HEREDITY AND STABILITY OF FLAX FIBER CONTENT

Florea Popescu, Ioana Marinescu and Ioana Vasile[1]

ABSTRACT

In comparison with many other crops, studies concerning heredity and stability for the majority of fiber flax (*Linum usitatissimum* L.) metric traits are very few or they are laking entirely. This paper has the aim to contribute to the covering of a little part of this lack of data with some results regarding heredity and stability of flax fiber content, one of the most important fiber flax traits. These results were achieved at the Research Institute for Cereals and Industrial Crops – Fundulea (R.I.C.I.C.), Romania in 1994 and 1995 years. The genetical assessment of flax fiber content was made on the basis of the test performed in the flax nursery on 36 F_1 flax direct hybrids (released by a p(p-1)/2 diallel cross among nine flax genotypes) and their parents, in the two experimental years. Phenotypic (simple) correlation coefficients among fiber content and plants length, deseeded straw yield and fiber yield suggested that this trait was significantly connected only with fiber yield. The main results of the study showed that both additive and dominance effects were involved in the heredity of this trait, dominance being however prevalent. For this set of flax parents, the gene or the group of dominant genes involved in the genetic control of fiber content operate after an "over dominance" type genetic mechanism, dominance being undirectional and dominant alleles having an increasing effect on it. These data suggested also that both types of genetic effects (additive and dominance) which are grovering this trait were very affected by the environmental conditons. In the strict case of this group of fiber flax parental genotypes, fiber content heritability coefficients, in narrow sense, have a high level, confirming that this trait is usually transmitted very uniformly to the offspring.

Key words: flax fiber content, genetic control and stability, *Linum usitatissimum* L., parent – offspring regression, phenotypic (simple) correlation.

INTRODUCTION

In Romania as in any other European countries (France, Belgium, Holland, Poland, Russia and so on), fiber flax has been grown as one of the most important textile crops along all Romanian people's history till nowadays, this plant being well adapted for many Romania's crop areas.

Fiber content or fiber percentage in the technical stem of flax, which besides other traits like: plants height, straw yield, lodging and disease resistance, are used in the breeding process, is one of the main criteria for choosing parents to be crossed into a hybridization programme to improve fiber yield in fiber flax.

All flax breeders know (more or less empirically) from the breeding practice that this trait has a good heritability and it is also quite well correlated with fiber yield potential (Fouilloux et al., 1991; Scheer-Triebel, 1993; Popescu et al., 1995) but only very few data exist concerning its genetic control (Fouilloux et al., 1991; Kowalinska and Rogalska, 1994; Popescu et al., 1995) and none regarding of its stability.

The purpose of this study was to clear up some aspects of these problems using the data achieved at RICIC Fundulea, in order to assist the theoretical and practical breeding programme of this crop.

MATERIALS AND METHODS

A set of 36 F_1 flax hybrid combinations was released by a p(p-1)/2 diallel cross system among nine parental flax genotypes at RICIC in 1993.

The nine parental genotypes, which differ in their mean fiber content, were Ethiopia (25.8%), Viking (25.0%), L-448-85 (24.9%), Atlas 23 (23.8%), Ariadna (23.1%), L-439-85 (22.2%), L-5416-87 (22.0%), L-6223-97 (21.7%) and Korean 132 (21.2%).

Origin, fiber content, plant length, deseeded straw yield and fiber yield of the parental genotypes are presented in table 1.

In 1994 and 1995, four replicate complete randomised block designs were used for testing F_1 hybrid generations and parental genotypes, each elementary plot consisting in three rows (1.5 m length, 0.21 m distance between rows) mechanically driled with Seedmatic machine (Wintersteiger, Austria).

Fiber content (chemically assessed) was established on the middle part of flax stems harvested on the central rows.

Results concerning fiber content of these experiments were subjected to a chain of sta-

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

Table 1. Characterization of nine flax parental genotypes. RICIC Fundulea, 1994 – 1995

Parent	Origin	Fiber content (%)			Plant length (cm)			Deseeded straw yield (kg/ha)			Fiber yield (kg/ha)		
		1994	1995	Mean	1994	1995	Mean	1994	1995	Mean	1994	1995	Mean
L-439-85	Romania	20.9	23.5	22.2	95.0	90.0	92.5	8760	7910	8335	1575	1673	1624
L-448-85	Romania	23.2	26.5	24.9	100.0	100.0	100.0	8200	7690	7945	1636	1834	1735
Viking	France	23.6	26.5	25.0	75.0	80.0	77.5	5800	6510	6155	1177	1552	1365
Ethiopia	Ethiopia	23.5	28.1	25.8	90.0	85.0	87.5	7680	6980	7330	1552	1765	1658
L-5416-87	Romania	20.3	23.6	22.0	90.0	90.0	90.0	7140	6730	6935	1247	1429	1338
L-6223-87	Romania	19.8	23.6	21.7	100.0	105.0	102.5	7080	7630	7355	1206	1620	1413
Ariadna	Poland	21.1	25.1	23.1	95.0	95.0	95.0	7080	7420	7250	1285	1676	1480
Korean 132	Korea	19.3	23.1	21.2	80.0	85.0	82.5	5910	6470	6190	981	1345	1163
Atlas 23	Germany	21.1	26.4	23.8	75.0	90.0	82.5	6300	6850	6575	1143	1628	1386
Mean		21.4	25.2	23.3	88.9	91.1	90.0	7110	7132	7119	1311	1614	1462
LSD 5%		0.2	0.3	0.2	4.0	5.2	4.5	570	510	535	105	146	122

tistical analyses such as: phenotypic correlations, block variance analysis and genotype x year interaction analysis (Ceapoiu, 1968), ½ diallel tables variance analysis (Walters and Morton, 1978), covariance and variance graphical analysis (Jinks and Hayman, 1953; Hayman, 1954), evaluation of components of genetic variance (Jinks, 1954; Hayman, 1954; Mather and Jinks, 1974), assessing of values of theoretical parents with maximum number of dominant and recessive genes (Joshi et al., 1961), correlation between mean parent values and the corresponding sum of covariance and variance (Mather and Jinks, 1974), stability of additive and dominance effects (Allard, 1965) and parent-offspring regressions (Simmonds, 1979).

RESULTS AND DISCUSSIONS

Phenotypic correlation coefficients among fiber content, plant length, deseeded straw yield and fiber content of the nine flax parental genotypes (Table 2) pointed out that in both experimental years, fiber content was positively correlated (P>0.05) only with fiber yield.

Mean fiber content of the nine flax parental genotypes and their 36 F_1 direct hybrids showed that in both 1994 and 1995 years, the best parents were Ethiopia, Viking and L-448-85 and their hybrids and the worst were generally Korean 132, L-6223-87 and L-5416-87 and their hybrids (Table 3).

The same results suggest also that F_1 hybrid values tend generally to the best parent value or to a better one.

Table 2. Phenotypic correlation coefficients among fiber content, plant length, deseeded straw yield and fiber yield of nine flax parental genotypes.
RICIC Fundulea, 1994 – 1995

Independent variable	Year	Dependent variable: Plant length	Deseeded straw yield	Fiber yield
Fiber content	1994	-0.07^{NS}	0.17^{NS}	0.66*
	1995	-0.25^{NS}	-0.15^{NS}	0.65*
Plant length	1994		0.78*	0.69*
	1995		0.73*	0.40^{NS}
Deseeded straw yield	1994			0.91**
	1995			0.68*

NS = non significant
*, ** = significant for P<0.05 and 0.01 respectively

In both experimental years, block variance analysis showed a very significant genotypic variance (Table 4).

Genotype x year interaction analysis spotlighted that genotypes, years and genotype x year interaction were very significant in the F test given to error variance (s^2_E), genotypes and years remaining also very significant in the F test given to error of interaction variance ($s^2_{G \times Y}$), what suggests that fiber content was very susceptible to the influence of each year growth conditions, so that each year should be treated individually (Table 5).

In the two experimental years, 1/2 diallel table variance analysis indicated that both additive and dominance effects were very significanly involved in the genetic control of flax fiber content (Table 6).

The same data proved also that dominance was prevalent in heredity of this trait because in both experimental years the all dominance effects variances ($I + I_i + I_{i \times j}$) were bigger than the additive ones (gi).

Table 3. Fiber content (%) of nine flax parental genotypes and of all their 1/2 diallel F_1 hybrids. RICIC Fundulea, 1994 – 1995

Genotype	1994					1995					1994-1995
	Replication					Replication					
	I	II	III	IV	Mean	I	II	III	IV	Mean	Mean
1. L-439-85	20.3	20.7	21.3	21.4	20.9	23.4	23.7	22.9	23.8	23.5	22.2
2. L-439-85/L-448-85	22.1	21.6	21.7	21.8	21.8	23.8	24.3	24.1	23.2	23.9	22.8
3. L-439-85/Viking	24.3	25.4	24.2	25.0	24.7	27.2	26.7	27.5	27.7	27.3	26.0
4. L-439-85/Ethiopia	24.4	23.8	24.1	24.4	24.2	28.1	27.6	28.5	28.3	28.1	26.2
5. L-439-85/L-5416-87	22.4	22.9	22.1	22.2	22.4	23.4	23.9	23.7	23.1	23.5	23.0
6. L-439-85/L-6223-87	21.5	21.9	21.8	21.7	21.7	25.4	25.0	25.9	25.2	25.4	23.5
7. L-439-85/Ariadna	22.6	22.7	22.2	22.7	22.6	26.4	26.9	26.7	26.0	26.5	24.6
8. L-439-85/Korean 132	22.5	21.8	22.4	22.1	22.2	23.9	24.2	24.5	23.4	24.0	23.1
9. L-439-85/Atlas 23	22.2	21.6	22.2	22.8	22.2	26.0	25.5	26.1	26.4	26.0	24.1
10. L-448-85	23.4	23.5	22.8	23.2	23.2	26.4	26.7	26.9	26.0	26.5	24.9
11. L-448-85/ Viking	22.6	23.2	23.2	22.2	22.8	26.6	27.1	26.1	26.9	26.7	24.7
12. L-448-85/ Ethiopia	23.4	22.8	23.1	23.1	23.1	28.0	28.4	27.5	28.3	28.1	25.6
13. L-448-85/ L-5416-87	21.6	20.6	20.9	21.3	21.1	22.4	21.9	22.7	22.9	22.5	21.8
14. L-448-85/ L-6223-87	20.5	20.3	20.5	21.0	20.6	24.5	24.8	24.9	24.1	24.6	22.6
15. L-448-85/ Ariadna	23.6	23.4	23.8	23.4	23.6	25.0	25.5	25.3	24.6	25.1	24.4
16. L-448-85/ Korean 132	20.2	19.9	19.8	19.3	19.8	23.1	24.1	22.6	23.5	23.3	21.6
17. L-448-85/ Atlas 23	20.8	20.6	20.7	21.0	20.8	24.5	24.7	24.1	25.0	24.6	22.7
18. Viking	23.0	24.5	23.2	23.6	23.6	26.5	26.6	26.8	26.1	26.5	25.1
19. Viking/ Ethiopia	23.7	23.1	24.4	23.1	23.6	26.1	26.6	25.6	26.4	26.2	24.9
20. Viking/ L-5416-87	23.4	23.4	22.7	24.0	23.4	26.4	26.0	26.1	26.3	26.2	24.8
21. Viking/ L-6223-87	22.8	23.5	23.2	23.3	23.2	28.3	27.9	28.8	28.6	28.4	25.8
22. Viking/ Ariadna	23.9	23.3	23.3	23.9	23.6	25.2	25.7	25.5	24.7	25.3	24.4
23. Viking/ Korean 132	21.6	21.1	21.7	21.5	21.5	25.7	25.2	26.1	26.0	25.8	23.6
24. Viking/ Atlas 23	23.0	23.2	22.8	23.0	23.0	27.1	28.0	27.6	27.3	27.5	25.3
25. Ethiopia	22.8	23.9	23.6	23.8	23.5	28.0	28.2	27.5	28.5	28.1	25.8
26. Ethiopia/ L-5416-87	23.1	22.9	22.7	23.9	23.2	27.2	27.6	27.5	26.7	27.3	25.2
27. Ethiopia/ L-6223-87	23.1	22.9	23.4	23.1	23.1	27.2	26.8	27.5	27.4	27.2	25.2
28. Ethiopia/ Ariadna	23.0	22.8	22.6	22.7	22.8	28.0	28.3	27.5	28.5	28.1	25.4
29. Ethiopia/ Korean 132	21.4	22.5	22.0	22.4	22.1	27.2	26.8	27.7	27.5	27.3	24.7
30. Ethiopia/ Atlas 23	23.3	23.9	24.0	23.4	23.7	29.5	29.0	29.8	30.1	29.6	26.7
31. L-5416-87	20.8	19.4	20.6	20.4	20.3	23.6	24.0	23.1	23.8	23.6	22.0
32. L-5416-87/ L-6223-87	20.6	20.6	20.9	19.8	20.5	24.7	25.0	25.2	24.2	24.8	22.6
33. L-5416-87/ Ariadna	20.3	21.3	19.7	20.4	20.4	23.0	23.5	22.5	23.4	23.1	21.8
34. L-5416-87/ Korean 132	19.1	19.6	19.8	19.3	19.5	24.3	24.5	27.7	23.9	25.1	22.3
35. L-5416-87/ Atlas 23	19.5	20.3	19.7	20.1	19.9	25.0	25.2	25.5	23.5	24.8	22.4
36. L-6223-87	19.9	19.7	19.5	20.0	19.8	23.5	24.0	23.7	23.0	23.6	21.7
37. L-6223-87/ Ariadna	20.5	21.0	20.6	20.1	20.6	25.2	25.6	25.5	24.7	25.3	22.9
38. L-6223-87/ Korean 132	20.5	20.7	20.8	20.8	20.7	23.8	23.3	23.3	24.1	23.6	22.2
39. L-6223-87/ Atlas 23	22.1	22.0	21.7	21.7	21.9	27.1	26.6	27.5	27.4	27.2	24.5
40. Ariadna	21.6	20.9	20.7	21.2	21.1	25.0	24.6	25.4	25.3	25.1	23.1
41. Ariadna/ Korean 132	20.4	20.2	20.7	20.1	20.4	26.1	25.6	26.4	26.6	26.2	23.3
42. Ariadna/ Atlas 23	20.9	21.1	21.1	21.2	21.1	27.2	27.3	27.6	27.4	27.4	24.2
43. Korean 132	19.0	19.8	19.3	19.2	19.3	23.0	22.5	23.5	23.3	23.1	21.2
44. Korean 132/ Atlas 23	19.8	19.3	20.6	20.5	20.1	25.6	25.1	26.1	25.9	25.7	22.9
45. Atlas 23	20.7	21.2	21.5	21.1	21.1	26.3	26.6	26.8	25.8	26.4	23.7
General mean					21.9				25.7	23.8	
LSD 5%					0.2				0.3	0.2	
Coefficient of variation, %					1.80					1.64	1.72

Table 4. Block variance analysis for flax fiber content. RICIC Fundulea, 1994 – 1995

Source of variation	1994			1995		
	SS	DF	s^2	SS	DF	s^2
Blocks	0.17	3		0.61	3	
Genotypes	368.01	44	8.36***	533.57	44	12.13***
Error	20.56	132	0.16	23.45	132	0.18
Total	388.74	179		557.63	179	

*** Significant for P<0.001

Table 5. Genotype x year interaction analysis for flax fiber content. RICIC Fundulea, 1994 – 1995

Source of variation	SS	DF	s^2	F	
				s^2_E	s^2_{GxY}
Blocks	0.78	6	0.13		
Genotypes (G)	772.27	44	17.55	105.29***	5.97***
Years (Y)	1321.35	1	1321.35	7926.50***	449.61***
G x Y	129.31	44	2.94	17.63***	
Error (E)	44.00	264	0.17		
Total	2267.71	359			

*** - significant for P<0.001

Table 6. 1/2 diallel table variance analysis for flax fiber content. RICIC Fundulea, 1994 – 1995

Source of variation	1994			1995		
	SS	DF	s^2	SS	DF	s^2
Additive contribution of i genotype (g_i)	84.46	8	20.56***	102.56	8	12.82***
Mean deviation due to dominance (l)	8.73	1	8.73***	14.59	1	14.59***
Dominance deviation due to i genotype (l_i)	33.98	8	4.25***	54.43	8	6.80***
Dominance deviation due to i x j cross (l_{ij})	54.55	27	2.02***	117.60	27	4.36***
Error	20.56	132	0.16	23.45	132	0.18

*** - significant for P<0.001

Both in 1994 and 1995 years, significance of all three kinds of dominance effects revealed that for this set of genitors, flax fiber content was unidirectional (l component), positive and negative alleles which control this trait were asymetrically distributed among the nine parents (l_i componenet) and some hybrids with specific reaction ($l_{i\ x\ j}$ component) were present.

In the two experimental years, investigating additive and dominance effects for fiber content at each individual parental level, one can see that the genotypes Ethiopia, Viking and L-448-85 had positive additive effects and L-439-85, L-6223-87, Ethiopia, Viking and Ariadna, positive dominance effects (Table 7).

Concerning the positive specific reaction for fiber content (dominance deviations due to the i x j cross), the best hybrid combinations in the two testing years were: L-448-85 / Ariadna, Viking / L-6223-87, Viking / L-5416-87, Ethiopia / Atlas 23, L-6223-87 / Atlas 23, Ethiopia / L-5416-87, L-439-85 / Viking, L-448-85 / Ethiopia and Ethiopia / Korean 132 (Table 8).

First step in covariance (Wr) and variance (Vr) graphical analysis was variance analysis of covariance differences (Wr – Vr) which represents a test of significance for additive dominance model, used to explain the genetic control of this trait. Since (Wr-Vr) were constant in both experimental years, there was no

Table 7. Additive effects (g_i), dominance deviation (l_i) and mean dominance deviation (l) of the nine flax parental genotypes for fiber content

Parental genotype	1994		1995	
	gi	li	gi	li
L-439-85	-0.25±0.01	1.10±0.02	-0.84±0.01	0.54±0.02
L-448-85	0.90±0.01	-1.23±0.02	0.68±0.01	-1.85±0.02
Viking	1.07±0.01	0.34±0.02	0.68±0.01	0.24±0.02
Ethiopia	1.04±0.01	0.35±0.02	1.46±0.01	0.69±0.02
L-5416-87	-0.57±0.01	-0.23±0.02	-0.75±0.01	-0.72±0.02
L-6223-87	-0.83±0.01	0.31±0.02	-0.79±0.01	0.74±0.02
Ariadna	-0.17±0.01	0.26±0.02	-0.03±0.01	0.04±0.02
Korean 132	-1.05±0.01	-0.34±0.02	-1.03±0.01	0.09±0.02
Atlas 23	-0.15±0.01	-0.32±0.02	0.62±0.01	0.22±0.02
	$\Sigma g_i = 0$	$\Sigma l_i = 0$	$\Sigma g_i = 0$	$\Sigma l_i = 0$
	I = 0.55±0.01		I = 0.71±0.01	

Table 8. Dominance deviations due to the i x j cross $l_{i\,x\,j}$ for flax fiber content. RICIC Fundulea, 1994 – 1995

Female genotype	Year	Male genotype							
		L-448-85	Viking	Ethiopia	L-5416-87	L-6223-87	Ariadna	Korean 132	Atlas 23
L-439-85	1994	-0.69	4.08	-0.05	0.37	-0.58	-0.14	0.77	-0.15
	1995	-0.53	0.80	0.43	-0.55	-0.11	0.94	-0.60	-0.38
L-448-85	1994	x	-0.26	0.06	0.25	-0.55	2.04	-0.45	-0.40
	1995	x	1.07	1.21	-0.74	-0.05	0.40	-0.42	-0.95
Viking	1994	x	x	-1.22	0.78	0.32	0.34	-0.53	0.08
	1995	x	x	-2.75	0.90	1.68	-1.51	-0.08	-0.11
Ethiopia	1994	x	x	x	0.57	0.27	-0.46	-0.09	0.75
	1995	x	x	x	0.73	-0.71	0.07	0.25	0.77
L-5416-87	1994	x	x	x	x	-0.19	-0.62	-0.34	-0.81
	1995	x	x	x	x	0.45	-1.29	0.92	-0.42
L-6223-87	1994	x	x	x	x	x	-0.77	0.63	0.89
	1995	x	x	x	x	x	-0.55	-1.22	0.52
Ariadna	1994	x	x	x	x	x	x	-0.10	-0.29
	1995	x	x	x	x	x	x	1.26	0.68
Korean 132	1994	x	x	x	x	x	x	x	-0.06
	1995	x	x	x	x	x	x	x	-0.10
Atlas 23	1994	x	x	x	x	x	x	x	x
	1995	x	x	x	x	x	x	x	x

var ($l_{i\,x\,j}$) 1994 = 0.029
var ($l_{i\,x\,j}$) 1995 = 0.029

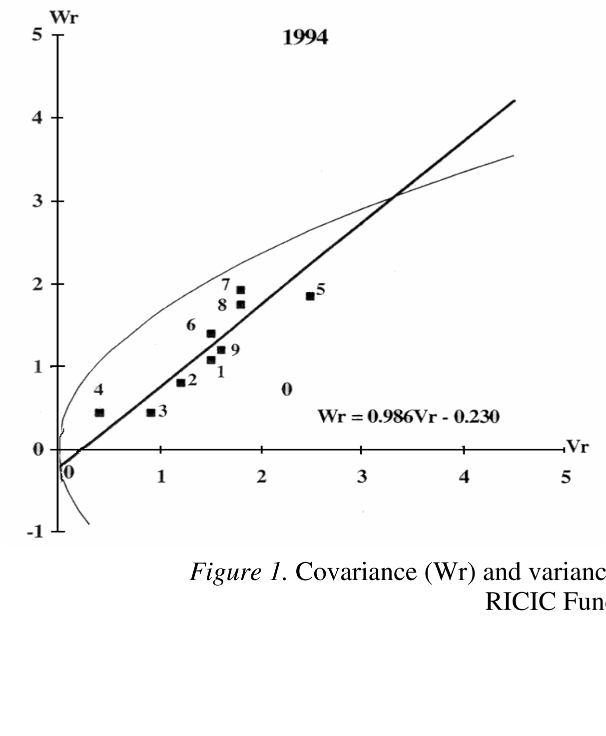
Table 9. Variance analysis of covariance – variance differences ($W_r - V_r$). RICIC Fundulea, 1994 – 1995

Source of variation	1994				1995			
	SS	DF	s^2	F	SS	DF	s^2	F
Blocks	0.572	3			3.693	3		
Arrays (Wr – Vr)	1.136	8	0.142	2.168^{NS}	2.634	8	0.329	1.906^{NS}
Error	1.572	24	0.066		4.146	24	0.173	
Total	3.280	35			10.473	35		

N.S. – non significant

reason to doubt that this model was adequate to explain fiber content heredity (Table 9).

The same thing was also confirmed in covariance and variance graphical analysis of the regression slope which do not differ significantly from the value of one, both in 1994 and 1995 years (Figure 1). Thus the two kinds of significance test agree in showing that the model is satisfactory in explaining the genetic control of fiber content.



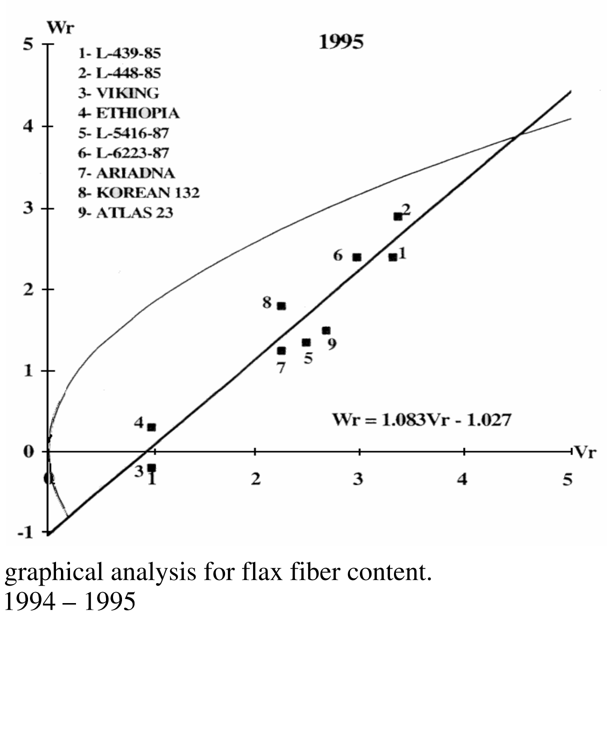


Figure 1. Covariance (Wr) and variance (Vr) graphical analysis for flax fiber content. RICIC Fundulea, 1994 – 1995

In both experimental years, the main aspects revealed by the covariance and variance graphical analysis were:

- flax fiber content had an “over dominance” type of genetic control, both in 1994 and 1995 years, departure from the origin of point where the regression line cutted Wr axis (a) have had a negative value (Figure 1);
- parents with the highest number of dominant genes were Ethiopia and Viking in 1994 and Viking and Ethiopia in 1995 (Figure 1);
- parents with the highest pluralism of recessive genes were L-5416-87, Ariadna and Atlas 23 in 1994 and L-448-85, L-439-85 and L-6223-87 in 1995 (Figure 1);
- in both years, none from these parental genotypes was too near to theoretical parents with a maximum number of dominant or recessive genes.

Next step of this genetic analysis was the estimation of the components of genetic variance D, H_1, H_2, F, h^2 and E, of their proportional values with genetical significance and of heritability coefficients (Table 10).

Table 10. Components of the genetic variation for flax fiber. RICIC Fundulea, 1994 – 1995

Component	Values 1994	Values 1995
a) Genetic parameter		
D	2.647±0.035	3.156±0.054
H_1	3.375±0.078	6.170±0.118
H_2	2.339±0.067	4.538±0.101
F	0.327±0.082	0.371±0.125
h^2	1.152±0.045	1.957±0.068
E	0.156±0.044	0.178±0.068
b) Proportional values		
$(H1/D)^{1/2}$	1.129	1.398
Vr/Wr	1.200	1.553
$H_2/4H_1$	0.172	0.184
$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}$	1.116	1.088
$\frac{1/2F}{[D(H_1-H_2)]^{1/2}}$	0.099	0.082
h^2/H_2	0.496	0.431
c) Heredity coefficients:		
- in narrow sense	0.694	0.627
- in broad sense	0.936	0.950

In the two experimental years, one remarks from this data that significance of both D (which estimate additive effects) and H_1, H_2 and h^2 (for dominance effects) parameters confirmed that in genetic control of fiber content the both kinds of effects were involved, however dominance being prevalent.

The values of F parameter near to one proved that among the nine flax parents, more dominant than recessive alleles were present, irrespective of whether they were increasing or decreasing in their effects on fiber content.

The over unitary values of proportional values $(H_1D)^{1/2}$ or V_r/W_r (which estimate the mean dominance ratio) indicated that dominance was of the “over dominance” type, what confirmed graphical analysis results.

The light over unitary values of the total number of dominant and recessive genes ratio among parents $((4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F)$, suggested a gentle asymetric distribution of these two kinds of genes into parental genotypes. In both years, this was also confirmed by H_2/H_1 ratio (estimating relative repartition of dominant and recessive genes among parents) which had values less than its maximum value of 0.25, which arises when these genes have the same frequency (0.5) at all loci.

Nearly zero values of $1/2F/(D(H_1-H_2)^{1/2}$ ratio suggested that dominance was very variable from one locus to another, in the both experimental years.

In the two testing years, from h^2/H_2 ratio, fiber content seems to be controlled by a gene or a group of dominant genes. Fiber content appeared to have a relatively high heritability, heritability coefficients being situated between 0.63 and 0.69 in narrow sense and between 0.94 and 0.95 in broad sense (Table 10).

Both in 1994 and 1995 years comparison between sum of covariance and variance of hybrids arrays with one common parent ($W'_r+V'_r$) and recessive ($W''_r+V''_r$) genes, evinced that none of the nine flax parental genotypes was near to these ones (Table 11). The highest dominant genes number among these nine parents exhibited Ethiopia and Viking in 1994 and Viking and Ethiopia in 1995.

Dominance order was very variable from one year to another being: Ethiopia, Viking, L-448-85, L-439-85, L-6223-87, Atlas 23, Korean 132, Ariadna and L-5416-87 in 1994 and Viking, Ethiopia, Ariadna, L-5416-87, Atlas 23, L-448-

Table 11. Mean parental fiber content (Yr), sum of covariance and variance of the arrays with one common parent (Wr + Vr), values of the theoretical parents with a maximum number of dominant (Wr' + Vr') and recessive (Wr" + Vr") genes and order of dominance for flax fiber content. RICIC Fundulea, 1994 – 1995

Parental genotype	1994				1995			
	Yr(%)	Wr+Vr	Wr'+Vr'	Wr" +Vr"	Yr(%)	Wr+Vr	Wr'+Vr'	Wr" +Vr"
L-439-85	20.93	2.81			23.45	5.41		8.43
L-448-85	23.23	2.73			26.50	5.08		
Viking	23.58	1.36			26.50	0.85	-0.61	
Ethiopia	23.53	0.93	-0.20		28.05	1.41		
L-5416-87	20.30	4.13		6.39	23.63	3.83		
L-6223-87	19.78	2.96			23.55	5.21		
Ariadna	21.10	3.81			25.08	3.60		
Korean 132	19.33	3.15			23.08	5.14		
Atlas 23	21.13	3.04			26.38	4.05		
Order of dominance	Ethiopia, Viking, L-448-85, L-439-85, L-6223-87, Atlas 23, Korean 132, Ariadna, L-5416-87				Viking, Ethiopia, Ariadna, L-5416-87, Atlas 23, L-448-85, Korean 132, L-6223-87, L-439-85			

85, Korean 132, L-6223-87 and L-439-85 in 1995.

In both experimental years, correlations between mean parental fiber content (Yr) and sum of covariance and variance of the hybrids arrays with one common parent (Wr + Vr) have had negative and significant values, r=-0.748* in 1994 and r=-0.694* in 1995 (Figure 2). It means that dominance of fiber content was unidirectional in both years, dominant alleles involved in genetic control of this trait having an increasing effect on fiber content.

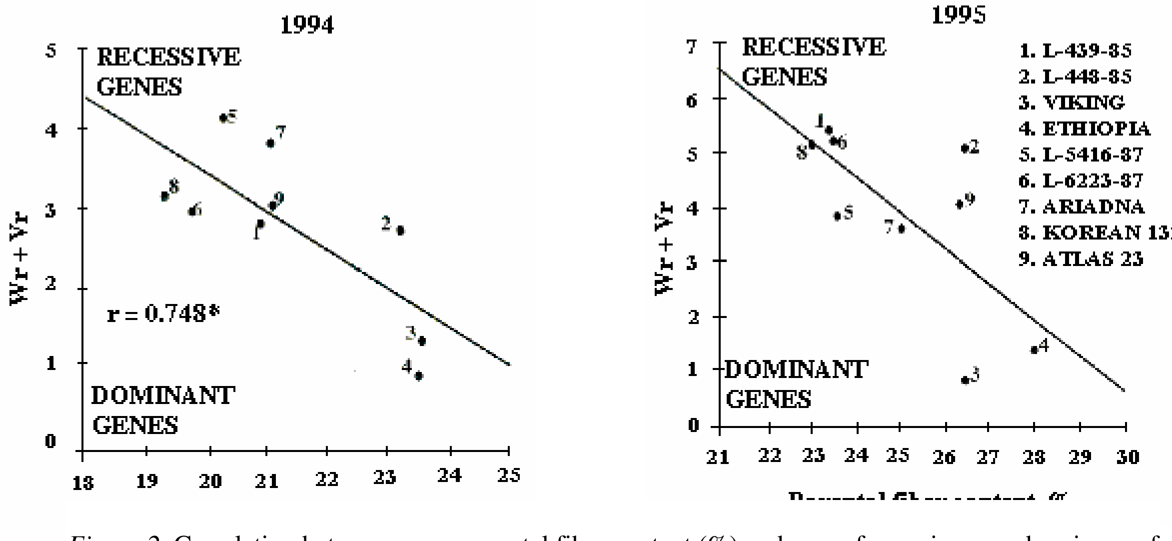


Figure 2. Correlation between mean parental fiber content (%) and sum of covariance and variance of hybrid array with a common parent (Wr + Vr) or flax fiber content. RICIC Fundulea, 1994 – 1995

The same results confirmed that varieties Viking and Ethiopia had the highest number of dominant genes for fiber content (Figure 2). Stability analysis of the genetic variance components, made in accordance with Allard's model (1956), had three stages.

First one was variance analysis of genotype x year interactions of parents in the two experimental years, like test for additive effects (Table 12). In a such kind of analysis, years (y) significance has not a genetical interpretation. Its significance, like in this case, means only that fiber content of the nine parental genotypes was very different from one year to another.

Additive effects constancy of genes which control fiber content was without doubt detected of the genotype x year interaction variance (G x Y).

Table 12. Genotype x year interaction variance analysis of the nine parental genotypes for flax fiber content. RICIC Fundulea, 1994 – 1995

Source of variation	SS	DF	s^2	F
Blocks	0.54	7	0.08	
Genotypes (G)	176.09	8	22.01	111.12***
Years (Y)	246.79	1	246.79	1245.88***
G x Y	10.94	8	1.37	6.90***
Error	9.31	47	0.20	
Total	443.67	71		

*** - Significant for P<0.001

Significance of this component indicated that fiber content additive effects were not constant from one year to another (Table 11).

Second stage of this analysis was represented by the dominance effects constancy testing. This was given by the genotype x years interaction analysis of covariance (Wr) and variance (Vr) of hybrid arrays with one common parent, in the two experimental years (Table 13).

Table 13. Genotype x year interaction variance analysis of the covariance (Wr) and variance (Vr) for flax fiber content. RICIC Fundulea, 1994 – 1995

Source of variation	SS	DF	s^2	F
Years (Y)	0.193	1	0.193	14.07***
Dominance (D)	1.010	1	1.101	80.34***
Y x D	0.209	1	0.209	15.28***
Arrays (A)	5.845	8	0.731	53.33***
Y x A	1.193	8	0.149	10.88***
D x A	0.132	8	0.016	1.20^{NS}
Y x D x A	0.191	8	0.024	1.74^{NS}
Error	1.437	105	0.014	

*** - Significant for P<0.001
NS – Non significant

For performing this analysis, covariance (Wr) and variances (Vr) from each replication were transformed by dividing to the parents mean variance obtained in the same replication. Years (Y), first component of this variance analysis, proved that fiber content mean dominance of these nine flax parents was very different in the two experimental years.

Significance of dominance (D) component indicated that dominance effects were present and $D<H_1$, it being a prove of the “over dominance” of fiber content.

Years x dominance (Y x D) component was the most obvious estimator of the mean dominance inconstancy, in the two experimental years. Its significance showed that fiber content dominance was not stable from one year to another and regression line in the Wr, Vr graphical analysis did not occupy the same position, in the two years (see Figure 1).

Arrays (A) component is a significance test for dominance differences among the nine parental genotypes from this diallel cross, its significance has proved that they differed very much one to another concerning dominance effects of the fiber content genes.

Inconstancy of the dominance relations among the nine flax parents from this diallel cross was tested by years x arrays (Y x A) component. Significance of this one has indicated that in the Wr, Vr graphical analysis the points representing these parents were different distributed from one year to another, dominance relationships among them being inconstant, in the two experimental years (see Figure 1).

The last two components of this analysis: dominance x arrays (D x A) and years x dominance x arrays (Y x D x A) are considered like a certain test for nonallelic interactions and for constancy of such kind of effects in different environments (Allard, 1956).

Non significance of these two components was a supplementary confirmation that for this set of parental genotypes, nonallelic interactions had not a considerable role in the fiber content heredity.

The last stage of this analysis, Wr, Vr, graphical analysis of genotype x year interaction for fiber content highlighted that fiber content heredity type was an “over dominance” one, this being uncomplicated of nonallelic interactions, for this group of genitors (Figure 3). In the same figure it is obvious that there were significant alterings of the parental positions along the regression line in the two experimental years, this showing the inconstancy of additive and dominance fiber content effects of these nine flax genotypes.

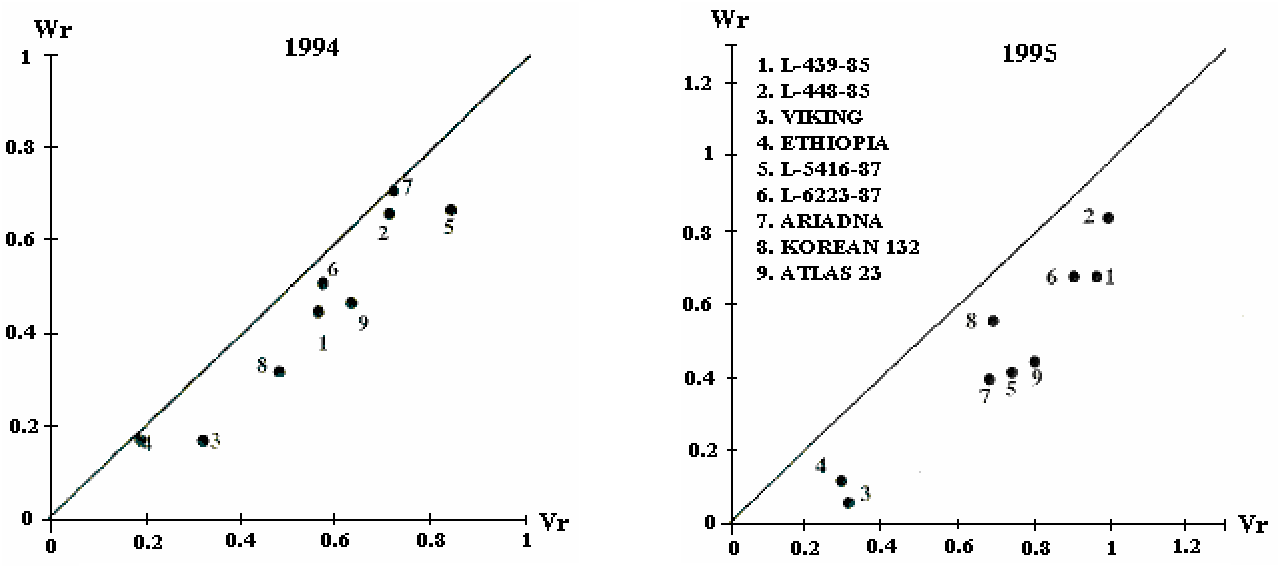


Figure 3. Covariance (Wr) and variance (Vr) graphical analysis of genotype x year interaction for flax fiber content. RICIC Fundulea, 1994 - 1995

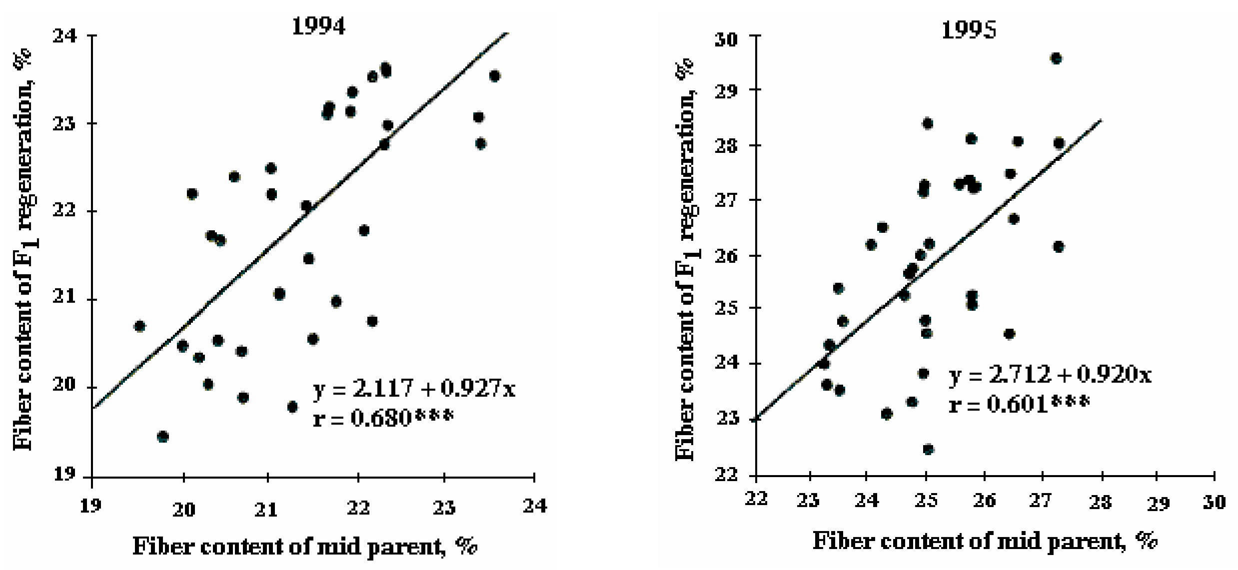


Figure 4. Mid parent – F_1 hybrid offspring regression for flax fiber content. RICIC Fundulea, 1994 – 1995

Parent-offspring regressions of the F_1 generation to mid parent fiber content (Figure 4), which give a direct measure of the narrow sense heritability (Simmonds, 1979), showed that flax fiber content had a high heritability (b = 0.927 in 1994 and b = 0.920 in 1995), these data proving also that previous values obtained by variance partition were underestimated (see Table 9). The magnitude of regression coefficients (significant for P<0.001) suggested that improvement of fiber content have a very good efficiency.

CONCLUSIONS

Fiber content is one of the most important fiber flax traits, its genetic study providing very valuable information, which is of a large interest in all flax breeding programmes.

These two years study data showed that both additive and dominance effects of the genes, which govern this trait, were involved in its control, dominance being however prevalent.

Dominance effects were unidirectional with an asymetric distribution of positive and negative alleles, which control this trait, among parents and with presence of some hybrids with specific reaction for fiber content.

All genetic picture of fiber content indicated that this trait had an “over dominant” genetic control. Total number of dominant and recesive genes had a light inequal frequencies among the nine flax parents, the dominant ones being more present, dominance being also very variable from one locus to another. It looks that in heredity of fiber content was involved one gene or group of dominant genes, this trait having a relatively high heredity. These dominant genes had generally an increasing effects on fiber content.

Because none of the nine flax parents was too nearly to the theoretical parents with maximum number of dominant or recessive genes, the probability to obtain superior segregants for fiber content is not so good by using these parents into a further breeding programme.

Both additive and dominance genes effects of the genes which govern this trait were very inconstant from one year to another, they being very affected by environment conditions.

Parent-offspring regression showed that fiber content had a higher heritability than that which was proved previously by variance partitions.

REFERENCES

Allard, R.W., 1965. The analysis of genetic environmental interactions by means of diallel crosses. Genetics, 41: 305-318.

Ceapoiu, N., 1968. Metode statistice aplicate în experiențele agricole biologice. Edit. Agro-Silvică, București: 183-191, 379-382, 457-461

Fouilloux, G., Trouve, J.P., Chabouche, L., Dhorne, D., 1991. Flax breeding for high productivity and high quality: Heredity of fibre content. Flax as a fibre and oil bearing crop. Proc. of the FAO European Regional Workshop on flax, 18-20 June, Brno, Czechoslovakia: 46-63.

Hayman, B.I., 1954. The theory and analysis of diallel crosses. Genetics, 39: 789-809.

Jinks, J.L., Hayman, B.I., 1953. The analysis of diallel crosses. Maize Genet. News. Letter, 27: 48-54.

Jinks, J.L., 1954. The analysis of heritable variation in a diallel cross of *Nicotiana rustica* varieties. Genetics, 39: 767-788.

Joshi, A.B., Ramanujam, S., Pillay, P.N.C., 1961. Breeding for quantitative characters in linseed. I. Utility of diallel crosses in selection of parents. Indian J. Genet. Pl. Breed., 21: 112-121.

Kovalinska, Z., Rogalska, S., 1994. Evaluation of combining abilities of flax. Report of Flax Genetic Resources Workshop, Second meeting, Brno, Czech Republic: 21-37.

Mather, K., Jinks, J.L., 1974. Biometrical genetics. Chapman and Hall Ltd. London: 249-271.

Popescu, F., Marinescu, I., Vasile, I., 1995. Study of the genetic control of the flax fiber content. Proc. of Third Meeting of the International Flax Breeding Research Group, 7-8 November, Saint-Valery-en-Caux, France.

Scheer-Triebel, M., 1993. Breeding of short fibre flax for industrial use. Proc. of the Third European Workshop on Flax, 15-17 June, Bonn, Germany: 139-147.

Simmonds, N.W., 1979. Principles of crops improvement. Longman, London and New-York: 95-96.

Walters, D.E., Morton, J.R., 1978. On the analysis of variance of half diallel table. Biometrics, 34: 91-94.