GENE ACTIONS, CYTOPLASMIC ACTIONS AND CYTOPLASMIC-NUCLEAR INTERACTIONS INVOLVED IN THE DETERMINATION OF FIBER CONTENT IN A SERIES OF ISONUCLEAR MAIZE LINES

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Abstract: *Maize fiber is a byproduct of the maize wet-milling industry. About half of the fiber in a maize grain is found in the pericarp. The pericarp consists of 35% hemicellulose, 18% cellulose and 20% remaining starch. Recent research on maize fiber has shown that it can be used for extraction of maize fiber oil, which has been shown that has higher levels of phytosterol than the germ oil, and has also negligible amounts of ferulate phytosterol esters.The present study was undertaken to investigate the fiber content in a series of single cross hybrids of maize. Experiments were performed under natural conditions, without irrigation, in field research of ARDS Turda. The experimental model was a comparative polifactorial settlement with plots. Two of the comparative crops had 28 plots each and three of them had 21 plots. The plot consists of two rows of 5 m long each, with a distance of 70 cm between rows, 23.7 cm distance between plants in a row, 23 plants in a row, to obtain a density of 60.000 plants/hectare. The content of fiber to the testing isonuclear inbred lines of maize was studied in 2 years (2009-2010), in two experimental views: in terms of self-pollination and open pollination. Plants were harvested individually, and for the determinations of chemical compounds, two sets of samples were prepared: evidence from open-pollinated cobs and samples from self-pollinated cobs. Determinations were made using the device INSTALAB 600, carrying out infrared analysis. Given the nature of soluble grain fiber, arising in particular from the pericarp, the differences between the two background of grain might be out of the conditions in which they were formed, and of the lower photosynthetic contribution of husk in the case of self-pollination (during the whole period from pollination to harvesting the maize cob was protected by a paper bag that was used for self-pollination).*

Key words: *maize, corn, fiber, isonuclear inbred lines, combining ability, open-pollination*

INTRODUCTION

Maize fiber is a potential raw material for the production of various products because it is widely available in maize-producing countries. About half of the fiber in a maize grain is found in the pericarp (Watson, 2003). The pericarp consists of 35% hemicellulose, 18% cellulose and 20% remaining starch (GASPAR MELINDA et. all 2007).

Maize fiber is a low value byproduct of the maize wet-milling industry. In the conventional maize wet-milling process, a maize kernel is separated into its individual components. Starch is the main product then come other components: germ (oil), protein anf fiber. Recent research on maize fiber has shown that it can be used for extraction of maize fiber oil, which has three different classes of phytosterol compounds: ferulate phytosterol esters (FPE), free phytosterol (St) and phytosterol fatty acyl esters (St:E). In numerous clinical studies phytosterol compounds have been shown to lower serum cholesterol levels and, therefore, have found applications as nutraceutical compounds. Maize fiber oil has higher levels of phytosterol than the germ oil, and has also negligible amounts of FPE (SINGH et. all, 2001).

MATERIAL AND METHODS

Experiments were performed under natural conditions, without irrigation, in field research of ARDS Turda, in 2009 and 2010. The experimental model was a comparative polifactorial settlement with plots. Two of the comparative crops had 28 plots each and three of them had 21 plots. The plot consists of two rows of 5 m long each, with a distance of 70 cm between rows, 23.7 cm distance between plants in a row, 23 plants in a row, to obtain a density of 60.000 plants/ hectare. Sowing took place between the 24th and 30th of April, and harvesting between the 28th of September and 5th of October, for each year. During the period of vegetation, for 5 plants from the rows of each plot phenotypic observation (plant height, height of insertion of main ear, number of branches/tassel, the total number of leaves/ plant, leaf length of the main ear, leaf width of the main ear), were performed. Plants were harvested individually to define the ear's weight, kernel's weight, ear's length, number of rows/ear, number of kernels/row, ear's diameter, rachides diameter, mass of a thousand grains, kernel number/ear, kernel's depth and kernel yield/plant. In the determinations of chemical compounds, corn ear’s were harvested and dryied in the corn dryer. For analysis, two sets of samples were prepared: evidence from open-pollinated corn and samples from self-pollinated corn. The average samples were weighed 50 g each, which were fine ground using the laboratory mill. Determinations were made using the device INSTALAB 600.

RESULTS AND DISCUSSIONS

The content of fiber to the testing isonuclear inbred lines of maize was studied in 2 years (2009-2010), in two experimental views: in terms of self-pollination and open pollination. Given the nature of soluble grain fiber, arising in particular from the pericarp, the differences between the two background of grain might be out of the conditions in which they were formed, and of the lower photosynthetic contribution of husk in the case of self-pollination (during the whole period from pollination to harvesting the maize cob was protected by a paper bag that was used for self-pollination).

For isonuclear inbred lines generated by the TC209 and TC243, tests were conducted using four testers, and for TC221 and TB367 tests were conducted using three testers; here come the differences of degrees of freedom of experimentation.

Analysis of variance for the content of soluble fiber in maize grains, for the five comparative testing groups of isonuclear inbred lines, in case the grains have originated from self-pollinated cobs are presented in Table 1.

In four of the five groups of tested lines, the fiber content was influenced by the experimental years. At each of the five groups of tests, the differences between genotypes were statistically significant. Also, the cytoplasm types have statistically significant influenced the differences between genotypes. In all five groups of inbred lines, testers variance was superior of the cytoplasm variance, the reciprocal interaction "testers x cytoplasm" was also statistically significant in all five experimental situations.

Experimental years give an influence on cytoplasm role and on “cytoplasm x tester” interaction. Still, gene actions transmitted by genes located in the nucleus of the testers are not influenced by the experimental years.

In figure 1 are given the weights of the factors involved in variance of soluble fiber content, at each of the five test groups, in situation of self-pollination. Calculating the weight factors involved in fiber content was made after the model proposed by LEIN, quoted by CEAPOIU (1968).

The share of the cytoplasm variance is from 18% to 57%, of the tester’s variance from 13% to 63%, and of “cytoplasm × testers” variance is from 19% to 54%.

Table 1

Analysis of variance for the fiber content in testing isonuclear lines (self-pollination)
ARDS Turda (2009-2010)

Source of variability	DF	TC209 isonuclear line		TC243 isonuclear line		DF	TC221 isonuclear line		TB367 isonuclear line		D105 isonuclear line	
		SP	s^2	SP	s^2		SP	s^2	SP	s^2	SP	s^2
Experimental year (Y)	1	6.21	6.21*	1.89	1.89*	1	3.50	3.50*	2.29	2.29	13.02	13.02*
Genotype	27	12.41	0.46**	12.69	0.47**	20	14.05	0.70**	8.01	0.40**	8.83	0.44**
Cytoplasm (C)	(6)	2.22	0.37**	2.77	0.46**	(6)	3.12	0.52**	4.57	0.76**	2.49	0.41**
Tester (T)	(3)	7.78	2.59**	7.17	2.39**	(2)	3.39	1.69**	1.05	0.53	1.74	0.87**
(CxT) interaction	(18)	2.41	0.13**	2.74	0.15**	(12)	7.54	0.63**	2.39	0.20 *	4.60	0.38**
(YxT) interaction	3	0.28	0.09	2.06	0.69**	2	0.33	0.16	0.83	0.41	0.50	0.25
(YxC) interaction	6	1.25	0.21**	0.83	0.14*	6	3.33	0.55**	3.32	0.55**	5.42	0.90**
(YxTxC) interaction	18	3.25	0.18**	5.71	0.32**	12	6.77	0.56**	4.57	0.38**	5.68	0.47**
Repetition (R)	2	0.14	0.07	0.17	0.09	2	0.03	0.02	0.46	0.23	0.04	0.02
Error Y	2	0.15	0.08	0.08	0.04	2	0.14	0.07	1.22	0.61	0.63	0.31
Error T	12	0.76	0.06	0.87	0.07	8	0.74	0.09	1.15	0.14	0.56	0.07
Error C	96	4.14	0.04	5.70	0.06	72	10.45	0.15	6.93	0.10	7.49	0.10

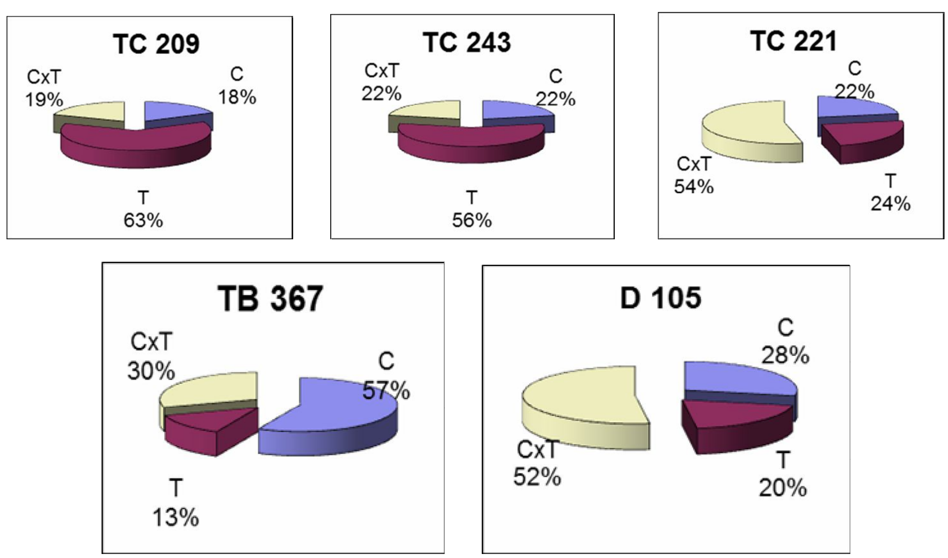

Figure 1. Weights of the factors involved in variance of soluble fiber content for the self-pollinated cobs

Table 2

Analysis of variance for the fiber content in testing isonuclear lines (open pollination), ARDS Turda (2009-2010)

Source of variability	**DF**	**TC209 isonuclear line**		**TC243 isonuclear line**		**DF**	**TC221 isonuclear line**		**TB367 isonuclear line**		**D105 isonuclear line**	
		SP	**s^2**	**SP**	**s^2**		**SP**	**s^2**	**SP**	**s^2**	**SP**	**s^2**
Experimental year (Y)	1	0.48	0.48	0.01	0.01	1	2.03	2.03	0.19	0.19	0.50	0.50
Genotype	27	8.60	0.32**	21.46	0.79**	20	30.10	1.50**	18.73	0.94**	9.67	0.48**
Cytoplasm (C)	(6)	2.07	0.34**	4.91	0.82**	(6)	6.54	1.09**	2.09	0.35	2.37	0.39**
Tester (T)	(3)	2.19	0.73**	11.47	3.82**	(2)	3.52	1.76**	2.32	1.16*	1.74	0.87 **
(CxT) interaction	(18)	4.34	0.24**	5.07	0.28**	(12)	20.04	1.67**	14.32	1.19**	5.56	0.46 **
(YxT) interaction	3	1.10	0.37**	2.83	0.94**	2	5.05	2.53**	6.31	3.15**	2.27	1.13 **
(YxC) interaction	6	0.84	0.14**	1.63	0.27**	6	2.98	0.50**	7.38	1.23**	1.76	0.29 **
(AxTxC) interaction	18	3.26	0.18**	10.10	0.56**	12	8.01	0.67**	7.98	0.66**	9.91	0.83 **
Repetition (R)	2	0.12	0.06	0.00	0.00	2	0.58	0.29	0.27	0.14	0.01	0.01
Error Y	2	0.13	0.07	0.41	0.21	2	0.25	0.12	0.13	0.07	0.74	0.37
Error T	12	0.49	0.04	0.97	0.08	8	0.72	0.09	1.21	0.15	0.12	0.02
Error C	96	3.15	0.03	6.56	0.07	72	9.15	0.13	11.72	0.16	5.02	0.07

Analysis of variance for the content of soluble fiber from whole cobs with open pollination is presented in Table 2. In this situation, experimental years have a smaller influence to the differentiation of the soluble fiber content. Among the genotypes tested in all five experimental situations (the five testing groups of isonuclear inbred lines, distinct differences were statistically significant. For four of the five groups of tested isonuclear lines, cytoplasm ensured the emergence of statistical differences, except the types of cytoplasm for that the nucleus of TB 367 inbred line was transferred. Also, in the case for analysis for the content of soluble fiber, tester's variance had higher values than the cytoplasm variance, being statistically significant in the five experimental situations. Although differences between the experimental years were not statistically significant, distinct statistically significant interactions with the experimental years were recorded, in all the experimental situations.

In Figure 2 are given the weights of the factors involved in the variance of the fiber content for genotypes of maize studied in the five groups of test, in situation of open pollination. The cytoplasm share was from 11% (TB3677) to 24% (TC209 and D105), the testers share from 12% (TB367 and TC211) to53% (TC243), and the share of "cytoplasm × testers " interaction was from 24% (TC243) to 77% (TB367).

Although the analysis of the general and specific combining ability for the content of soluble fiber was made both for the situation of self-pollinated cobs, as well as for open-pollinated cobs, for all five groups of tested isonuclear lines, this paper presents results just from one group of isonuclear lines testing open pollination (Table 3, group of TC209 isonuclear lines) and one group of isonuclear lines testing self-pollination (Table 4, group of isonuclear lines TC 221).

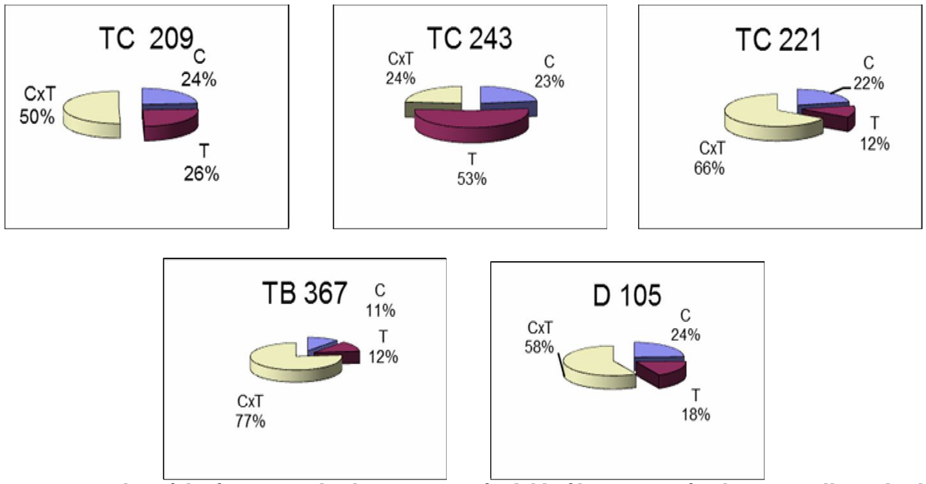

Figure 2. Weights of the factors involved in variance of soluble fiber content for the open-pollinated cobs

The average fiber content of testing isonuclear lines TC209 group (open pollination, Table 3) was 4.4%; amplitude values was between 4% for the TC209(citT248) x Lo3Rf hybrid, and 5% for the TC209 (citD105) xTB329 hybrid.

Table 3

General and specific combining ability efects in transmission of fiber content in the isonuclear inbred line TC 209 (open pollination), ARDS Turda (2009-2010)

	TC 344		Lo3Rf		TB 329		TD 233			
	%	$\hat{s}_{citxtest}$	%	$\hat{s}_{cit\ x\ test}$	%	$\hat{s}_{cit\ x\ test}$	%	$\hat{s}_{citxtest}$	χ	$\hat{g}_{cit}$
TC 209	4.7	0.00	4.4	0.03	4.4	-0.20	4.6	0.17	**4.5**	**0.06**
TC 209 (cit A665)	4.6	0.08	4.1	-0.11	4.3	-0.09	4.3	0.12	**4.3**	**-0.14**
TC 209 (cit T291)	4.7	0.09	4.5	0.10	4.5	-0.03	4.2	-0.16	**4.5**	**0.02**
TC 209 (cit T248)	4.6	0.05	4.0	-0.29	4.5	0.06	4.5	0.18	**4.4**	**-0.09**
TC 209 (citW633)	4.5	-0.16	4.7	0.33	4.4	-0.22	4.5	0.05	**4.5**	**0.07**
TC 209(citTC177)	4.4	-0.11	4.3	0.11	4.5	0.15	4.1	-0.15	**4.3**	**-0.12**
TC 209 (cit D105)	4.9	0.05	4.4	-0.17	5.0	0.33	4.3	-0.21	**4.6**	**0.19**
Testers average	**4.6**		**4.3**		**4.5**		**4.4**		**4.4**	
ĝ test	**0.16**		**-0.12**		**0.06**		**-0.10**			

LDS 5% ĝ cit = 0.10
LDS 5% ĝ test = 0.10
LDS 5% ŝ cit x test = 0.21

The highest general transmission ability for the fiber content had the D105 cytoplasm (+0.19%) and the lowest ability had the A665 cytoplasm (-0.14%) and TC177 cytoplasm (-0.12%). In all three reported cases, the differences were statistically insured, when compared to the cytoplasm of TC209 inbred line.

Among the tester inbred lines, the highest average content of soluble fiber was submitted to TC 344 - 4.6% (g test = 0.16%). TD233 and Lo3Rf testers have submitted at the level of general combining ability, lower values of average fiber content, and by default, negative values of general combining ability effects (-0.12% and -0,10%). The values of specific combining ability (cytoplasm x tester interactions) were quite large, with values ranging between -0.3% and 0.3%. This shows the importance of hybrid combinations in transmitting the content of soluble fiber to maize hybrids.

Analyzing the effects of general and specific combining ability for fiber content in the testing group of isonuclear inbred lines TC 221 for self-pollinated cobs (table 4) finds that average value was 3.9%, amplitude values recorded was from 3.2% for TC221xT291 hybrid, to 4.5% for TC22 (citTC209)xT291 and TC221(citT248)xTD233 hybrids.

The highest capacity transmission at level of general combining ability was recorded in the TC209 cytoplasm (0.21%), and lowest capacity in TC243 cytoplasm (-0.24%) and TC208 cytoplasm (-0.18%).

Among the tester inbred lines, the highest transmission capacity of fiber content is recorded to TD233 (0.22%) and lowest at T291 (-0.17%). Again, in this case the values are quite high with the sign "+" or "-" for interaction effects "cytoplasm x testers", indicating the preponderance of such gene actions in transmission of the fiber content.

Table 4

General and specific combining ability efects in transmission of fiber content in the isonuclear inbred line TC 221 (self-pollination), ARDS Turda (2009-2010)

	T 291		**TC 209**		**TD 233**			
	%	$\hat{s}_{citxtest}$	%	$\hat{s}_{citxtest}$	%	$\hat{s}_{citxtest}$	**χ**	**ĝ cit**
TC 221	4.7	0.15	4.6	0.13	3.9	-0.29	**4.4**	**-0.02**
TC 221 (cit T248)	3.9	-0.27	4.2	0.06	4.0	0.21	**4.1**	**-0.35**
TC 221 (cit TC243)	4.9	0.18	4.3	-0.42	4.6	0.23	**4.6**	**0.17**
TC 221 (cit TC208)	5.1	0.25	4.1	-0.70	4.9	0.45	**4.7**	**0.31**
TC 221 (cit TC209)	4.6	0.06	4.1	-0.36	4.4	0.31	**4.4**	**-0.05**
TC 221 (cit K 1080)	4.3	-0.49	5.8	1.04	3.8	-0.54	**4.6**	**0.20**
TC 221 (cit TC 316)	4.4	0.12	4.5	0.25	3.5	-0.38	**4.1**	**-0.27**
Testers average	4.5		4.5		4.2		**4.4**	
ĝ test	0.13		0.10		-0.24			

LDS 5% ĝ cit = 0.25
LDS 5% ĝ test = 0.15
LDS 5% ŝ cit x test = 0.44

CONCLUSIONS

1. The soluble fiber content in maize, studied through testing of isonuclear inbred lines groups, has relatively high values ranging from 3.0 to 5.0%

2. In the genetic determinism of fiber content, nuclear gene actions (due to testers), cytoplasmic-nuclear gene actions and genetic factors located in the cytoplasm are involved.

3. Analyzing the fiber content from the samples recorded from self-pollinated cobs and open-pollinated cobs differences are relatively small, probably due to the fact that in the self-pollinated cobs amassments were lower due to non-involvement of husk in photosynthesis.

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