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Phenotypical Variability of "TURDA" Maize Germplasm for Grain Chemical Composition

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Abstract. Maize grain has many and diverse uses in the food and feed industry. The diversity of applications requires characteristics of quality in accordance to that. To examine phenotypical diversity in the grain content, it was evaluated a total of 754 maize samples: 265 local populations (landraces); 59 synthetics/composites; 430 "TURDA" inbred lines for their grain quality attributes. Comparison of the inbred lines diversity is on average the most divergent in grain starch concentration (range value 19.9) from landraces (range value 11.8) and synthetics (range value 12.5). The grain oil and ash content showed high variability among the genotypes. The quality attributes in most of the cases showed positive phenotypic correlation except grain starch contents which was negatively correlated at phenotypic levels.

The **objective** of this study was to evaluate the potential of maize "TURDA" germplasm in according to its grain quality content, such as: protein, oil, fiber, ash and starch concentration; to estimate the extent of phenotypical variability and correlation for various quality components to formulate a selection criterion in a breeding program.

Key words: maize germplasm, phenotypical diversity, grain chemical composition

INTRODUCTION

Maize is one of the most important grain crops produced in Romania, with over 2 million hectares in production. Maize crop is an integral part of our agriculture and has a potential to compete with its multi-products.

In Romania and in almost all of the European maize-growing countries, the diffusion of maize hybrids, characterized by a superior yield performance, brought a progressive substitution of local population. As a consequence, the genetic variability of the cultivate maize germplasm was reduced over the past 50 years, in term of both number of alleles and genetic diversity between hybrids (Reif et al., 2005). The necessity to collect and maintain the traditional maize landraces emerged for the first time in past decades, as it became evident that some actions were to be taken to avoid a significant loss of the genetic variability existing in Europe for this species (Berardo et al., 2009). In different countries, collections of populations (landraces, local varieties and so on) were activated.

Because maize is a relevant food source, the quantification of the grain constituents with a nutritional role is important for the best exploitation of the different genotypes. In this context, the traditional germplasm represents a good source of genetic variability to explore and could be help to identify the most suitable materials for the development of more nutritious foods.

Specifically, different industries have different requirements of maize for their particular use. The wet milling industry would like soft starch, and low protein content, while hard starch is require for dry milling and for masa production. The feed industry would gain value from maize with increased energy content, i. e. maize with higher oil content, and from increased protein content and a better amino acid balance. The genetic variability needed to modify maize to satisfy all of these requirements is currently available in maize germplasm (Smith, 1990). It is necessary to explore germplasm and genetic variability for such quality traits and their association with grain yield and other yield attributes.

Knowledge about germplasm diversity and genetic relationships among breeding materials could be an invaluable aid in maize improvement strategies (Mohammadi and Prasanna, 2003). Numerous studies have documented genetic and phenotypic variability for grain composition traits in maize (Smith, 1990; Whitt et al., 2002; Has et al., 2004; Uribelarrea, et al., 2004; Duarte et al., 2005; Pollak and Scott, 2005; Reynolds et al., 2005; Bernardo et al., 2009).

Turda - Romania maize genotypes have great phenotypic and genetic variability, consisting of local populations, varieties, synthetics and single-cross, double-cross, and three-way hybrids. Genotype germplasm sources range from very early to late and from dent to flint grain characteristics (Has et al., 2004).

The **objective** of this study was to evaluate the variability existing for some chemical components of the grain in a large range of maize "TURDA" germplasm, to identify genotypes that could be interesting in term of nutritional value.

MATERIALS AND METHODS

Maize samples. Maize samples used in this study consisted of 754 accessions from "TURDA" germplasm collection, among which there were 265 local populations (landraces), collected in different Romanian regions, 59 synthetics/composites among which 30 synthetics were created at ARDS Turda and 29 synthetics acquired from different countries (Spain, Italy, Germany, University of Minnesota, University of Pennsylvania); 430 "TURDA" inbred lines. All local populations (landraces), synthetics and inbred lines, currently used in the framework of breeding and genetic program at the Agricultural Research Station, Turda – Romania (ARS Turda). The studied genotypes differed by germplasm source, grain type, maturity classification (very early, early, intermediate and late) and grain appearance and color.

Grain composition was determined after the crop reached full maturity. At least six plants in each experimental unit were cross-pollinated by male plants from the same plot to avoid xenia effects. Collected grains were processed and samples used to determine protein, fat, starch, fiber and ash. Fifteen grains from the middle of the ear were removed and used for % moisture content. A representative 50-g sample of the grain was ground, and the concentration of starch, protein, oil, fiber and ash in the ground sample was determined with a Dickey-John Instalab 600 near-infrared reflectance analyzer.

Statistical Analysis of Maize Germplasm. All grain physical quality tests were performed in duplicate, and the mean value was analyzed statistically. Analyses of variance by ANOVA, using a one-factor model without replications were done for each trait and for each group of genotypes, as well as Pearson's correlation coefficients were computed to express the relationship among characters.

RESULTS AND DISCUSSIONS

Although there is little variation in the percent **starch** among germplasm studied here, there appears to be differences in the percent of recoverable starch in these materials.

The local populations showed starch contents ranging between 64.9% and 68.9% (Tab. 1). The range of variation observed for synthetics was larger than in local population ranging between 60.1% and 72.6%. Among synthetics were identified some interesting forms with high level of starch content: Tu SRR Comp. A (Comp. B) (1), Tu SRR Comp. B (Comp. A) (1), Tu Comp. A (10).

Tab. 1

Means values, range of variation, and coefficients of variation (CV) for grain content in TURDA germplasm

Trait		Grain content in:				
		Starch	Oil	Protein	Fiber	Ash
Germplasm	Range	%				
Local Populations (Count=265)	Minimum	57.1	3.8	11.2	3.3	0.03
	Mean	64.9	5.4	13.7	5.3	2.3
	Maximum	68.9	9.1	15.6	7.3	7.2
	C.V.%	3.0	12.3	6.2	14.9	51.1
“Turda” Synthetics (Count=59)	Minimum	60.1	3.5	11.7	3.6	0.01
	Mean	65.9	5.4	13.6	5.4	2.1
	Maximum	72.6	7.3	14.8	6.7	5.8
	C.V.%	4.0	14.7	5.1	10.5	70.3
Inbred lines (Count=430)	Minimum	52.8	2.4	10.8	2.3	0.01
	Mean	67.5	4.2	13.4	4.9	1.6
	Maximum	72.7	8.0	14.8	7.5	10.6
	C.V.%	4.1	21.2	8.0	18.9	88.2

Comparison of the inbred lines diversity is on average the most divergent in grain starch concentration (range value 19.9) from landraces (range value 11.8) and synthetics (range value 12.5). The mean starch concentration of inbred lines has the most value 67.5%, comparatively with local population 64.9% and synthetics 65.9% (Fig. 3).

About 100 genotypes have been characterized by high starch content, with an increased *per se* value. Some of them are “TURDA” inbred lines that were identified with high starch content (>71%) in grain (Tab. 2). Most of these inbred lines are characterized by dent or demi-dent grain type. Among “TURDA” inbred lines were identified some interesting forms with high level of starch content: TC 384A cmsC (72.5%), TC 384 A cmsT (72.2%), TE 210 72.1%), TC 378 (72.0%). All these genotypes characterized by high starch grain content may be used as high starch maize parent in a breeding program. Either pedigree selection or recurrent selection could be used to increase the percent of starch in grains.

Tab. 2

Some “TURDA” inbred lines with high grain content (>71%) in starch

No.	Inbred line	Grain type	Grain content in:				
			Protein	Oil	Starch	Fiber	Ash
			%				
1.	T 169acmsC	Dent	11.7	3.6	71.3	3.9	0.5
2.	TC 182	Flint	12.8	2.6	71.9	4.1	0.3
3.	TD 246	Dent	10.8	4.2	71.3	4.8	1.0
4.	TD 270 Nrf C	Dent	12.0	3.0	71.6	3.6	1.0
5.	TD 270 cmsC	Dent	11.4	3.4	71.4	3.7	1.2
6.	TD 276	Demi-dent	12.4	3.8	71.1	5.2	0.9
7.	TE 210	Dent	11.7	3.4	72.1	4.7	0.8
8.	TC 321	Dent	12.1	3.5	71.4	4.7	0.1
9.	TC 330A	Demi-dent	13.0	2.4	71.8	3.4	0.2
10.	TC 354	Demi-dent	12.6	3.6	71.2	4.4	0.2
11.	TC 362	Dent	12.7	3.9	71.5	5.4	0.2

12.	TC 374	Demi-dent	13.5	3.6	71.2	3.2	0.2
13.	TC 378	Demi-dent	12.9	2.5	72.0	3.8	0.3
14.	TC 384A Nrf	Dent	11.7	3.1	71.7	3.6	1.9
15.	TC 384A cmsC	Dent	11.8	2.9	72.5	3.8	1.1
16.	TC 384 A cmsT	Dent	12.4	2.9	72.2	4.1	1.5
17.	TC 384 B	Demi-dent	12.7	2.5	71.4	3.4	0.8
18.	TD 375	Demi-dent	12.2	3.1	71.9	4.6	0.7
19.	TE 325	Dent	12.8	3.2	71.4	4.8	1.0
20.	TA 439	Dent	13.2	2.7	71.3	4.1	0.6

The **oil** percentage ranged from a low level of 2.4% (inbred lines) to a high level of 9.1% (local populations). Local populations showed oil content ranging between 3.8% and 9.1%. Among local populations (landraces) were identified some interesting forms with high level of oil content: Blaj (Veza)/01 (7.3%), Iclod/01 (7.0%), Salva/01 (7.1%), Sarmisegetuza/01 (7.1%), and Vânători/01 (7.1%). The data about synthetics showed a range among the genotypes for oil content of 3.5% to 7.3%. The high oil contents were found in the following synthetics: Tu Syn 1 (7.1%), Tu Syn 2 (7.0%) and Tu Syn (3) (per se) (1) (7.3%). All these genotypes characterized by high oil grain content may be used as high oil maize source material in a breeding program. The same range of variation was observed by Berardo et al. (2009) in a collection of 93 landraces. These high oil local populations and synthetics have a large reduction in the starchy endosperm (Tab. 3) and most of them are characterized by flint or demi-flint grain type. For this germplasm Smith (1990) supported that pedigree selection has been used to develop some elite high oil lines.

Tab. 3

High **oil** content (> 6.0%) local populations and synthetics and some grain traits

Local populations	Protein	Oil	Starch	Fiber	Ash	Grain type
	%					
Acăţari/02	14.8	6.6	60.1	6.1	3.6	Flint + Demi-flint
Apoldu de Sus/01	14.0	6.7	62.2	6.5	4.9	Flint
Băiţa Câinelui de Sus/99	14.2	6.1	64.0	6.7	3.1	Demi-dent
Berind CN26-84/99	13.4	6.2	63.7	5.5	3.2	Flint + Demi-flint
Beriu (sugary)/99	11.3	9.1	57.1	4.7	7.2	sugary
Blaj (Veza)/01	14.6	7.3	59.3	6.6	5.9	Flint
Bradu B-18/01	13.8	6.2	63.4	6.1	3.4	Demi-dent
Castori/03	14.2	6.6	61.8	6.3	4.5	Demi-flint
Câmpeni/01	13.9	6.5	63.0	6.6	4.1	Demi-dent
Cârnesti/01	**15.0**	**6.9**	59.5	6.6	4.9	Flint
Coldău/01	14.2	6.1	62.9	6.3	3.4	Flint
Cornesti/01	14.0	6.2	61.7	5.3	3.9	Flint
Danes/01	14.9	6.6	61.4	6.9	4.2	Demi-flint
Dumbrăviţa/03	14.4	6.1	63.2	6.6	3.9	Demi-flint
Feldioara/01	15.0	6.2	62.8	7.0	3.4	Demi-flint
Geoagiu/01	15.3	6.1	62.0	6.8	2.9	Demi-flint
Ghiula/04	**15.2**	**6.7**	60.2	7.0	5.5	Flint
Gurghiu/04	14.6	6.2	61.3	5.9	4.6	Demi-flint
Hădăreni/01	14.5	6.3	62.4	6.7	3.4	Demi-flint
Iclod/01	**15.1**	**7.0**	60.3	7.2	5.0	Demi-flint
Ighiu/01	14.9	6.3	62.3	6.9	3.8	Demi-flint
Lujerdiu/04	13.0	6.6	61.8	5.3	5.7	Flint
Mărunt Alb de Virstea/99	13.6	6.3	62.4	5.1	3.9	Flint
Mihaiesti CN-8/99	13.7	6.4	63.5	6.5	4.0	Flint
Ohaba/03	13.1	6.8	61.9	5.4	4.7	Demi-flint

Rodna/01	14.6	6.5	62.3	7.0	4.0	Flint
Salva/01	**15.5**	**7.1**	59.3	7.2	4.9	Demi-flint
Sarmisegetuza/01	14.7	7.1	60.4	7.3	5.0	Flint
Satu Lung/01	**15.6**	**6.7**	60.2	7.1	4.4	Demi-flint
Sânpetru de Campie/01	14.1	6.2	63.5	6.5	3.8	Flint
Sântana de Mures/01	14.1	6.3	61.6	5.5	3.6	Flint + Demi-flint
Secuieni/01	14.2	6.3	62.2	6.0	3.8	Flint
Stânceni/03	12.6	6.1	63.5	4.8	3.4	Flint
Susenii Bargaului/01	14.7	6.4	61.2	6.3	3.7	Flint
Şona/01	14.7	6.4	62.4	7.1	3.7	Dent
Telciu/01	13.7	6.2	63.2	5.9	3.9	Flint
Uriu Ilişua/03	13.6	6.6	61.9	6.0	3.4	Demi-flint
Vânători/01	14.2	7.1	60.1	6.6	5.1	Flint
Zetea (B145-84)/99	13.6	6.4	62.2	5.4	4.0	Demi-flint
Synthetics	Protein	Oil	Starch	Fiber	Ash	Grain type
	%					
Tu Syn 1	13.2	7.1	60.9	5.2	4.6	Flint
Tu Syn 2	13.8	7.0	60.1	5.6	4.8	Flint
Tu Syn (3) (per se) (1)	13.7	7.3	60.8	6.3	4.9	Flint
Tu SRR 6I (5D)	13.3	6.3	63.1	5.3	3.7	Flint
Tu SRR 2I (5D) (1)	14.8	6.1	61.9	5.7	3.5	Flint
Syn 54 Marano - Italia	13.5	6.5	62.6	5.4	4.4	Flint
Syn 55 Marano - Italia	13.6	6.4	61.3	4.6	3.7	Flint
Syn 57 Marano - Italia	14.1	6.8	61.8	6.2	5.8	Flint
Syn 66 Marano - Italia	13.1	6.1	63.3	4.9	3.5	Flint
Coruna Early – Spania	14.1	6.4	62.8	6.1	4.4	Flint
Sarria	13.8	6.3	64.3	6.4	4.8	Flint
Coruna Prolific Syn	14.3	6.4	61.8	6.0	3.7	Demi-flint

The inbred lines recorded the high mean value for oil percentage among the genotypes analyzed. Some of inbred lines were identified with a high content in oil (Tab. 4). All these genotypes characterized by high oil grain content may be used as high oil maize parent in a breeding program.

Tab. 4

Some “TURDA” inbred lines with high grain content in **oil** and **fiber**

No.	Inbred line	Grain type	Grain content in:				
			Protein	Oil	Starch	Fiber	Ash
			%				
1.	TA 25	sugary	15.7	8.0	52.8	6.2	9.6
2.	TC 344A	Dent	15.2	7.6	58.1	7.2	5.5
3.	TC 334	Dent	15.1	7.5	59.0	7.5	6.8
4.	TC 106	Flint	16.4	7.5	55.1	7.1	8.0
5.	TC 375	Dent	14.7	7.1	60.3	7.3	4.3
6.	T 442	Flint	15.6	7.2	56.1	6.2	6.6
7.	TC 336	Flint	15.3	6.8	59.1	6.6	6.9

Analyses of **protein** show that the percent ranged from a low level of 10.8% for inbred lines to a high level of 15.6% for local populations. Some of local populations were identified with high content grain (>15.0% protein and >6.0% oil) in protein and oil (Tab. 3): Cârnesti/01 (15.5% protein and 6.9% oil), Ghiula/04 (15.2% protein and 6.7% oil) , Iclod/01 (15.1% protein and 7.0% oil), Salva/01 (15.5% protein and 7.1 oil), Satu Lung/01 (15.6% protein and 6.7% oil). The work at the University of Illinois has also shown the protein percent from 8-11% found in normal maize (Smith, 1990).

The mean values recorded for **fiber** content were found in the range of 2.3% to 7.5%. The following inbred lines (Tab. 4) exhibited maximum grain fiber and oil content: TC 334, TC 375, TC 344A and TC 106.

Mean values for grain ash content ranged from 0.01% to 10.6%. Some genotypes exhibited high grain ash contents (Tab. 5).

Tab. 5

Some genotypes with high grain content in ash

No.	Inbred line	Grain type	Grain content in:				
			Protein	Oil	Starch	Fiber	Ash
			%				
Local population (Landraces)							
1.	Beriu (zaharat)/99	sugary	11.3	9.1	57.1	4.7	7.2
2.	Blaj (Verza)/01	Flint	14.6	7.3	59.3	6.6	5.9
3.	Ghiula/04	Flint	15.2	6.7	60.2	7.0	5.5
Inbred lines							
1.	TA 25	sugary	15.7	8.0	52.8	6.2	9.6
2.	TD 106	Flint	16.4	7.5	55.1	7.1	8.0
3.	TC 336	Flint	15.3	6.8	59.1	6.6	6.9
4.	TC 334	Demi-flint	15.1	7.5	59.0	7.5	6.8
5.	T 442	Flint	15.6	7.2	56.1	6.2	6.6
6.	TC 221	Flint	15.4	6.7	58.6	6.5	6.3
7.	TC 344A	Demi-dent	15.2	7.6	58.1	7.2	5.5
8.	TE 239	Flint	13.1	5.2	65.2	5.2	5.2
9.	TE 243A	Demi-dent	12.9	5.5	63.7	4.9	5.2
10.	TE 244	Dent	14.2	5.5	63.1	5.9	5.0
11.	TE 215	Flint	11.9	5.0	63.8	3.2	5.0

The local population (landraces) and variability has been more divergent in oil concentration with a maximum value = 9.1% comparatively with inbred lines with a maximum value of 8.0%.

According to Tab. 1 and Fig1, 2, 3, CV values for grain content reflect:

- lower diversity for starch and protein concentration: 3.0 to 4.1%, respectively 5.1 to 8.0% for all germplasm analyzed;
- medium diversity for oil (local populations = 12.3% and synthetics = 14.7%) and fiber concentration;
- high diversity for oil (inbred lines 21.5%) and minerals concentration for all genotypes analyzed.

Phenotypic correlation

Starch content was negatively and significantly correlated with protein, oil, fiber and ash per grain content for all groups of germplasm analyzed (Tab. 6).

Tab. 6

Phenotypic correlations among grain quality traits in maize

7.I. Local populations

Trait	Starch	Protein	Oil	Fiber
Protein	-0.50^{0}	-		
Oil	-0.87^{0}	0.20*	-	
Fiber	-0.58^{0}	0.73*	0.58*	-
Ash	-0.80^{0}	0.18*	0.90*	0.52*

N = 265

7.II. Synthetics

Sintetici	Starch	Protein	Oil	Fiber
Protein	-0.46^{0}			
Oil	-0.93^{0}	0.22		
Fiber	-0.32^{0}	0.59*	0.38*	
Ash	-0.87^{0}	0.22	0.92*	0.30*

N = 59

7.III. Inbred lines

Trait	Starch	Protein	Oil	Fiber
Protein	-0.62^0	-		
Oil	-0.85^0	0.39*	-	
Fiber	-0.52^0	0.68*	0.66*	-
Ash	-0.66^0	0.11	0.69*	0.28*

N = 430

* = Significant at 5% level of probability

The results showed that an increased in starch content may decreased protein, oil, fiber and ash content ultimately, so breeding for high starch genotypes require moderate balance among these quality grain traits. The results are in accord with Saleem et al. (2008).

The data presented in Tab. 7 exhibited that grain oil contents were positively and significantly correlated with protein, fiber and ash contents. The results showed that an increase in oil contents may increase also protein contents, so breeding for high oil and high protein genotypes may be made simultaneously.

Negative and significant correlation was found between ash contents and starch contents at all genotypes analyzed. The results showed that the breeding for high ash contents level may caused significant decreased in grain starch content.

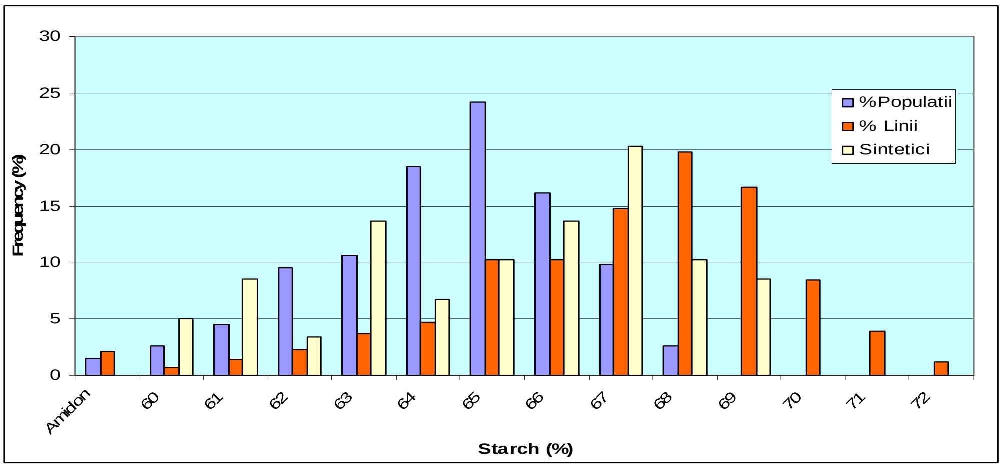

Fig. 1 Frequency distribution of genotypes by their grain content in starch

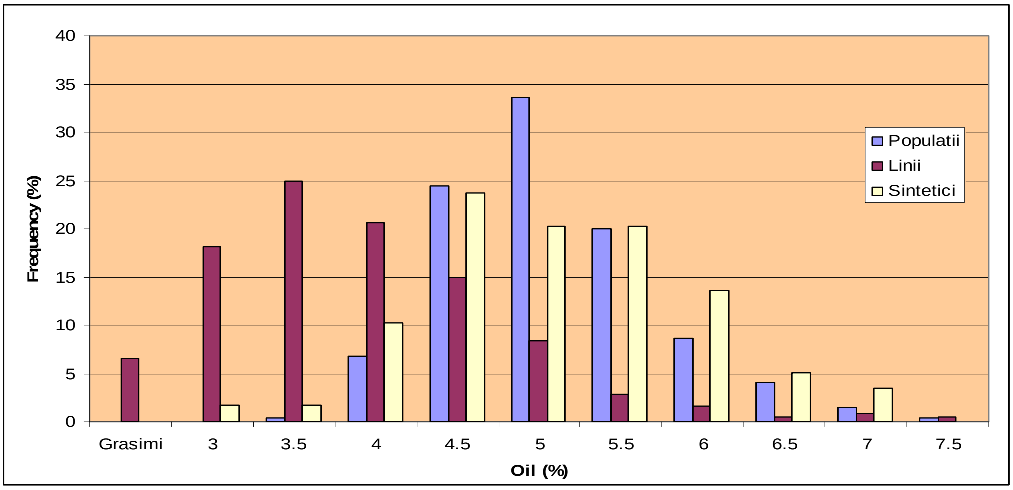

Fig. 2 Frequency distribution of genotypes by their grain content in starch

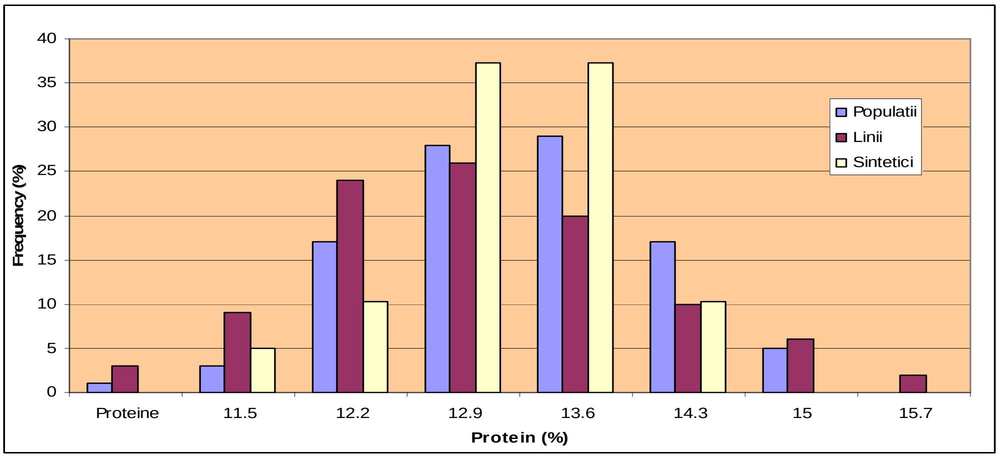

Fig. 3Frequency distribution of genotypes by their grain content in starch

CONCLUSIONS

The screening of TURDA-Romanian germplasm revealed the presence of a wide phenotypic variability for oil, fiber and ash concentration.

Although there is little variation in the percent starch among normal germplasm, there appears to be differences in the percent of starch in these materials.

Maize local populations and synthetics with high oil content in grains may be used as source material for recurrent selection for increased oil content. Pedigree selection may be used to develop elite high oil lines. The inbred lines recorded the high mean value for oil percentage could be used in combination with normal elite lines to make hybrids with increased oil content.

The results showed that an increased in starch content may decreased protein, oil, fiber and ash content ultimately, so breeding for high starch genotypes require moderate balance among these quality grain traits.

Positive and significant correlations were found between oil and protein contents. In consequently, an increase in oil contents may increase also protein contents, so breeding for high oil and high protein genotypes may be made simultaneously.

Negative and significant correlation was found between ash contents and starch contents at all genotypes analyzed. The results showed that the breeding for high ash contents level may caused significant decreased in grain starch content.

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