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Biochemical Study of some Maize Hybrids, Created at ARDS Turda

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Abstract

Improving the quality of the grains allows both diversification and increasing the economic value of the maize crop. Knowing the determinism of grain quality is important in association with the improvement of yield, but also for the improvement of some nutritional and industrial properties. The biological material used in the study is represented by simple hybrids resulted within a system of cyclic (factorial) crossings of the m×n type, meaning 7 inbred lines were crossed with 3 tester inbred lines. 3 control hybrids were added, resulting in 24 variants – 3 repetitions x 2 rows/plot, in three experimental years: 2016, 2017 and 2018. The biochemical content of the hybrids was determined using the Tango NIR chemical analyzer. Protein, fat, starch, fiber, NCGD, NDF and ADF were analyzed. In all three experimental years, statistically significant differences were noted for the studied quality indices, being influenced both by the factor year, genotype and by the interaction between the two.

Keywords: GCA, hybrids, inbred lines, maize, SCA.

1. Introduction

Maize (*Zea mays* L.) is one of the most important crops worldwide, due to its uses in human nutrition, animal feed, industry, for medicinal purposes, as well as many other uses. According to the Food and Agriculture Organization of the United Nations data [5], the areas cultivated with maize almost doubled in the last 60 years. Regarding the total production of all cereals, maize ranks first, followed by rice and wheat. Maize therefore has an important role in the food security of the continuously growing population [2].

Along with the high productions, the quality of the production is also of particular importance. A primary objective of the food industry is to supply the population with healthy and high-quality food. In order to achieve this objective, the European Union insistently requires member countries to comply with the strict quality rules stipulated in the ratified international agreements, the highlighting of risk factors, risk assessment and their presentation to society for the production of food and raw materials. Thus, producers must be concerned about food quality and, on the other hand, the government must protect the health and welfare of consumers, as well as the interests of honest producers, processors and sellers, against unfair competition [7].

From a biochemical point of view, maize kernels contain approximately 72% starch, 10% protein and 4% fat, providing an energy of approximately 365 Kcal/100g. Maize is an important source of some B vitamins, essential minerals, fiber, but lacks other nutrients, such as vitamin B12, vitamin C, is generally a poor source of calcium and iron [8]. In some countries facing problems related to population anemia and lack of iron, the content of maize is improved with iron, carotenoids and other minerals [3,11,16]. Also, maize has a very good digestibility, the kcal losses in the digestion process being only 8.28% [4].

The improvement in the quality of the grains allows both diversification and increasing the economic value of the maize crop. Knowing the determinism of grain quality is important in association with the improvement of grain production and other agronomic characteristics, but also for the improvement of some nutritional and industrial properties [9,10].

In general, attempts to improve grain quality are accompanied by some undesirable consequences such as reduced production capacity and resistance to diseases and pests. Therefore, when choosing maize hybrids, it is necessary to take into account the achievement of a balance between production capacity and grain quality indicators [13]. Knowing the chemical composition of the grains is an important component in the characterization of each hybrid, so that their choice for cultivation can also be made in the vision of a more efficient utilization of the harvest [1,12].

The objectives of the maize breeding program at the Agricultural Research and Development Station (ARDS) Turda are consistent with climate change, so that newly created maize hybrids at SCDA Turda have a longer vegetation period, good ecological plasticity, high production potential, reaching maturity in the ecological conditions of area [6]. Even though in recent decades production has been an important factor in the promotion of new hybrids, quality has not been ignored, this aspect being of particular importance in the research carried out.

In the present study, the quality of the grains of some maize hybrids produced in a cyclic system was analyzed, meaning the content of proteins, fats, starch, fibers, NCGD, NDF and ADF.

2. Material and Method

The biological material used in the study is represented by simple hybrids resulted within a system of cyclic crosses (factorial) of the m×n type: 7 inbred lines were crossed with 3 other tester inbred lines, resulting 21 hybrids. Three more hybrids were added as control. The hybrids were tested in comparative plots, arranged according to the method of randomized blocks in three repetitions. Each genotype was sown in 2 rows, 5 m long, at a seeding density of 60,000 plants/ha.

The natural setting of the ARDS Turda is marked by the thermal resources of the area specific to the Transylvanian Plateau, a fact that determined the choice of hybrids from early and semi-early groups, biological material capable of exploiting the resources offered by the environment [14].

The study was carried out in the fields of the Maize breeding laboratory, in three experimental years: 2016, 2017 and 2018. The dominated soils are vertical clay-iluvial chernozem type. The most important biochemical indices have the following average values: humus content over 3.5%, mobile phosphorus content 4.5 mg P_2O_5/100 g soil, and mobile potassium content over 30 mg K_2O/100 g ground. The soil reaction is neutral, with a pH between 6.2 and 6.8 [3].

The technology used includes classic plough, minimum fertilization, hand sowing, the use of two herbicides, and manual harvest. It was used as crop rotation: soybean, wheat and maize. Along with the preparation of the seedbed, the fertilization of the experimental field was carried out, by applying 400 kg/ha of NPK 27:13,5:0 complex fertilizer. The herbicide was applied in two stages: pre-emergent with a quantity of 1.2 l/ha, using as active substance dimethanamid-p (720g/l) and post-emergent with 2l/ha using tembotrione (44g/l) and isoxadifen-ethyl (22g/l) active substance [3,15].

The biochemical analyzes were carried out in the ARDS Turda Biotechnology Laboratory. The biochemical content of the hybrids was determined using the spectrophotometer Bruker Tango NIR. Tango NIR is a compact spectrometer, designed for the analysis of liquids in transmission, as well as solid samples and powders in reflection. As a non-destructive, fast analytical method, achievable with minimal or no sample processing, NIR spectrophotometry provides results in record time, contributing to the increase of quality and efficiency in the fields in which it was implemented, in parallel with the increase of profitability and competitiveness. This study presents results on the percentage of protein, fat (% of total dry matter), starch, fiber, NCGD (Neutral Cellulase Gammanase Digestibility) (% of total fiber), NDF (neutral detergent fibers) and ADF (acid detergent fibers). For each genotype, 10 cobs were chosen and ground, and a sample of approximately 100 grams was analyzed. Each analysis was repeated three times.

The data were processed statistically by variance analysis using ANOVA. The determinations and results obtained from each hybrid combination after testing in comparative cultures help to determine the general combinatory capacity, the method frequently used for the purpose of choosing the most valuable parental forms.

3. Results and Discussions

According to the variance analysis table (table 1), the protein content, fats, starch and fiber were distinctly significantly influenced both by the experimental factor year, genotype, and by the interaction between the two.

Table 1. Analysis of the variance regarding the biochemical content of some maize genotypes in the years 2016-2018 at ARDS Turda in a cyclic system

Variability source	DF	Protein	Fats	Starch	Fibers	NCGD	NDF	ADF
		F test						
TOTAL	215							
Years (A)	2	59481**	8527**	897**	8208**	2253**	76812**	6185**
Error (a)	4							
Genotypes (H)	23	241**	346**	172**	71.2**	75.5**	60.7**	145.9**
Year x Genotype (AxH)	46	265**	92.2**	86.9**	47.4**	82.3**	59.4**	171.2**
Error (H)	138							

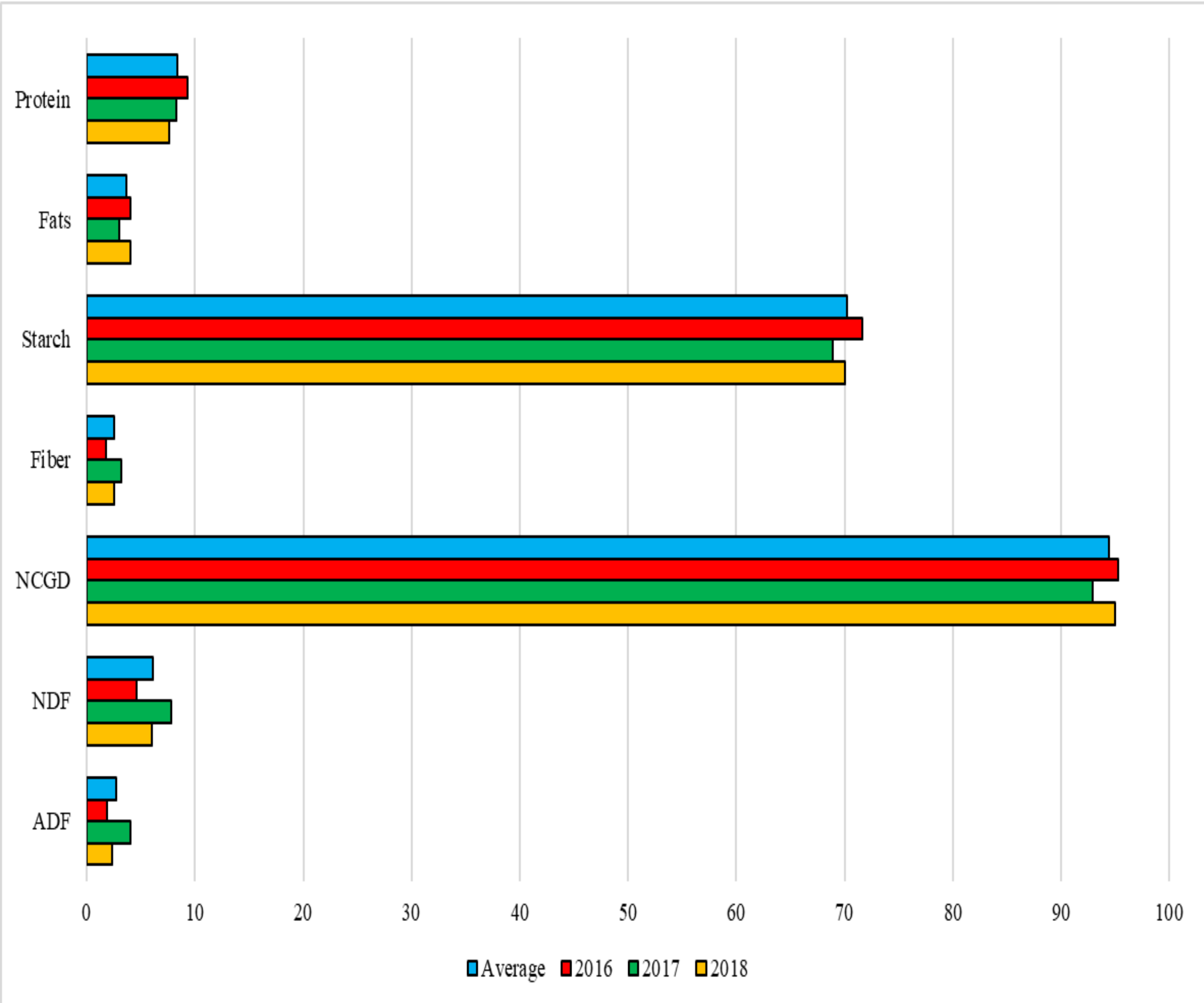

Figure 1. The influence of the year on the grain quality, for the studied maize hybrids

In the first experimental year, the quality of the grains was higher than the experimental average; significant differences were observed for protein, fat, starch and NCGD (Fig. 1). However, the percentage of fibers was lower than in other years. The year 2017 was less favorable from the point of view of grain quality, significant negative differences were observed for most of the analyzed traits, the average values being exceeded only for fiber, NDF and ADF. The last year was one with values close to the experimental average, the differences being very small and statistically insignificant.Regarding the maternal lines, the TA447 inbred line stood out with a general combining Ability (GCA) for the transmission of the higher percentage of protein, fat, fiber and NDF, and for the TE342 line a higher GCA was observed for the content of proteins, starch and ADF. For the fat content, the TE317 line stood out, with a higher GCA than the other lines (Table 2).

Following the GCA analysis of the paternal lines, the TC385A line was noted for transmitting a higher protein content, but the calculated differences were relatively low. However, the influence of the paternal line TE289 can be noted, which led to average increases of 1.04% in terms of starch content (Table 3).

Regarding the specific combining ability (SCA) (Table 4), the hybrids that have the TC385A line as their paternal form have a high protein content compared to the other hybrids studied, the following being noted: TE383 x TC385A with 8.92% and TA 470 x TC 385 A with 8.87%. The hybrid TE317 x TC385A was noted for the highest fat content, 4.88% and TA45 x TC385A had the highest NDF percentage, 7,42%.

Table 2. The General Combining Ability of the maternal lines, for some qualitative traits

Maternal inbred line	Protein %	Fats %	Starch %	Fiber %	NCGD %	NDF %	ADF %
Average	8.47	3.71	70.01	2.53	94.29	6.19	2.77
TA447	8.65***	3.81**	68.96^{000}	2.66**	94.23^{ns}	6.55**	2.80^{ns}
TA452	8.01^{000}	3.73^{ns}	68.76^{000}	2.76***	93.92^{00}	6.96***	3.06***
TE342	8.73***	3.53^{000}	70.82***	2.52^{ns}	94.45^{ns}	5.86^{00}	2.90**
TA470	8.31^{000}	3.47^{000}	71.41***	2.34^{000}	94.72***	5.85^{00}	2.63^{00}
TE383	8.38^{0}	3.60^{00}	71.36***	2.37^{000}	94.78***	5.65^{000}	2.50^{000}
TA468	8.29^{000}	3.40^{000}	71.43***	2.22^{000}	94.93***	5.68^{000}	2.50^{000}
TE317	8.52^{ns}	4.19***	68.71^{000}	2.60^{ns}	93.98^{00}	6.27^{ns}	2.87*
LSD (p 5%)	*0.08*	*0.07*	*0.36*	*0.08*	*0.22*	*0.23*	*0.09*
LSD (p 1%)	*0.10*	*0.09*	*0.48*	*0.11*	*0.30*	*0.30*	*0.12*
LSD (p 0.1%)	*0.13*	*0.12*	*0.62*	*0.14*	*0.38*	*0.39*	*0.15*

*,**,***= significant at 5%, 1% and 0.1% probability levels, positive values; ^{0},^{00},^{000}= significant at 5%, 1% and 0.1% probability levels, negative values; ^{ns}=not significant.

Table 3. The General Combining Ability of the paternal lines, for some qualitative traits

Maternal inbred line	Protein %	Fats %	Starch %	Fiber %	NCGD %	NDF %	ADF %
Average	8.47	3.71	70.01	2.53	94.29	6.19	2.77
TC385A	8.72***	3.90***	69.50^{00}	2.42^{00}	94.36^{ns}	6.04^{ns}	2.63^{00}
TE335	8.23^{000}	3.83***	70.08^{ns}	2.41^{00}	94.26^{ns}	5.98^{ns}	2.82^{ns}
TE289	8.29^{000}	3.28^{000}	71.05***	2.66***	94.57*	6.33^{ns}	2.79^{ns}
LSD (p 5%)	*0.08*	*0.07*	*0.36*	*0.08*	*0.22*	*0.23*	*0.09*
LSD (p 1%)	*0.10*	*0.09*	*0.48*	*0.11*	*0.30*	*0.30*	*0.12*
LSD (p 0.1%)	*0.13*	*0.12*	*0.62*	*0.14*	*0.38*	*0.39*	*0.15*

*,**,***= significant at 5%, 1% and 0.1% probability levels, positive values; ^{0},^{00},^{000}= significant at 5%, 1% and 0.1% probability levels, negative values; ^{ns}=not significant.

From the group of hybrids that have the TE335 line as their paternal line, the TE342 x TE335 hybrid stands out for protein, 8.94%, the highest value in the experiment, TE317 x TC335 for the highest ADF (3,35%), but also TE383 x TE335 for fat (4.08%) and TA452 x TE335 for NDF (6.89%).

For the starch content, the hybrid TA470 x TE289 stood out with the highest value, 73%, the same hybrid also having the highest value in the entire experimental system for NCGD (95.50%). From the same group of hybrids, with the TE289 line as father, the TA447 x TE289 line stood out with the highest percentage of fibers 2.99%.

Table 4. The grain quality (SCA) of some maize hybrids studied in a cyclic crossing system

Hybrid	Protein (%)	Fats (%)	Starch (%)	Fiber (%)	NCGD (%)	NDF (%)	ADF (%)
Average	8.47	3.71	70.01	2.53	94.29	6.19	2.77
TA447 x TC385A	8.79***	3.92***	69.19^{000}	2.42^{0}	94.29^{ns}	6.22^{ns}	2.42^{000}
TA452 x TC385A	8.57*	3.67^{ns}	67.94^{000}	2.86***	93.64^{000}	7.42***	3.22***
TE342 x TC385A	8.80***	3.91***	70.99***	2.50^{ns}	94.27^{ns}	5.80^{000}	2.98***
TA470 x TC385A	8.87***	3.75^{ns}	70.18^{ns}	2.34^{000}	94.68***	5.98^{ns}	2.45^{000}
TE383 x TC385A	8.92***	3.64^{ns}	71.41***	2.36^{000}	94.59**	5.48^{000}	2.57^{000}
TA468 x TC385A	8.29^{000}	3.58^{000}	70.58**	2.02^{000}	94.94***	5.45^{000}	2.27^{000}
TE317 x TC385A	8.79***	4.88***	66.27^{000}	2.44^{ns}	94.14^{ns}	5.96^{ns}	2.46^{000}
Control 1	9.15***	4.04***	66.11^{000}	2.82***	92.36^{000}	7.50***	3.32***
TA447 x TE335	8.45^{ns}	3.99***	68.31^{000}	2.58^{ns}	93.45^{000}	6.56***	2.91**
TA452 x TE335	7.73^{000}	3.86***	68.29^{000}	2.60^{ns}	93.54^{000}	6.89***	3.07***
TE342 x TE335	8.94***	3.50^{000}	70.65***	2.40^{00}	94.80***	5.34^{000}	2.91**
TA470 x TE335	7.98^{000}	3.44^{000}	71.06***	2.43^{0}	93.99^{00}	6.27^{ns}	3.20***
TE383 x TE335	8.00^{000}	4.08***	71.08***	2.20^{000}	94.99***	5.41^{000}	2.16^{000}
TA468 x TE335	8.04^{000}	4.02***	71.53***	2.04^{000}	95.49***	5.18^{000}	2.12^{000}
TE317 x TE335	8.46^{ns}	3.95***	69.64^{0}	2.61	93.55^{000}	6.18^{ns}	3.35***
Control 2	9.21***	4.29***	68.99^{000}	2.82***	93.86^{000}	6.50**	2.96***
TA447 x TE289	8.71***	3.52^{000}	69.39^{000}	2.99***	93.96^{00}	6.88***	3.07***
TA452 x TE289	7.73^{000}	3.66^{ns}	70.04^{ns}	2.82***	94.59**	6.58**	2.88*
TE342 x TE289	8.45^{ns}	3.18^{000}	70.83***	2.67***	94.28^{ns}	6.45*	2.80^{ns}
TA470 x TE289	8.09^{000}	3.21^{000}	73.00***	2.26^{000}	95.50***	5.29^{000}	2.23^{000}
TE383 x TE289	8.21^{000}	3.08^{000}	71.60***	2.56^{ns}	94.76***	6.07^{ns}	2.76^{ns}
TA468 x TE289	8.54^{ns}	2.59^{000}	72.18***	2.61*	94.35^{ns}	6.40^{ns}	3.12***
TE317 x TE289	8.32^{000}	3.74^{ns}	70.22^{ns}	2.74***	94.25^{ns}	6.68***	2.79^{ns}
Control 3	8.27^{000}	3.48^{000}	70.86***	2.55	94.59**	6.15^{ns}	2.45^{000}
LSD (p 5%)	*0.08*	*0.07*	*0.36*	*0.08*	*0.22*	*0.23*	*0.09*
LSD (p 1%)	*0.10*	*0.09*	*0.48*	*0.11*	*0.30*	*0.30*	*0.12*
LSD (p 0.1 %)	*0.13*	*0.12*	*0.62*	*0.14*	*0.38*	*0.39*	*0.15*

*,**,***= significant at 5%, 1% and 0.1% probability levels, positive values; ^{0},^{00},^{000}= significant at 5%, 1% and 0.1% probability levels, negative values; ^{ns}=not significant.

4. Conclusions

In all three experimental years, statistically significant differences were noted for the studied quality indices, being influenced both by the factor year, genotype and by the interaction between the two. The hybrids that have as paternal form TC385A line stand out for their high protein content compared to the other hybrids studied, notably: TE383 x TC385A with 8.92% and TA470 x TC385 A with 8.87%. However, the highest protein content was recorded at TE342 x TE335 (8.94%). The TA447 inbred line was distinguished by a good GCA for transmitting a higher percentage of protein, fat, fiber and NDF.

References

[1] Antohe I., O. Cosmin, T. Sarca, G. Dicu, C. Naidin, V. Năescu, 2007, High Yielding, Drought Resistant Maize Hybrids with Good Quality Traits, Analele I.N.C.D.A. Fundulea, 74, 61-64.

[2] Călugăr R.E., C.D. Vana, A. Varga, L.A. Ceclan, N. Tritean, A.B. Ghețe, 2023, Germplasm Collection – Valuable Resources of Variability for Plant and Ear Traits in Maize Breeding. Notulae Botanicae Horti Agrobotanici, 51(2), 13141, doi.org/10.15835/nbha 51213141.

[3] Călugăr R.E., E. Muntean, A. Varga, C.D. Vana, V.V. Haș, N. Tritean, L.A. Ceclan, 2022, Improving the Carotenoid Content in Maize by Using Isonuclear Lines. Plants, 11 (13), 1632, doi:10.3390/plants11131632.

[4] Cristea M., 2004, Importanța Economică, Răspândirea Geografică, Producția Și Comerțul Cu Porumb. In Porumbul - Studiu monografic; Editura Academiei Române: București, 1, 17–2.

[5] FAOSTAT, https://www.fao.org

[6] Haș V., A. Copândean, C. Vana, A. Varga, R. Călugăr, 2017, Sase Decenii de Cercetari Si Realizari in Ameliorarea Porumbului La Turda. In Contribuții ale cercetării științifice la dezvoltarea agriculturii, 7, 87–130.

[7] Măruțoiu C., M. Tofană, D. Nica-Badea, A. Popescu, 2005, Cromatografia pe strat subțire. Analiza Produselor Alimentare. Ed. Etnograph, Cluj-Napoca.

[8] Nuss E.T., S.A. Tanumihardjo, 2010, Maize: A Paramount Staple Crop in the Context of Global Nutrition. Comprehensive Reviews in Food Science and Food Safety, 9, 417–436.

[9] Osorno J.M., M.J. Carena, 2008, Creating Groups of Maize Genetic Diversity for Grain Quality: Implications for Breeding. Maydica, 53, 131–141.

[10] Pollak L.M., M.P. Scott, 2005, Breeding for Grain Quality Traits. Maydica, 50, 247–257.

[11] Ranum P., J.P. Peña-Rosas, M.N. Garcia-Casal, 2014, Global Maize Production, Utilization, and Consumption. Annals of the New York Academy of Sciences, 1312 (1), 105–112.

[12] Sarca T., O. Cosmin, I. Antohe, 2007, Cercetări Și Realizări În Ameliorarea Porumbului La Fundulea. Analele I.N.C.D.A. Fundulea, 75, 99–135.

[13] Scott M.P., J.W. Edwards, C.P. Bell, J.R. Schussler, J.S. Smith, 2006, Grain Composition and Amino Acid Content in Maize Cultivars Representing 80 Years of Commercial Maize Varieties. Maydica, 51, 417–423.

[14] Varga A., 2021, Studiul Înrudirii/Divergenței Genetice Și Valorii Genetice a Unor Linii Consangvinizate de Porumb (Zea Mays L.), Teză de doctorat, Universitatea de Științe Agricole și Medicină Veterinară.

[15] Varga A., R.E. Călugăr, C. Vana, L. Ceclan, I. Racz, N. Tritean, 2023, Assessment of the Degree of Relatedness of Some Inbred Lines Created at ARDS Turda, Agronomy, 13(6), 1505, doi:10.3390/agronomy13 061505.

[16] Zurak D., D. Grbeša, M. Duvnjak, G. Kiš, T. Međimurec, K. Kljak, 2021, Carotenoid Content and Bioaccessibility in Commercial Maize Hybrids. Agriculture, 11(7), 586, doi:10.3390/agriculture 11070586.