COMBINING ABILITY AND HEREDITY OF SOME IMPORTANT TRAITS IN LINSEED BREEDING

Florea Popescu, Ioana Marinescu and Ioana Vasile [1)]

ABSTRACT

A set of 66 direct hybrids, in F_1 generation, obtained in a diallel system by crossing 12 parental linseed (*Linum usitatissimum* L.) genotypes in the Research Institute for Cereals and Industrial Crops – Fundulea, was used in 1995 to determine the general combining ability (GCA) and the specific combining ability (SCA) as well as heritability coefficients (in a broad and restricted sense) of the following traits: plant length, boll number/m^2, TKW, seed yield, oil content and oil yield. In the case of all these traits, the effects of general combining ability were much more important, which confirms the idea that for all these traits additivity effects of genes are prevailing. On the basis of GCA for all the traits studied the best parental genotypes were the following lines: L-5312-93, L-3060-91 and L-6106-94 created at RICIC – Fundulea. Heratibility coefficients in a restricted sense confirm the uniform transmission to offspring particularly of the traits: oil content and plant height, but also other traits, except TKW, show a rather good heritability (values for these coefficients exceed 0.5). Simple (phenotypic) correlation coefficients among the six traits reveal the tight link between: seed yield and boll number/m^2; oil content and oil yield; plant height and boll number/m^2; boll number and oil content and oil yield; oil content and oil yield.

Key words: broad sense and narrow sense heritability, general (GCA) and specific combining ability (SCA), linseed, *Linum usitatissimum* L., simple (phenotypic) correlation, parental offspring regression.

INTRODUCTION

Selection of superior segregants followed by the selection of the best ones are the basic tasks of any breeding process (Simmonds, 1989).

To this aim the selection of the most valuable parental forms to achieve the crossing programme which will results in obtaining the best segregants, is the first step of this process and on its accuracy there greatly depends the success and efficiency of the whole programme. This may be achieved on the basis of some objective criteria offered by the determination of the combining ability in parental forms used.

The concept of good combining ability (Sprague and Tatum, 1942) refers to the potential of a parental form of producing by its crossing with another parent superior offsprings for the breeding process and it is widely used in the breeding of cross-pollinated plants.

Due to the numerous theoretical and practical advantages of this method, in recent years the choice of these parental forms on the basis of combining ability has extended more and more also to self-pollinated plants, such as linseed.

Numerous experiments related to the study of combining ability in some parental linseed genotypes were developed especialy in India (Dalal and Gill, 1965; Murty et al., 1967; Anand and Murty, 1969; Badwal et al., 1972a; Patil and Chopde, 1981) but also in other countries such as Rusia (Galkin, 1969), USA (Kasim, 1962; Shehata and Comstock, 1971) or Romania (Doucet, 1976; Doucet et al., 1979, 1981). The object of this study consisted of the numerous quantitative linseed traits such as: seed yield, boll number/plant, boll number/m^2, seed number/boll, TKW, plant height, oil content, fusarium resistance etc.

Most of these papers reveal significant effects of both general combining ability (GCA) and specific combining ability (SCA) but with a prevalence (greater or smaller, depending on the trait) of GCA effects.

According to Falconer (1967), heritability is one of the most important aspects of a quantitative trait as it expresses the rate of total variation attributed to mean gene effect which determines this trait, therefore the resemblance degree among relatives. Therefore heritability coefficients are the surest guide of breeding value. In the case of linseed, research strictly related to this matter was developed by Rosbaco (1959) and Badwal et al. (1972b), while in another series of papers (Comstock, 1960; Comstock and Gates, 1965; Doucet, 1978;

[1)] Research Institute for Cereals and Industrial Crops, 8264, Fundulea, Cãlãrasi County, Romania

Popescu et al. 1995, etc) only brief references were made regarding determination of some heritability coefficients for the investigated traits.

From the theoretical point of view, the present paper could enrich the literature with data obtained in this field in 1995 by the team of linseed breeders at the Research Institute for Cereals and Industrial Crops of Fundulea, and from the practical point of view, it facilitates the selection of the best parent forms for linseed breeding in Romania.

MATERIALS AND METHODS

Twelve linseed genotypes (nine Romanian lines and three foreign varieties) were crossed in 1/2 diallel system in the experimental plot of the linseed breeding team of RICIC Fundulea, in 1994, thus obtaining 66 hybrid F_0combinations.

The parental genotypes used were the Romanian lines: L-6529-90, L-506-91, L-3060-91, L-8254-91, L-6106-93, L-5115-92, L-4222-92, L-4272-92 and L-5312-93 and the varieties C.I. Nos. 1432 and N.P. (R.R.) from India and Crista B-15 from Germany, which were well differentiated as regards all the six traits analysed (Table 1).

The 66 F_1 hybrid combinations beside the parental genotypes were sown in 1995 in a trial arranged according to the four replicate complete randomized block design. Sowing was done in a mechanized way with a "Seedmatic" sowing machine on plot variants consisting of three rows each (1.5 m long x 0.21 m distance between rows). All measurements and determinations were done on plants comprised on a distance of 1 m, in the central row, after having done all frontal and terminal eliminations (about 0.25 m each).

Determinations were made regarding: mean plant height, boll number/m^2, TKW, oil content and oil yield (Table 1).

After having developed variance analysis (Ceapoiu, 1968), experimental data obtained for these trait were used to determine combining ability, by using the method II of the model proposed by Griffing (1956). Heritability coefficients of all six traits were calculated on the basis of decomposing total variance into its component elements (Singh et al., 1993) and compared against the values of regression coefficients obtained by calculating mid parent – F_1 offspring regression, for each trait separately (Simmonds, 1979).

In the end all simple (phenotypic) correlations among these traits were calculated (Ceapoiu, 1968).

RESULTS AND DISCUSSIONS

The results of variance analysis for all six traits analysed (Ceapoiu, 1968) revealed the fact that genotype variance was very significant (Table 2). This permit further decomposition of this variance into its GCA and SCA components (Griffing, 1956).

Combining ability variance analysis showed that both GCA and SCA were very significant for all traits analysed, whereby GCA variances were in all cases prevailing as compared to SCA variances (Table 3).

Table 1. Characterization of the 12 parental linseed genotypes, RICIC Fundulea, 1995

Parental genotype	Origin	Trait					
		Plant height (cm)	Boll no/m^2	TKW (g)	Seed yield (t/ha)	Oil content (%)	Oil yield (kg/ha)
L-6529-90	Romania	49.25	4.40	6.20	2.30	47.20	1086
L-5506-91	Romania	62.50	4.26	7.00	2.08	42.60	886
L-3060-91	Romania	60.75	5.24	7.80	2.54	47.60	1209
L-8254-91	Romania	50.75	3.14	7.00	2.18	44.68	976
L-6106-93	Romania	55.50	4.24	7.50	2.30	49.53	1140
L-5116-92	Romania	68.50	4.60	6.40	2.02	41.78	844
L-4222-92	Romania	59.25	4.36	7.10	2.16	44.70	965
L-4272-92	Romania	70.25	5.67	7.00	2.80	46.58	861
L-5312-93	Romania	50.90	5.34	7.10	2.40	46.08	1105
CI Nos. 1432	India	35.50	2.28	4.80	1.48	40.23	595
Crista B-15	Germany	35.25	2.10	8.10	1.51	41.40	623
NP (RR)	India	39.25	2.21	8.30	1.55	40.83	633
Mean		53.14	3.99	7.03	2.05	44.43	910
LSD 5%		2.05	0.55	0.08	0.22	0.22	109

This emphasizes the fact that in linseed in the case of all these traits, additivity effects of genes involved in their control are much more important as compared to non-additive effects although these too have a significant role.

By classifying the six traits studied in terms of additivity share per total variance (Table 3), the traits most easely to be bred seem to be oil content (GCA/SCA = 29.7) and plant height (25.96), followed by oil yield (14.91), seed yield (10.49), boll number/m^2 (10.31) and TKW (3.28).

The analysis of general combining ability effects (gi) for the six traits analysed (Table 4) revealed that the best parental genotypes were the following:

Table 2. Block variance analysis in linseed, RICIC Fundulea, 1995

Variance cauze	GL	Trait: Plant height (cm)		Boll no/m^2		TKW (g)		Seed yield (t/ha)		Oil content (%)		Oil yield (kg/ha)	
		SP	s^2	SP	s^2	SP	s^2	SP	s^2	SP	s^2	SP	s^2
Blocks	3	1.44	-	0.04	-	0.84	-	0.08	-	0.06	-	21.28	-
Genotypes	77	19006.25	246.63***	399.33	5.19***	219.35	2.85***	60.82	0.79***	1736.19	22.55***	15805.60	205.27***
Error	231	502.31	2.17	35.41	0.15	0.69	0.003	6.01	0.03	5.56	0.02	1409.12	6.10
Total	311	19510.00	-	434.78	-	220.88	-	66.91	-	1741.81	-	17236.00	-

*** - significant for 0.1%

Table 3. Combining ability variance analysis, RICIC Fundulea, 1995

Va-riance cauze	GL	Trait: Plant height (cm)		Boll no/m^2		TKW (g)		Seed yield (t/ha)		Oil content (%)		Oil yield (kg/ha)	
		SP	s^2	SP	s^2	SP	s^2	SP	s^2	SP	s^2	SP	s^2
GCA	11	60989.14	5544.47***	1009.71	91.79***	317.34	28.85***	154.74	14.07***	5776.86	525.17***	450809.16	40982.63***
SCA	66	14095.00	213.56***	587.62	8.90***	580.59	8.80***	88.55	1.34***	1167.88	17.70***	181471.00	2749.56
Error	231	502.31	2.17	35.41	0.15	0.69	0.003	6.01	0.03	5.56	0.02	1409.12	6.10
GCA/SCA			25.96		10.31		3.28		10.49		29.68		14.91

*** - significant for 0.1%

Table 4. Effects of general combining ability (Îi) and GCA and SCA variances of the traits studied in linseed, RICIC Fundulea, 1995

Genotype	Trait: Plant height **(cm)** Îi	Variant GCA	SCA	Boll no/m^2 Îi	Variant GCA	SCA	TKW (g) Îi	Variant GCA	SCA	Seed yield (t/ha) Îi	Variant GCA	SCA	Oil content (%) Îi	Variant GCA	SCA	Oil yield (kg/ha) Îi	Variant GCA	SCA
L-6529-90	6.44	41.33	24.86	1.38	1.82	5.90	-0.39	0.15	8.59	1.19	1.42	1.47	2.39	5.71	15.91	57.21	3272.58	3001.50
L-5506-91	17.58	318.48	28.68	1.62	2.61	1.66	-0.05	0.00	1.90	0.34	0.12	0.27	-3.05	9.30	13.73	6.83	46.25	615.62
L-3060-91	7.01	49.00	49.39	1.25	1.55	6.86	0.86	0.74	3.05	0.93	0.86	0.45	6.57	43.16	4.20	55.91	3125.53	835.64
L-8254-91	-5.70	32.35	26.79	-1.72	2.95	6.94	-1.11	1.23	3.46	0.30	0.09	1.29	-0.99	0.98	5.73	11.04	121.48	2657.91
L-6106-93	2.01	3.90	45.61	0.85	0.71	4.57	0.66	0.44	3.12	0.72	0.52	0.57	11.39	129.73	4.73	58.19	3385.68	1161.03
L-5116-92	21.58	465.55	29.23	0.38	0.13	7.18	-1.17	1.37	2.96	-0.27	0.07	0.71	-7.29	53.14	8.63	-27.65	764.12	1619.65
L-4222-92	10.51	110.32	62.48	0.62	0.37	3.64	-1.14	1.30	1.64	0.19	0.04	0.54	1.23	1.51	9.84	10.75	115.16	1214.12
L-4272-92	22.94	526.10	19.98	2.67	7.12	6.63	-0.51	0.26	2.83	-0.09	0.01	0.63	4.72	22.28	9.95	-1.24	1.14	1511.76
L-5312-93	6.73	45.15	60.59	3.85	14.81	7.89	0.44	0.19	3.92	1.13	1.28	1.28	4.05	16.40	4.30	58.74	3449.99	2498.83
CI Nos. 1432	-38.85	1509.2	50.82	-2.98	8.87	7.16	-2.14	4.58	9.29	-1.73	2.99	0.56	-8.04	64.64	5.48	-91.10	8298.81	1135.89
Crista B-15	-25.13	631.37	56.29	-4.01	16.07	4.35	1.26	1.59	5.80	-1.30	1.69	0.67	-7.09	50.27	16.19	-69.99	4898.20	1531.29
NP (RR)	-25.13	631.37	19.40	-3.88	15.04	3.49	3.29	10.82	7.88	-1.41	1.99	0.54	-3.89	15.13	30.39	-68.69	4717.92	1509.72
LSD 5%	1.10			0.30			0.04			0.13			0.11			1.84		
1%	1.46			0.39			0.05			0.17			0.14			2.43		
0.1%	1.87			0.50			0.07			0.22			0.18			3.12		

- L-4272-92, L-5116-92, L5506-91, L-4222-92, for plant height;

- L-5312-93, L-4272-92, L-5506-91, L-6529-90, for boll number/m^2;

- NP (RR), Crista B-15, L-3060-91, L-6106-93, for TKW;

- L-6529-90, L-5312-93, L-6106-93 for seed yield;

- L-60106-93, L-3060-91, L-4272-92, L-5312-93, for oil content;

- L-5312-93, L-6106-93, L-6529-90, L-3060-91, for seed yield.

By harmoniously combining the positive effects of GCA for all traits analysed, the most valuable parental genotypes for linseed breeding developed at RICIC Fundulea, from among the twelve ones analysed were: L-5312-93 and L-6106-93 followed rather closely by L-6529090 and L-4222-92 (Table 4).

Correlation coefficients among the values of each of the six traits analysed and the effects of combining ability (gi) of the twelve parental genotypes showed a very close link between the high values of all traits in parents and the high effects of the corresponding GCA (Table 5).

Table 5. Correlation coeffcients between the value of parental forms and the effects of the corresponding general combining ability for the six traits analysed, in linseed, RICIC Fundulea, 1995

No.	Trait	Value of correlation coefficient
1.	Plant height	0.94***
2.	Boll no/m^2	0.96***
3.	TKW	0.83***
4.	Seed yield	0.97***
5.	Oil content	0.96***
6.	Oil yiels	0.98***

*** - sifnificant for 0.1%

With regard to the effects of specific combining ability (SCA) for these traits, the best hybrid combinations were:

- L-6529-90/L-5506-91, L-6529-60/ L-5116-96, L-5506-91 / L-6106-93, for plant height (Figure 1);

- L-6529-90/L-5312-93, L-5116-92/ L-5312-93, L-5116-92 / L-4272-92, L-3060-91 / L-8254-91, for boll number/m^2 (Figure 2);

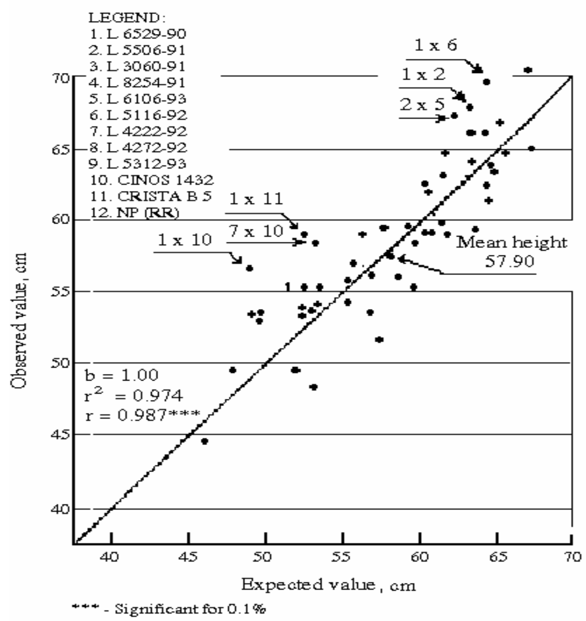

Figure 1. Combining ability for plant height in linseed, RICIC – Fundulea, 1995

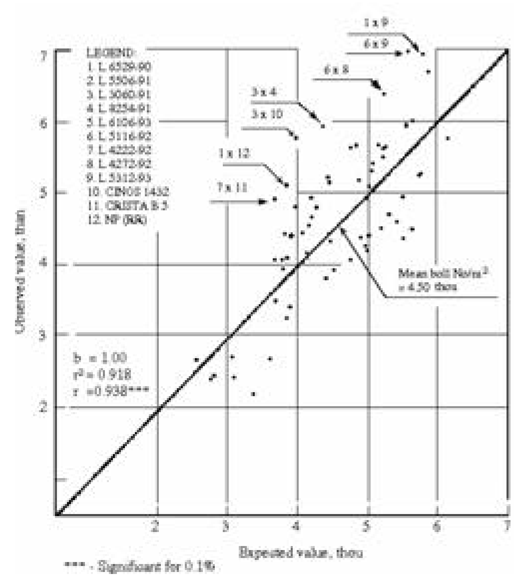

Figure 2. Combining ability for boll number/m^2 in linseed, RICIC – Fundulea, 1995

- L-6529-90 (RR), L-6106-93 / NP (RR) and L-6529-90 / CI Nos 1432, for TKW (Figure 3);

- L-6529-90 / L-5312-93 and L-3060-91 / L-8254-91, for seed yield (Figure 4);

- L-6106-93 / L-4272-92, L-3060-91 / L5312-93, L-3060-91 / NP (RR), L-4272-92 / NP (RR), for oil content (Figure 5);

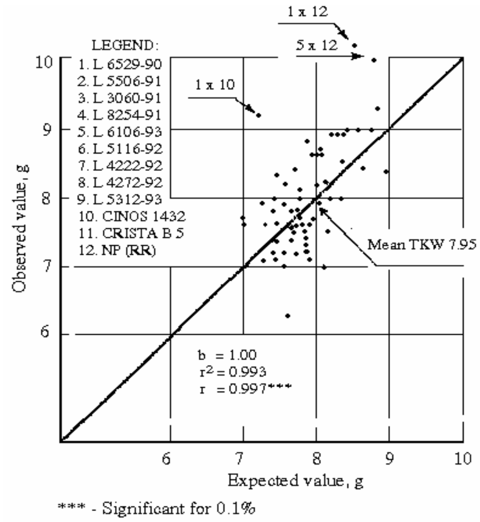

Figure 3. Combining ability for TKW in linseed, RICIC – Fundulea, 1995

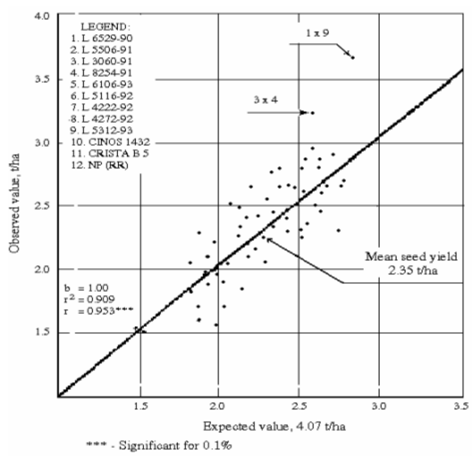

Figure 4. Combining ability for seed yield in linseed, RICIC – Fundulea, 1995

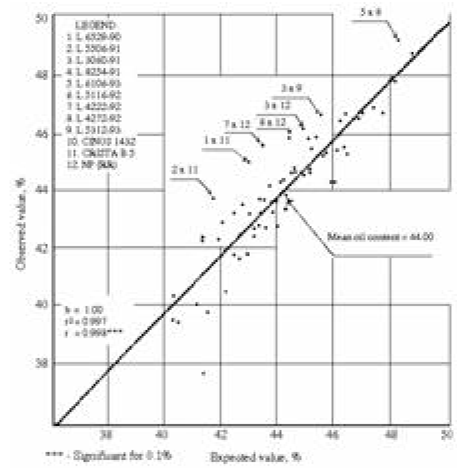

Figure 5. Combining ability for oil content in linseed, RICIC – Fundulea, 1995

- L-6529-90 / L-5312-93, L-3060-91 / L-6254-91, L-6106-93 / L-5116-92 and L-4222-92 / L-5312-93, for oil yield (Figure 6).

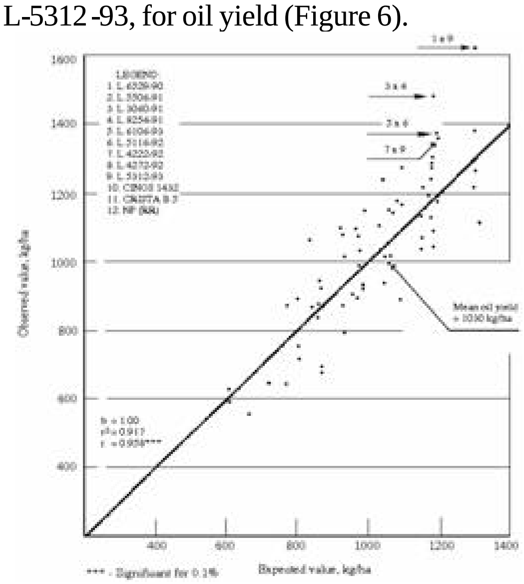

Figure 6. Combining ability for oil yield in linseed, RICIC – Fundulea, 1995

Among these results the fact was revealed that the two hybrid combinations L-6529-90 / L-5312-93 and L-3060-91 / L-8254-91 were superior specific hybrids for three traits (boll number/m^2, seed yield and oil yield) and for this reason they will have to be followed up with special attention in the breeding process, while the other specific combinations observed for each trait will be also considered with special care during this process.

Analysis of broad and narrow sense heritability coefficients of the six traits analysed, for this set of parental genotypes (Table 6), reveals the fact that total genetic variance had a higher weight within phenotypic variance for all these traits (all broad sense heritability coeffciients exceed the value of 0.90) and additive variance (respectively narrow sense heritability coefficient) was lower, this being nevertheless higher for traits of oil content and plant height which have the most uniform transmission to the offspring. The traits oil yield, boll number/m^2 and seed yield, had lower narrow sense heritability coeffcients but nevertheless sufficiently high (values of over 0.50) to assert that in the strict case of these parental genotypes these traits too may be bred quite efficiently.

Table 6. Comparison between broad and narrow sense heritability and parent – offspring regression for the six traits studied in linseed, RICIC Fundulea, 1995

Specification	Trait					
	Plant height	Boll No/m^2	TKW	Seed yield	Oil content	Oil yield
Heredity coefficient						
- broad sense	0.97	0.92	0.99	0.91	0.99	0.92
- narow sense	0.78	0.58	0.36	0.58	0.83	0.65
Parent – offspring regression (b)	0.71	0.68	0.50	0.47	0.88	0.62

For the same traits, the rather close values of regression coefficients within parent-offspring regression (Table 6), permit us to state that these heritability coefficients were quite accurately estimated by variance decomposition and that all these traits are in general free of complications due to maternal effects or other types of interactions. By analysing in greater detail parent-offspring regressions, which as Simmonds (1979) shows, are a very good empirical estimate of narrow sense heritability, we may observe that all regressions were very significant for all these traits (Figures 7-12).

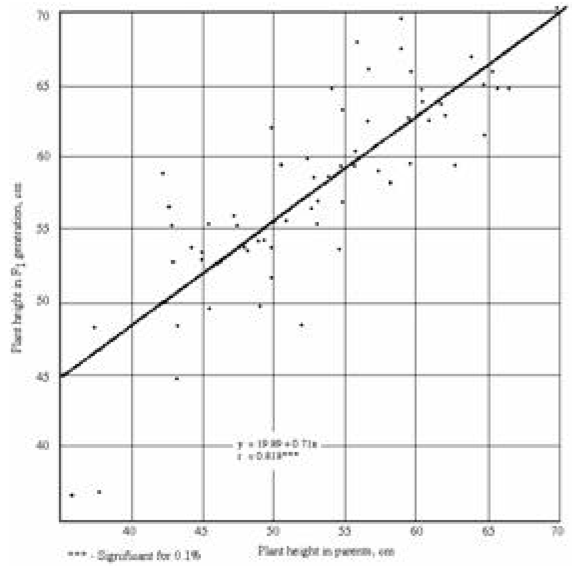

Figure 7. Mid parent – F_1 offspring regression for plant height in linseed, RICIC – Fundulea, 1995

These regressions show that by using this set of genitors, the breeding process for oil content and plant height will be much simpler and efficient as compared to the other traits, but these too will have rather high chances to be bred.

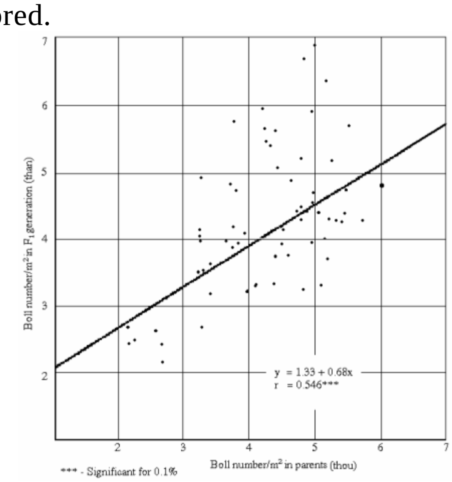

Figure 8. Mid parent – F_1 offspring regression for boll number/m^2 in linseed, RICIC – Fundulea, 1995

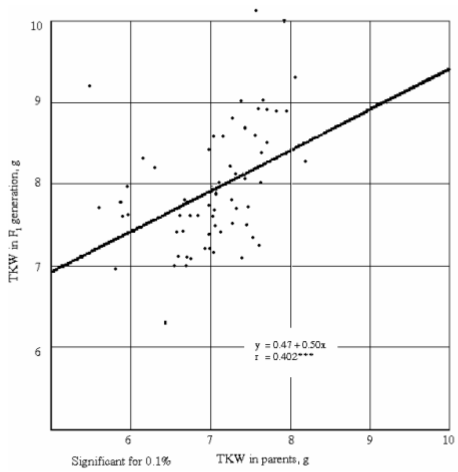

Figure 9. Mid parent – F_1 offspring regression for TKW in linseed, RICIC – Fundulea, 1995

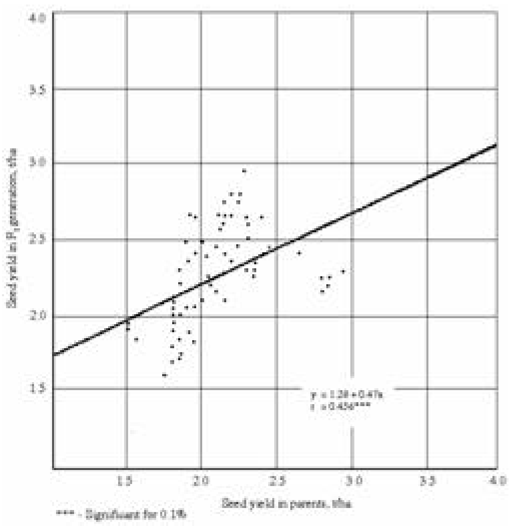

Figure 10. Mid parent – F_1 offspring regression for seed yield in linseed, RICIC – Fundulea, 1995

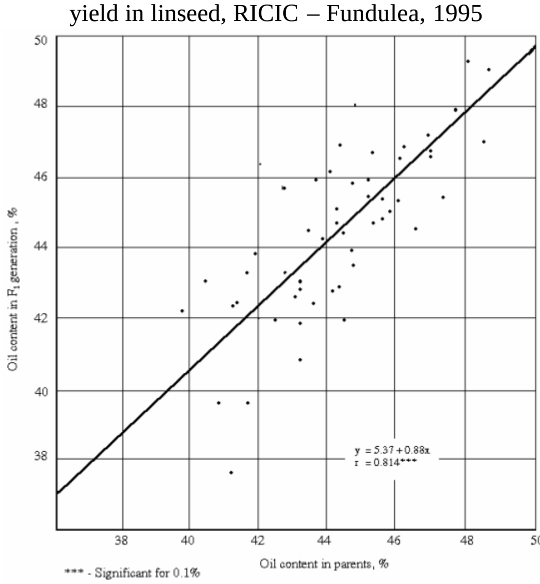

Figure 11. Mid parent – F_1 offspring regression for oil content in linseed, RICIC– Fundulea, 1995

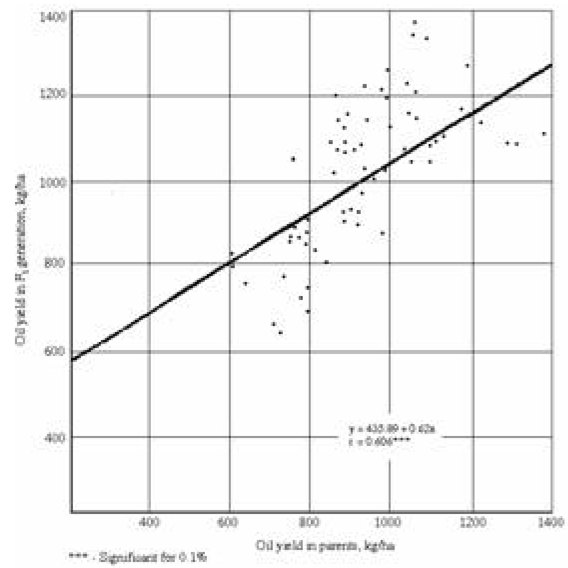

Figure 12. Mid parent – F_1 offspring regression for oil yield in linseed, RICIC – Fundulea, 1995

All phenotypic correlations among the six traits studied were positive and are rendered in table 7. From among these data we may observe that seed yield was strongly correlated to oil content and boll number/m^2 and poorer but very significantly statistically ensured with oil content.

Plant height was distinct significantly correlated only with boll number/m^2.

Table 7. Correlation coefficients among the 6 traits analysed in linseed, RICIC – Fundulea, 1995

Trait	Plant height	Boll No/m^2	TKW	Oil content	Oil yield
Seed yield	0.21^{NS}	0.81***	0.09^{NS}	0.56***	0.98***
Plant height	X	0.53**	0.00^{NS}	0.16^{NS}	0.20^{NS}
Boll No/m^2	X	X	0.08^{NS}	0.46***	0.78***
TKW	X	X	X	0.13^{NS}	0.10^{NS}
Oil content	X	X	X	X	0.69***
Oil yield	X	X	X	X	X

, * - Significant for 1% respectively 0.1%
NS – Non – significant

Boll number/m^2 was furthermore very significantly correlated with oil yield and oil content.

From the six traits analysed, TKW seems to be the most neutral traits as compared to the other ones, as it is not significantly correlated to either of these.

Logically speaking, oil content was very significantly correlated with oil yield.

These data show that boll number/m^2 is one of the most important determining factors of seed yield in linseed, this being an aspect emphasized in all papers of Badwal et al. (1970 and 1971).

CONCLUSIONS

This study confirms the previous results, by showing that in the heritability of some important traits for the breeding process in linseed such as plant height, boll number/m^2, TKW, seed yield and oil content, both additive and non-additive effects of genes involved in their control are equally important. Nevertheless, additive effects of genes play a prevailing role which permits us to assert that in the case of linseed the utilization of a correctly selected material as well as the utilization of the most adequate selection methods, will result in a continous genetic progress in breeding these traits.

Parental genotype which proved to have high GCA effect will be able to be exploited in linseed breeding, on the basis of recurrent selection system.

Narrow sense heritability coeffcients or parent – offspring regression showed in general rather high values for most of these traits, a fact which means that these traits have a relatively uniform or uniform transmission to the offspring.

Considering the aim of using in the breeding process of these traits both additive and non-additive effects of the genes which control them, it is necessary to use in this process a system of selection and of inter-crossing within early generations (preferable F_2), which will lead to fixing these trait at a level as high as possible.

REFERENCES

Anand, I.J. and Murty, B.R., 1969. Serial analysis of combining ability in diallel and fractional diallel crosses in linseed. T.A.G. 39: 88-94.

Badwal, K.S., Gill, K.S., Singh, H., 1970. Path coefficient ananlysis of seed yield in linseed. Indian J. Gen. Pl. Beed. 30 (3): 551-556.

Badwal, K.S., Gill, K.S., Singh, H., 1971. Correlation and regression studies in linseed. Indian J. Agric. Sci. 41: 4

Badwal, S.S., Gupta, V.P., Gill, K.S., 1972a. Combining ability studies of selected world germplasm lines of linseed.. J. Res. Punjab Agric. Univ. 9: 383-388.

Badwal, S.S., Gupta, V.P., Gill, K.S., 1972b. Heritability of seed yield and its components in linseed (*Linum usitatissimum* L.). J. Res., IX (4): 528-530.

Ceapoiu, N., 1968. Metode statistice aplicate în experienţele agricole ºI biologice. Edit. Agric. Silvicã, Bucureºti.

Comstock, V.E., 1960. Early generation selection for high oil content and high quality in flax. Univ. Minn. Agr. Exp. Sta. Tech. Bul. 234.

Comstock, V.E. and Gates, C., 1965. Effectiveness of selection for seed quality characters in advanced generations of flax. Crop Sci. 5 (4).

Dalal, J.L. and Gill, K.S., 1965. General combining ability and heterosis in some F_1 intervarietal crosses of linseed, Indian Oil Seeds J. 9: 61-66.

Doucet, I., 1976. Capacitatea combinativã a unor soiuri de in. Prob. Genet. Teor. Apl., CIII (2): 17-92.

Doucet, I., 1978. Analiza geneticã a unor caratere la in. Probl. Genet. Teor. Apl., X (6): 597-609.

Doucet, I., Doucet, M., Popescu, F., 1979. Capacitatea combinativã a unor soiuri de in analizate prin metoda hibridãrilor dialele incomplete. An. ICCPT Fundulea, XLIV: 51-62.

Doucet, I., Popescu, F., Doucet M., Ioan G., Marinescu, I., 1981. Capacitatea combinativã privind rezistenţa la fuzariozã a unor soiuri de in. An. ICCPT Fundulea, XLVIII: 55-65.

Falconer, D.S., 1967. Introduction to quantitative genetics. Oliver and Boyd Ltd. Edinburgh and London.

Galkin, F.M., 1969. Combinaţionaia sposobnosti sortov Ina maslicinogo. Biul. Naucino. Tehn. Inform. Po Mals. Kulturam: 84-88.

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing system. Australian J. Biol. Sci. 9: 463-493.

Kasim, H.M., 1962. The analysis of combining abilities for oil content and iodine number in diallel crosses among ten variaties of flax. 32nd Annual Flax Institute of the U.S.: 7-10.

Murty, B.R., Aurachalam, V., Anand, I.J., 1967. Diallel and partial diallel analysis of some yield factors in *Linum usitatissimum*. Heredity 22: 35-41.

Patil, V.D. and Chopde, p.R., 1981. Genetic arhitecture of yield in *Linum usitatissimum* L. Z. Pflanzezuchtg. 87: 248-253.

Popescu, F., Marinescu, I. Vasile, I., 1995. Heredity of the linseed oil content. Rep. Flax. Breed. Gen. Resour. Group Worksh., 5 – 7 Nov. 1995, France.

Rosbaco, A., 1959. Determination de la “Heredabilidad” en diversos caracteres agronomicos en lino. Rev. invest. Agric., XIII (1): 5-17.

Shehata, A.H. and Comstock, V.E., 1971. Heterosis and combining ability estimates in F_2 flax populations as influenced by plant density. Crop Sci. 11: 534-536.

Simmonds, N.W., 1979. Principles of crop improvement. Longman Group Ltd., London and New York.

Simmonds, N.W., 1989. How frequent are superior genotypes in plant breeding populations. Biol. Rev. 64: 341-365.

Singh, M., Ceccarellli, S., Hamblin, J., 1993. Estimation of heritability from varietal trials data. T.A.G. 86: 437-441

Sprague G.F. and Tatum, L.A., 1942. General versus specific combining ability in crosses of corn. J. Amer. Agron. 34: 923-932.

Table 1

Sunflower inbred lines with high oleic acid content, after introducing Ol gene

The genotypes (inbred lines)	High oleic content (%)
HO-842-1 (very tolerant to *Phomopsis*)	89.8
HO-97-842-2 (tolerant to *Phomopsis*)	81.1
HO-804-1 (very tolerant to *Phomopsis*)	89.2
HO-804-2 (tolerant to *Phomopsis*)	80.0
HO-850 (medium tolerant to *Phomopsis*)	88.2
HO-822 (medium tolerant to *Phomopsis*)	83.5
HO-837 (resistant to *Orobanche*)	89.0
HO-884-RF (medium tolerant to *Phomopsis*)	81.2

HO-920 -RF (resistant to *Orobanche*)	89.1
HO-875 -RF (medium tolerant to *Phomopsis*)	81.1
HO-942 -RF (resistant to *Orobanche*)	85.0
HO-918 -RF (tolerant to *Phomopsis*)	84.3

Figure 1 - Selection scheme for introducing of high oleic acid content in fertility restoring and supporting of sterile lines.

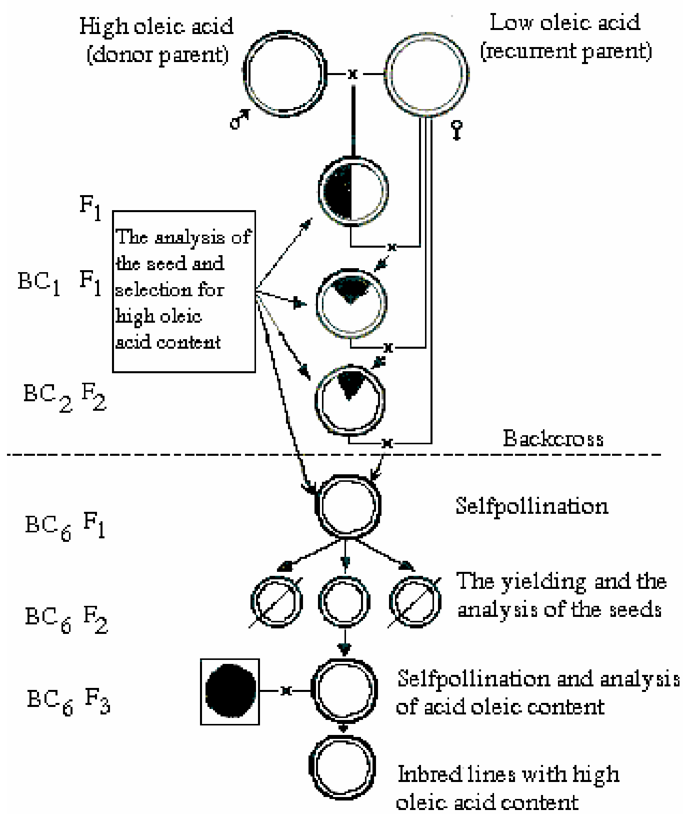

Table 2

The results concerning the tests for resistance to *Phomopsis / Diaphorte helianthi* Munt. Cvet et al. and *Orobanche cumana* Wall. of twelve sunflower inbreed lines with high oleic acid content, Fundulea, Constanta, 1998 - 1999

No.	The genotypes	*Phomopsis*				*Orobanche*			
		natural attack		artificial infection		natural attack		artificial infestation	
		high oleic (%)	attack	high oleic (%)	attack	high oleic (%)	attack	high oleic (%)	attack
1.	HO-842-1	82.0	1.7	80.0	7.8	89.0	68	88.7	77
2.	HO-842-2	80.7	3.9	78.1	12.9	80.7	53	79.1	61
3.	HO-804-1	84.2	0.9	81.1	1.7	88.3	57	87.4	66
4.	HO-804-2	79.2	5.0	71.9	14.2	80.3	48	78.2	61
5.	HO-850	69.1	20.7	49.9	50.0	77.2	37	77.0	59
6.	HO-822	65.0	20.3	40.1	58.1	78.0	41	74.7	74
7.	HO-837	65.2	27.4	48.7	59.4	89.1	0	89.1	0
8.	HO-884-RF	67.0	21.0	49.3	60.7	78.0	67	77.1	89
9.	HO-920-RF	69.0	19.3	51.4	44.6	79.3	1	78.0	3
10.	HO-875-RF	72.0	22.1	50.0	47.3	79.5	59	74.3	87
11.	HO-942-RF	71.3	18.2	51.4	43.8	80.7	1	77.0	2
12.	HO-918-RF	79.9	8.3	77.0	18.9	80.3	49	79.0	64
13.	Control 1 *Phomopsis*		**78.4**		**94.0**				
14.	Control 2 *Phomopsis*		**1.1**		**3.1**				
15.	Control 1 *Orobanche*						**89**		**100**
16.	Control 2 *Orobanche*						**0**		**0**

LSD 5% = 6,7	LSD5 % = 7,6	LSD 5% = 6,2	LSD 5% = 6,9
0,1% = 13,3	0,1% = 15,3	0,1% = 12,4	0,1% = 13,1

Table 3

Relations between *Phomopsis* resistance and higholeic acid content in F2 generation-seeds

No	Cross	High oleic content (%)	*Phomopsis* attack
1.	HO-842 -1 x HO-884 RF	81.1	7.3
2.	HO-842 -1 x HO-875 RF	80.0	11.0
3.	HO-842 -1 x HO-918 RF	89.3	0.4
4.	HO-842 -2 x HO-884 RF	66.6	27.3
5.	HO-842 -2 x HO-875 RF	52.4	31.5
6.	HO-842 -2 x HO-918 RF	80.1	10.7
7.	HO-804 -1 x HO-884 RF	80.0	5.2
8.	HO-804 -1 x HO-875 RF	77.2	13.7
9.	HO-804 -1 x HO-918 RF	89.1	1.7
10.	HO-804 -2 x HO-884 RF	67.2	33.5
11.	HO-804 -2 x HO-875 RF	50.0	29.7
12.	HO-804 -2 x HO-918 RF	79.8	12.8
13.	HO-850 x HO-884 RF	35.2	41.5
14.	HO-850 x HO-875 RF	34.5	39.1
15.	HO-850 x HO-918 RF	68.3	19.4
16.	HO-822 x HO-884 RF	37.7	47.1
17.	HO-822 x HO-875 RF	31.0	44.7
18.	HO-822 x HO-918 RF	61.3	32.4

LSD 5% = 6,3
LSD 0,1% = 11,8 r = -0,94***

Table 4

Relations between *Orobanche* resistance and high oleic acid content, in F2 generation-seeds

No	Cross	High oleic content (%)	*Orobanche* attack
1.	HO-837 x HO-884 RF	82.8	0
2.	HO-850 x HO-884 RF	60.3	72
3.	HO-822 x HO-884 RF	61.8	67
4.	HO-837 x HO-920 RF	81.7	0
5.	HO-842 -1 x HO-920 RF	84.7	9
6.	HO-804 -1 x HO-920 RF	81.0	11
7.	HO-850 x HO-920 RF	60.3	14
8.	HO-822 x HO-920 RF	68.5	17
9.	HO-837 x HO-875 RF	82.3	0
10.	HO-850 x HO-875 RF	66.6	87
11.	HO-837 x HO-942 RF	85.3	0
12.	HO-842 -1 x HO-942 RF	81.1	15
13.	HO-804 -1 x HO-942 RF	84.4	22
14.	HO-850 x HO-942 RF	71.2	19
15.	HO-822 x HO-942 RF	70.4	12
16.	HO-837 x HO-918 RF	85.3	0
17.	HO-850 x HO-918 RF	75.4	78
18.	HO-822 x HO-918 RF	71.9	83
19.	HO-842 -1 x HO-884	80.4	64
20.	HO-842 -1 x HO-875	82.8	77

LSD 5% = 5,5 r = -0,42*
0,1% = 10,1