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THE EFFECT OF CLIMATIC CONDITIONS ON THE YIELD AND QUALITY OF MAIZE IN THE CENTRAL PART OF OLTENIA

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ABSTRACT

The Oltenia area is often affected by drought and heat that strongly influence plant development and yield. This paper aims at evaluation the genotype x environment interaction of yield and quality components of maize hybrids under different climatic conditions. The trials have been located on the experimental field at Agricultural Research and Development Station (SCDA) Şimnic, during three years (2012, 2013 and 2015). As biological material, there have been used five Romanian maize hybrids: F376, Milcov, Iezer, F475M and Crişana. The results have shown that the genotype x year interaction influenced the yield and protein content, but not the oil content. The average yield for all examined hybrids was 2743 kg/ha, the average protein content was 14.70% and the average oil content was 5.22%. The yield was negatively statistically significant, correlated with protein content and with air temperature. As average values for the research period, the Iezer hybrid was highlighted by high yield and high contents of protein and oil, therefore, this Romanian hybrid is recommended for use in the future breeding programs.

INTRODUCTION

Maize (Zea mays L.) is a field crop that is cultivated worldwide, being the second staple crop after wheat in international trade. But changes in climatic conditions (heat, water scarcity and heavy rains) threaten crop quality and yield (Yumurtaci, 2015). The quality of the maize grains is seen differently in function of purpose (food, animal meal, biodiesel, etc). The protein and oil content can be considered quality characters for the maize that is used as human food as well as fodder for animals. Magsood et al. (2012) report that the protein content is the most important parameter affecting the palatability and nutritional value of forage crops.

The malnutrition still remains a grave problem especially in developing countries with low GDP. Globally, almost 200 million children under 5 years old are underfed, this situation that can determines: the cease of growth, intellectual problems and poor diseases resistance of the body (Chukwu et al., 2013). The oil content is an important character of the maize grains when the yield is used for animal feeding because the oil has bigger calorific power than starch (Abou-Deif et al., 2012). Also, the maize oil is good as human food, being recommended for cooking due to its high content in unsaturated fatty acids (Mangolin et al., 2004).

The yield and the quality are metric characters with polygenic determinism and are influenced by the environment (Popovic et al., 2015). Because, the genetic variation determined by the genotype x environment interaction, decreases heritability and makes it difficult to obtain good estimates of genotypic breeding value, it is necessary to characterize genotypes according to their performance under a certain environmental conditions (Miladinovic et al., 2011). In Oltenia, maize crop is frequently affected by drought (Urechean et al., 2010).

One of the main directions of agricultural biotechnology is plant breeding for obtaining highly productive lines, resistant to diseases and extreme weather conditions.

This direction includes the production of plants with increased rates of photosynthesis, plants resistant to cold or high temperatures, drought or increased soil salinity (Bonciu, 2012).

Therefore, the goal of the present study was to determine the maize yield and its quality under the influence of the interaction between maize hybrids and climatic conditions of the researching years within the Central part of Oltenia Region (Romania).

MATERIALS AND METHODS

Experimental design

There were researched 5 Romanian maize hybrids: F376, Milcov, Iezer, F475M and Crişana. The trials have been located on the experimental field at Agricultural Research and Development Station (SCDA) Şimnic (44019' N; 23048' E) in different climatic conditions of 2012, 2013 and 2015 years, on a preluvisoil (with a humus content between 1.8 % and pH= 5.7), that is medium supplied by NPK. The trial had three randomized blocks and three replications.

Crop management

In 2012 maize was sowed on 30 April, in 2013 on 22 April and in 2015 on 17 April, with a plant density of 60000 plants per ha. The trial has been fertilized by complex fertilizers 250 kg/ha (NPK 20: 20: 0) before sowed and by ammonium nitrate 250 kg/ha, in vegetation (10-12 leaves of maize). The weeds were controlled by Camix herbicide 2.8 l/ha when the maize had 2-4 leaves and the low growing stage of the weeds. There were, also made two mechanical hoeings and two manual hoeings.

Determinations and data analysis

The total protein and oil content of the maize grains was determined by PERTEN Instrument (NIR). The experimental data have been statistically processed by ANOVA with two factors as well as LSD test (5%). The correlations have been tested for probability levels of 5% and 1%. The stability of studied was determined in function of the variation coefficient (CV%).

Climatical data

The climatic conditions of May-August period during three years of experiment were different (2012, 2013 and 2015) as shown in Table 1. The 2012 year was the most unfavorable because of deficient rainfall and mean monthly temperature which exceeded average (+ 1.650 C). The years 2013 and 2015 have been average favorable for maize crop due to less than average rainfall and close to average temperature.

Table 1.

Monthly mean, temperature and total rainfall during experiment, ARDS Simnic

Parameter		IV	V	VI	VII	VIII	Average
Rainfall l per m^2	2012	79.3	130.0	28.0	13.5	-	50.16
	2013	56.0	55.0	88.0	20.0	27.0	49.20
	2015	36.0	72.0	63.0	24.0	64.0	51.80
	Multiannual average	54.5	70.8	75.1	86.1	48.8	67.06
Temperature ^{0}C	2012	13.7	17.9	21.8	26.6	25.4	21.05
	2013	14.5	19.4	21.3	23.4	24.5	20.60
	2015	11.6	18.3	20.8	25.9	23.9	19.90
	Multiannual average	12.1	18.6	21.5	23.8	22.2	19.40

RESULTS AND DISCUSSIONS

Grain yield

The results of the analysis of variance for the yield have shown distinct significant differences among genotype, year, as well as for the genotype x year interaction (at 1% probability level) (Table 2). Haş *et al.* (2010) have reported that the environment fluctuations have a high impact on the maize yields and its chemical composition.

Table 2.

ANOVA for yield

Source of variation	SS	df	MS	F
Genotype	3380481	4	845120.3**	8.195523
Year	1.09E+08	2	54623877**	529.713
Interaction	7637471	8	954683.8**	9.258011
Error	3093593	30	103119.8	

*and ** = significant at 1% and 5% probability levels

The studied hybrids have recorded relatively low yields, the average amount being 2743 kg/ha in the research period of three years (Table 3).

As regard the stability of the maize yields that is evidentiated through the variation coefficient (CV%), this it recorded very high values, between 56.51% (F475M) and 84.28% (Crişana). As average, the yields recorded in 2013 (3882 kg/ha) and 2015 (3807 kg/ha) have been significantly higher than the yields of 2012 year (540 kg/ha). During the unfavorable year of 2012, there was obtained the lowest average yield. This year, the best yield has been given by F475M (910 kg/ha) and F376 hybrids (810 kg/ha). In 2013 the best yield has been given by Iezer hybrid (4577 kg/ha) and in 2015 by F376 (4401 kg/ha) and Iezer (4385 kg/ha) hybrids.

The best average yields for the research period (2012, 2013 and 2015) have been given by Iezer (3077 kg/ha) and F376 (2895 kg/ha) hybrids.

Table 3.

Maize yield (kg/ha) and stability of yield (CV %) ARDS Simnic

No	Genotype (A)	Yield, kg/ha			Average per genotype	Stability, CV%
		Year (B)				
		2012	2013	2015		
1	F376	810	3473	4401	2895	64.39
2	Milcov	485	3880	4174	2846	72.02
3	Iezer	269	4577	4385	3077	79.10
4	F475M	910	3447	3500	2619	56.51
5	Crişana	226	4033	2578	2279	84.28
Average per year		540	3882	3807	2743	69.56

Indicator	LSD	A	B	AXB
Yield	5%	218.4	169.1	378.2

Protein content

The quality of the maize yield is a complex character that is formed during ontogenesis representing the phenotypic expression of genotype x environment interaction.

The analysis of the significations of the variances for the protein content have shown the presence of distinct significant differences as a result of the influences of genotypes but and of researching years. Also, the genotype x year interaction had a distinct effect on the protein content (at 1% probability level) (Table 4).

Table 4.

ANOVA for protein content

Source of variation	SS	df	MS	F
Genotype	13.02889	4	3.257222**	23.19225
Year	16.128	2	8.064**	57.41772
Interaction	6.189778	8	0.773722**	5.509098
Error	4.213333	30	0.140444	

*and** = significant at 1% and 5% probability levels

Similar results have been reported previously by de Zaidi *et al*. (2008). Haş *et al*. (2010) have reported significant differences for the protein content as a result of researching years and less as a result of genotypes. Fabijanac *et al*. (2006) have reported that the protein content was influenced by both the researching years and the genotype x year interaction.

The content of grains in protein had higher values in 2012. The obtaining of higher protein content in dry years has been confirmed by other author, too Zaidi *et al*. (2008), Haş *et al*. (2010) and Pandrea (2012). As average, the protein content of maize grains in 2012 (15.34%) has been significantly higher than in 2013 (14.86%) and in 2015 (13.90%) for all studied hybrids (Table 5). The highest protein content in dry year 2012, was recorded with the Iezer (15.93%) and F376 (15.87%) hybrids. In 2013, the Milcov hybrid evidenced by a high protein content of grains (15.70%) and in 2015 there were evidenced the Crişana (14.60%) and Milcov (14.50%) hybrids.

Average values of protein content for the researching period (2012, 2013 and 2015) were recorded with all studied hybrids, excepting F475M (13.63%).

The good stability of the average protein content, compared with the stability of the yields was evidenced by low values of the variation coefficient that ranged between 2.01% (Crişana) and 8.50% (F475M).

Table 5.

Protein content (%) in maize and its stability (CV, %) - ARDS Simnic

No.	Genotype (A)	Protein content, %			Average per genotype	Stability, CV%
		Year (B)				
		2012	2013	2015		
1	F376	15.87	15.30	13.90	15.02	6.73
2	Milcov	15.00	15.70	14.50	15.07	3.99
3	Iezer	15.93	14.60	14.10	14.88	6.36
4	F475M	14.70	13.80	12.40	13.63	8.50
5	Crişana	15.20	14.90	14.60	14.90	2.01
Average per year		15.34	14.86	13.90	14.70	4.98

Indicator	LSD test	A	B	AXB
Protein content	5%	0.25	0.20	0.44

Oil content

The results of the analysis of variance for the oil content of maize grains have indicated the presence of distinct significant differences under the genotype influence. There were recorded no significant differences due to researching years. Also, the interaction between the analyzed factors (genotype x year) has had no statistically significant effect on oil content (at 1% and 5% probability level) (Table 6). It means that the genetic factors have a higher importance on the oil content than the environment factors. Our results are contradicting with the ones obtained by Haş et al. (2010) who reported significant influence both genotypes and years, yet they are similar with the ones obtained by Fabijanuc et al. (2006) who observed that the years had no significant effect on the oil content of maize grains.

Table 6.

ANOVA for oil content

Source of variation	SS	df	MS	F
Genotype	3.918667	4	0.979667 **	10.52148
Year	0.320444	2	0.160222-ns	1.720764
Interaction	1.290667	8	0.161333- ns	1.732697
Error	2.793333	30	0.093111	

ns = non-significant, ** = significant at 1% and 5% probability levels

The average oil content for the researching period (2012, 2013 and 2015) have been of 5.22%, significant values being recorded with Milcov (5.53%) and Iezer 5.48%) hybrids (Table 7). Lower values of the variation coefficient for the average oil content have been ranged between 1.26 (Iezer) and 6.65% (Crişana), emphasizing the good stability of this character.

Table 7.

Oil content (%) of maize and its stability (CV, %) - ARDS Simnic

No	Genotype (A)	Oil content, %			Average per genotype	Stability, CV%
		Year (B)				
		2012	2013	2015		
1	F376	5.23	5.10	5.30	5.21	1.93
2	Milcov	5.90	5.20	5.50	5.53	6.34
3	Iezer	5.40	5.50	5.53	5.48	1.26
4	F475M	4.60	4.80	4.70	4.70	2.12
5	Crişana	5.00	5.00	5.60	5.20	6.65
Average per year		5.23	5.12	5.33	5.22	1.97

Indicator	LSD test	A	B	AXB
Oil content	5%	0.21	0.16	0.36

Correlations between the studied characters

In order to identify the relations between the studied characters as well as for comparing our results with correlations reported previously, there were calculated the correlations.

The correlations between the studied characters, for the researching period (2012, 2013 and 2015 are presented in the Table 8.

Table 8.

Correlations between tested characters in maize grain

Character	Yield	Protein content	Oil content	Rainfall	Temperature
Yield	1	-			
Protein content	-0.912^{00}	1	-		
Oil content	-0.047	-0.365^{0}	1		
Rainfall	0.129	-0.523^{00}	0.984**	1	
Temperature	-0.784^{00}	0.969**	-0.581^{00}	-0.716^{00}	1

^{*,0}r – P 5% = 0,31; ^{**,00}r – P 1% = 0,40

The average yield in the researching period was statistically significantly negatively correlated with protein content (r = -0.912^{00}) and with temperature (r = -0.784^{00}). Similar results for yield and protein content were reported by Saleem *et al.* (2008) and Fabijanac *et al*. (2006). Between yield and oil content has been a low relationship and no significant (-0.047). Sreckov *et al*. (2011) found low relation between yield and oil content, in two testcross populations of maize.

The protein content was negatively significantly correlated with oil content (r = -0.365^{0}) and rainfall (r = -0.523^{00}) and positively significantly correlated with air temperature (r = 0.969**) (Table 8). The contradictory results were obtained by Alda *et al.* (2011), Stevanovic *et al.* (2012), Fabijanuc *et al.* (2006) which have reported a positive relationship between protein content and oil content.

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The oil content was highly significantly positively correlated with rainfall (r = 0.984**) and negatively significantly correlated with temperature (r = -0.581^{00}).

The rainfall showed negatively highly significantly correlation with temperature (r = -0.716^{00}).

Haş *et al.* (2010) have reported that the choosing of maize genotype that holds simultaneously the high yield and all indices of quality with higher values it is difficult to achieve, thus it is indicated to choose genotypes that achieve at the same time, with high yield one of the quality indices at higher leves.

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CONCLUSION

The effect of the genotype, the year and the genotype x year interaction have proven to be significant only on the yield and the protein content but not for the oil content. During unfavorable year 2012 the protein content has been significantly higher and during average favorable years 2013 and 2015 the yields have been significantly higher.

The average yield for all examined hybrids was 2743 kg/ha, the average protein content was 14.70% and the average oil content was 5.22%. The highest average yields for the researching period have been given by Iezer and F376 hybrids. During the driest year there were emphasized the F475M and F376 hybrids.

The yield was negatively statistically significant correlated with protein content and with air temperature.

The Iezer hybrid has, both, high yielding potential and high contents of protein and oil in grains. This hybrid is recommended for future breeding programs.

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