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GENETIC ANALYSIS OF FATTY ACID COMPOSITION AND QUANTITATIVE YIELD IN A HIGH OLEIC SUNFLOWER POPULATION

M.Baldini[1], F.Cecconi[2], P.Megale[1], G.P.Vannozzi[3]

[1] *Agronomy Department of Pisa University, via S.Michele, 2, 56100, Pisa*
[2] *Genetic Department of Pisa University, via Matteotti, 1/A, 56100, Pisa*
[3] *Vegetable Yield Department of Udine University, area Rizzi, 33100, Udine*

SUMMARY

In 1989, 11 inbred lines, randomly selected from the ND–02 bulk population characterized by a high oleic acid content, were mated following a factorial design. The obtained hybrids were sown in 1990 and were analyzed for fatty acid composition of the oil and quantitative yield (seed and oil).

The genetic variability is consistent for all the characters analyzed and the non–additive variance component (S.C.A.) was more important than the additive variance (G.C.A.) for oleic acid, linoleic acid and seed yield characters. The absence of correlation between seed yield and oleic acid content does not seem to prevent breeders from obtaining hybrids with a high level of both characters and a positive correlation between stearic acid oil content and seed yield, if confirmed in the subsequent studies, could indicate interesting new research lines.

Key words: High oleic sunflower, fatty acid composition, genetic analysis

INTRODUCTION

For many years a lot of work was put into the study of the inheritance of fatty acid composition of oil (Putt, 1969; Fick, 1975; Škorić et al., 1978; Andrich et al., 1984; Fernandez–Martinez and Alba, 1984), but it is only in the last years that the quality of sunflower oil has assumed such a great interest because a diet rich in mononsaturated fatty acids seems to reduce plasma–cholesterol, which is a risk factor for coronary heart disease (Grundy, 1986).

So some breeders, working in various parts of the world, tried to obtain a sunflower oil with high oleic acid content (more than 80%) basing their research on an old variety, "Pervenets", able to give genotypes with this qualitative character (Soldatov, 1976; Fick, 1984;). This variety, having a seed yield potential less than the current commercial hybrids, was used to transfer its qualitative character into the best inbred lines selected by breeders. But althougth the high oleic character derived from the same germoplasm, some differences have emerged from the genetic control studies (Urie, 1985; Miller et al, 1987; Fernandez–Martinez et al., 1987), indicating a strong environmental interaction.

The objectives of this paper are to evaluate, before beginning a breeding programme, the source material (a high oleic bulk population) in the specific environment and to study the expression of high oleic character in the F_1 hybrid combinations and its correlation with quantitative yield.

MATERIALS AND METHODS

The experimental material was the population ND–02 characterized by high oleic acid content in seed oil (Miller et al., 1987). From this population a set of inbred lines was randomly selected and among these we have used six lines as male parents (code 1–6) and five lines as female parents (code 7–11). The crosses were made according to the factorial design (Method II mating system) (Hallauer and Miranda, 1981); each female was emasculated and pollinated with each male during the winter 1989 in the greenhouse. The 30 hybrids obtained were sowed on 20 May 1990 at the experiment station, "Torretta" of Pisa University on a salty–clay soil to which 90 kg/ha of N had been applied. One irrigation was given at the incipient flowering stage. A randomized block design with three replications was used with the experimental unit of four rows, 7 m long and 0.7 m apart.

At physiological maturity, two central rows were hand–harvested and seed yield calculated (q/ha). On the self–pollinated seeds, fatty acid composition (mg/100 oil mg) and seed oil content (%) were determined, by capillary gas chromatography and by the Soxelet method, respectively.

The analysis of variance and the expected mean squares for the model used are given in Table 1.

Table 1. Analysis of variance and expected mean squares for factorial design for one environment and one year

Source	Degrees of freedom	Mean squares	Expected mean squares
Replications	r–1		
Males	m–1	M4	$\sigma^2 + r\sigma^2 fm + rf\sigma^2 m$
Females	f–1	M3	$\sigma^2 + r\sigma^2 fm + rm\sigma^2 f$
Males x females	(m–1)(f–1)	M2	$\sigma^2 + r\sigma^2 fm$
Error	(r–1)(mf–1)	M1	σ^2
Total	rmf–1		

r,m,f = number of replications, males and females, respectively; M = mean squares

Genetic parameters ρ^2A (additive component of variance), ρ^2D (dominance deviation component of variance) and the index derived as h^2 (heritability expressed in narrow sense) and $\sqrt{\sigma^2 D/\sigma^2 A}$ (degree of dominance) were calculated as reported by Fehr (1987) using the following equations:

$$\sigma^2 m = \frac{1}{4}\sigma^2 Am \qquad \sigma^2 m = \frac{1}{4}\sigma^2 Af$$

$$\sigma^2 f * m = \frac{1}{4}\sigma^2 D \qquad \sigma^2 = E$$

$$h^2 = \frac{1}{2}\sigma^2 A / \frac{1}{2}\sigma^2 A + \frac{1}{4}\sigma^2 D + E$$

Phenotypic correlation was calculated using the appropriate lines' mean squares and mean cross products; genetic correlations were calculated using the breeding values of the parents since they represented the additive genetic effects (Falconer, 1981).

RESULTS AND DISCUSSION

The analysis of variance (Table 2) shows a significant genetic variability for all the traits analyzed in the F_1 hybrids obtained by the inbred lines coming from the ND–02 population. A significant variability among the male and female inbred lines tested was found for all characters analyzed except for palmitic acid. This means that the additive genetic variance accounted for a major portion of genetic variation, while the only non–additive genetic variance resulted for palmitic acid. In fact this character (Table 3) showed the lowest heritability expressed in narrow sense and resulted superdominantly inherited giving the average degree of dominance higher than 1. A significant dominance deviation was found in the seed yield and (for 5% level) in the oleic, linoleic and palmitic acid contents (Table 2) and even if the additive genetic variance accounted for a major portion of genetic variation (Table 3), the ratio of non–additive variance component to additive component approaches 1, indicating a strong dominance effect on genetic control of these characters. It may be that in the F1 hybrids the heterosis effect has more importance in character expressions than the parent breeding value.

Table 2. Analysis of variance for traits measured in experimental hybrids from Factorial design

Source of variation	df	Mean squares					
		palmitic ac.	stearic ac.	oleic ac.	linoleic ac.	oil %	yield (q/ha)
Replications	2	0.07	0.22	27.76	41.14	37.70	36.26
Males	5	0.28	1.64**	202.05**	136.31**	82.02**	418.91**
Females	4	0.25	1.46**	212.34**	164.02**	102.30**	544.14**
Males x females	20	0.14*	0.27	71.76	36.28*	12.12	139.06**
Error	58	0.06	0.18	35.81	18.60	9.46	40.12

*, ** Significant at the 5 and 1% levels, respectively

Table 3. Estimates of aditive variance (ρ^2A),dominance variance (ρ^2D),degree of dominance $\sqrt{\sigma^2 D/\sigma^2 A}$ and heritability in narrow sense (h^2) for traits measured

Character	ρ^2A	ρ^2D	$\sqrt{\sigma^2 D/\sigma^2 A}$	h^2
Palmitic acid	0.031	0.10	1.79	0.15
Stearic acid	0.282	0.12	0.65	0.40
Oleic acid	33.00	47.92	1.20	0.26
Linoleic acid	27.54	23.92	0.93	0.36
Oil content	19.34	3.56	0.43	0.48
Seed yield	82.32	131.92	1.26	0.36

The additive component is considerably more important in the inheritance of stearic acid and seed oil content than the non–additive action as confirmed by the highest heritability among the other analyzed characters (Putt, 1966; Miller et al., 1980).

A strong genetic and phenotypic negative correlation between the oleic and linoleic contents in seed oil was found (Table 4), confirming the results of many authors (Škorić et al., 1978; Škorić et al., 1982), similar to the positive correlation between linoleic and palmitic acid contents. An interesting result is the positive genetic and phenotypic correlation found between stearic acid and seed yield.

Table 4. Genetic (above) and phenotipic (below) correlation coefficients

Character	Oleic ac.	Linoleic ac.	Stearic ac.	Palmitic ac.	Oil seed	Seed yield
Oleic ac.		–0.70**	0.16	–0.23	0.07	0.18
Linoleic ac.	–0.88**		0.01	0.69**	0.18	–0.04
Stearic ac.	0.34	–0.07		0.24	0.13	0.44*
Palmitic ac.	–0.39	0.69*	0.11		0.24	0.04
Oil seed	–0.19	0.44	0.60	0.58		0.40*
Seed yield	0.45	–0.36	0.70*	–0.20	0.45	

*, ** significant at the 5 and 1% levels of probability
phenotypic correlation d.f.=28
genetic correlaction d.f.=9

A positive phenotypic correlation was found between oil content in seed and seed yield; this could explain that a good development of the second phase of the crop cycle can give a high oil content in seed and at the same time could improve seed yield.

CONCLUSIONS

In the ND–02 population, we found significant genetic variability for the analyzed characters and therefore this population will be included in our next breeding programme.

The great importance of non–additive gene action in the mode of inheritance of oleic acid content, linoleic acid content and seed yield means that in the hybrid combinations these characters cannot be predicted only by the general combined ability of the parents, but above all by heterotic effects.

The absence of correlation between seed yield and oleic accid content offers a possibility of selecting both characters at the highest level in the same genotype.

To conclude, the positive correlation between stearic acid content and seed yield, if confirmed by successive studies, could prove to be an important factor for breeding purposes.

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ANALISIS GENETICOS DE LA COMPOSICION DE ACIDOS GRASOS Y EL RENDIMIENTO EN UNA POBLACION DE GIRASOL ALTO OLEICO

RESUMEN

En 1989 once líneas puras, seleccionadas al azar de la población ND–02 caracterizada por su alto contenido en acido olćico, fueron cruzadas siguiendo un diseño factorial. Los híbridos obtenidos fueron sembrados en 1990 y fueron analizados para composición de ácidos grasos del aceite y rendimiento (semilla y aceite).

la variabilidad genética es consistente para todos los caracteres analizados y el componente no aditivo de la varianza (S.C.A.) resulta más importante que el aditivo para los ácidos oléico, linoléico y rendimiento. La ausencia de correlación entre el rendimiento de semilla y el contenido de oléico no parece impedir a los mejoradores obtener híbridos con un alto nivel de ambos caracteres y la correlación positiva encontrada entre el ácido esteárico contenido de aceite y rendimiento do semilla, si se confirma sus estudios posteriores, podría indicar nuevas interesantes lineas de investigación.

ANALYSE GÉNÉTIQUE DE LA COMPOSITION EN ACIDE GRAS ET RENDEMENT QUANTITATIF DANS UNE POPULATION DE TOURNESOL À FORTE TENEUR EN ACIDE OLÉIQUE.

RÉSUMÉ:

En 1989, 11 lignées sélectionnées au hasard à partir de la bulk population ND-02 caractérisée par une haute teneur en acide oléique, ont été croisées selon un plan factoriel. Les hybrides obtenus ont été semés en 1990 et ont été analysés pour la composition en acides gras de leur huile et le rendement quantitatif (graines et huile).

La variabilité génétique est constante pour tous les caractéres étudiés et la composante non additive de la variance (SGA) est plus importante que la composante additive de la variance (GCA) pour les caractéres suivants: acide oléique, linoléique et rendement en graines. L'absence de corrélation entre le rendement en graines et la teneur en acide oléique ne semble pas empêcher le sélectionneur d'obtenir des hybrides présentant ces deux caractéres à un haut niveau. La corrélation positive trouvée entre la teneur en acide stéarique de l'huile et le rendement en graines, si elle est confirmée au cours d'études ultérieures, pourraient permmettre l'obtention de nouvelles lignées trés interessantes.