seed yield per plant, its direct and indirect effects on the other traits through it were negative among the germplasm accession, whereas it was positive but less for the inbred lines. Nevertheless, the high positive correlation observed between plant height and seed yield per plant is partially explainable by its high positive indirect effect through number of filled seeds and 100 seed weight. Negative direct effect of plant height on seed yield per plant was reported by Jayarame Gowda (1994). Conversely, positive direct effects were reported as low by Patil *et al.* (1996) and as positive and high by Chaudhary and Anand (1993).

Table 3: Direct and indirect effects of some component characters on oil yield per plant for the germplasm accessions (GA) and inbred lines (IL) of sunflower (n = 78)

Character	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Seed yield (g/plant)	100 seed weight (g)	Number of filled seeds	Oil content (%)	Correlation coefficient
Plant height (GA)	**0.023**	-0.042	-0.004	0.554	-0.002	0.016	0.000	0.546
(IL)	**0.029**	-0.013	0.028	0.566	-0.013	-0.034	0.048	0.612
Stem girth (GA)	0.018	**-0.054**	-0.005	0.736	-0.002	0.020	0.011	0.724
(IL)	0.018	**-0.021**	0.046	0.689	-0.025	-0.035	0.004	0.676
Head diameter (GA)	0.015	-0.043	**-0.006**	0.831	-0.002	0.026	0.053	0.874
(IL)	0.014	-0.016	**0.058**	0.763	-0.031	-0.036	-0.018	0.733
Seed yield per plant (GA)	0.014	-0.044	-0.006	**0.903**	-0.003	0.029	0.016	0.910
(IL)	0.017	-0.015	0.045	**0.967**	-0.025	-0.050	0.044	0.984
100 seed weight (GA)	0.009	-0.022	-0.003	0.561	**-0.005**	-0.001	-0.067	0.472
(IL)	0.010	-0.013	0.046	0.617	**-0.039**	-0.016	-0.021	0.583
Number of filled seeds (GA)	0.012	-0.032	-0.005	0.805	-0.000	**0.033**	0.073	0.886
(IL)	0.017	-0.013	0.037	0.847	-0.011	**-0.057**	0.059	0.878
Oil content (GA)	0.000	-0.002	-0.001	0.037	-0.001	0.006	**0.389**	0.243
(IL)	0.008	0.000	-0.006	0.241	-0.005	-0.019	**0.177**	0.405

Residual for germplasm accessions = 0.0154; residual for inbred lines = 0.0054;
the main diagonals (bold) are direct effects

Among the germplasm accessions, stem girth had a substantial positive direct effect on seed yield per plant. But, this was too low to justify the high magnitude of correlation it showed with seed yield per plant, had it not been influenced by the indirect effects via number of filled seeds and 100 seed weight. Among the inbred lines, stem girth resulted in low negative direct effect. Its indirect effect through head diameter was negative, whereas its indirect effect via number of filled seeds and 100 seed weight were positive and high. Apparently, stem girth had a negligible influence on seed yield per plant through plant height. Doddamani *et al.* (1997) reported negative direct effect of stem girth on seed yield per plant, whereas positive but low direct effect was reported by Jayarame Gowda (1994).

Genotypic path coefficient analysis for seven different characters influencing oil yield revealed that seed yield per plant had the maximum direct positive effect among both the germplasm accessions and inbred lines (Table 3). Hence, both the correlation and path analysis established that seed yield per plant is the most influential trait on oil yield. Indeed, the highly positive correlation observed between seed yield per plant and oil yield was largely composed of the positive direct effect of seed yield per plant. Indirect effects of seed yield per plant through other traits were all very small, irrespective of their direction.

Similar to the case of seed yield per plant, here too, the correlation analysis could not reflect the true associations between the dependent and independent traits. Stem girth, head diameter (in the case of germplasm accession), 100 seed weight and number of filled seeds (in the case of inbred lines) were the traits which had a negative but less direct effect on oil yield, in spite of their positive and high correlation coefficients. Rather, their positive and high correlations was totally attributable to the high and positive indirect effects they produced via seed yield per plant. This was true for plant height, head diameter (in the case of inbred lines), number of filled seeds (in the case of germplasm accessions) and 100 seed weight. While their direct effect was less but positive, their correlation coefficient with oil yield was high and positive, owing to their positive and high indirect effects through seed yield per plant. This would strongly indicate the insufficiency of correlation coefficients to set up selection criterion in crop breeding.

In spite of its low correlation coefficient, oil content appeared to be the second most important trait influencing oil yield. High direct effect of oil content on oil yield was masked in the total correlation owing to its negative or low indirect influence through other traits.

An overall analysis of path coefficient suggested that selection should be made for plants with high number of well-filled seeds to increase seed yield per plant in sunflower. By the same token, seed yield per plant and oil content were the two factors exerting the maximum influence on oil yield. Seed yield per plant was found as the most important trait in every association that involves oil yield directly or indirectly.

The low value of residual factor (Tables 2 and 3) indicates that the factors considered in the present study were sufficient enough for making prediction for increasing seed and oil yields in sunflower.

ACKNOWLEDGMENTS

We are grateful to Dr. S. Ramesh and Mr. Nigussie Alemayehu for their helpful comments and critical reading of the manuscript.

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CORRELACIONES Y ANALISIS DEL CAMINO DE CARACTERISTICAS FISIO-MORFOLÓGICAS DE GIRASOL (*Helianthus annuus* L.) EN DEPENDENCIA DE METODO DE SELECCIÓN

RESUMEN

Las relaciones mutuas de doce caracteristicas fisio-morfológicas de 144 genotipos de girasol, incluyendo 66 números del banco de plasma germinal, 75 lineas inbred y tres controles, eran investigados por el cultivo en una simple red 12 x 12 en la Universidad of Agricultural Sciences en Bangalore, India. La investigación constató la existencia de las correlaciones positivas importantes entre el rendimiento de semilla por planta y la altura de planta, y el número de semillas ljenadas, el diámetro de cabeza, el volumen de tallo, el peso de 100 granos y el indice de cosecha por un lado, y el rendimiento de aceite por planta por otro lado. El porcentaje de la autogamia era en la correlación negativa con el rendimiento de semilla por planta y con otras componentes del rendimiento. El número de dias hasta la madurez y el contenido del aceite eran considerablemente relacionados con el rendimiento de semilla solo en caso de las lineas inbred. El método de selección aplicado en la formación de genotipos tenia menor influencia sobre la amplitud y la dirección de las correlaciones constatadas. El analisis del camino de genotipos mostró que el número de semillas llenadas y el peso de 100 granos tenia un efecto directo positivo considerable sobre el rendimiento de semilla por planta. El rendimiento por planta seguido por el contenido del aceite tenian la más grande influencia directa positiva sobre el rendimiento de aceite por planta. Estas caracteristicas han canalizado las influencias de otras componentes del rendimiento sobre los rendimientos de semilla y aceite por planta.

CORRÉLATIONS ET ANALYSE DE LA TRANSFORMATION DES CARACTÉRISTIQUES PHYSIO-MORPHOLOGIQUES DU TOURNESOL (*Helianthus annuus* L.) SELON LA MÉTHODE DE SÉLECTION

RÉSUMÉ

Les relations entre douze caractéristiques physio-morphologiques de 144 génotypes de tournesol qui comprenaient 66 nombres de la banque de germeplasmes, 75 lignes inbred et trois contrôles, ont été étudiées par une culture sur une grille simple de 12 x 12 à l'Université des sciences de l'agriculture à Bangalore, Inde. L'étude a révélé qu'il y avait d'importantes corrélations positives entre le rendement de graines par plante et la hauteur de la plante, le nombre de graines pleines, le diamètre de la tête, la circonférence de la tige, le poids de 100 graines et l'index de récolte d'un côté et le rendement d'huile par plante, de l'autre. Le pourcentage d'autogamie avait une corrélation négative avec le rendement de graines par plante et les autres composantes du rendement. Le nombre de jours avant la maturité et le contenu en huile était significativement associés au rendement en graines par plante seulement dans les lignes inbred. La méthode de culture suivie dans le développement des génotypes a moins d'influence dans le changement de magnitude et le sens de la corrélation. L'analyse de la transformation des génotypes a révélé que le nombre de graines pleines et le poids de 100 graines avaient des effets directs positifs importants sur le rendement en graines par plante. Le rendement de graines par plante accompagné du contenu d'huile ont eu l'influence positive directe la plus importante sur le rendement d'huile par plante. Ces caractéristiques ont canalisé les effets des autres composantes du rendement sur le rendement de graines et d'huile par plante.