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EVALUATION OF MAIZE HYBRIDS FOR GRAIN YIELD AND QUALITY TRAITS UNDER FIELD CONDITIONS FROM SOUTHWESTERN ROMANIA

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Abstract

This paper presents the effects of the experimental year and the hybrid (genotype) on the grain yield, protein and oil contents of Romanian commercial maize hybrids. Field trials were conducted at Agricultural Research and Development Station Şimnic located in southwestern Romania, during three successive years (2016, 2017 and 2018). The average grain yield for all hybrids tested was 7.53 t/ha. The 2018 yields were significantly higher than the 2016 and 2017 yields. The F376 hybrid achieved the highest average grain yield and oil content but the lowest protein content. The very dry year 2017 was the best year for the synthesis of protein and oil in maize grains. The average protein content for all hybrids tested was 14.5% and the average oil content was 5.1%. Oituz and F423 hybrids achieved the highest average protein content compared to other hybrids tested. The Oituz hybrid also achieved the highest average oil content (except the F376 hybrid). The combined three years of data revealed that grain yield was significantly negatively correlated with the protein and oil contents.

Key words*: maize, oil content, protein content, yield.*

INTRODUCTION

Agro-ecological factors are dominant in the forming process of the yield of field crops.

The year weather conditions are decisive in the yield creation process of crops and their interaction with other factors leads to regulation of particular growth phase in which the quantity and quality of the final yield are formed (Černy et al., 2011; Popović et al., 2013).

The Oltenia region located in southwestern part of Romania represents an important agricultural region, which has vast areas that can be cultivated properly only if climate restrictions are taken into account. In this region, drought and heat are common, with only two out of ten years being favorable for crops. These abiotic factors always lead to different levels of yield loss depending on its intensity and crop stage (Bonea & Urechean, 2019; Urechean & Bonea, 2017; Urechean et al., 2019; Drăghici et al., 2019; 2021). According to Bonea & Urechean (2020), the average temperatures from grain-filling period and the rainfall from sowing to anthesis period were the dominant climatic factors that explained 94.6% and 93.3% respectively, of the inter-annual variability of maize yield.

Many researchers believe that a proper choice of cultivar, in addition to optimal cultural practices, can ensure a high yield and quality of maize grown under different agro-ecological conditions (Popovic et al., 2013; Bojović et al., 2019).

Maize (*Zea mays* L.) is one of the most important plants grown in the world from an economic point of view and it is used as a source of food, animal feed and for various industrial applications.

The oil content is an important trait of maize grains when the yield is used for animal feed because the oil has a higher calorific power than starch (Abou-Deif et al., 2012). Maize oil is also good for consumption, being recommended for cooking due to its high content of unsaturated fatty acids (Mangolin et al., 2004; Sing et al., 2014). Therefore, the promotion and cultivation of high-yielding maize hybrids with good nutritional quality and drought tolerance is a prerequisite for resolving food insecurity.

The objectives of this paper were to evaluate the effects of the experimental year and the hybrid on grain yield and the quality of Romanian maize hybrids and also to investigate the association of yield with protein and oil content.

MATERIALS AND METHODS

Four Romanian commercial hybrids developed by NARDI Fundulea (Oituz, Iezer, F376 and F423) were used in this study.

The field experiments were conducted in three consecutive growing seasons (2016, 2017 and 2018) at the Agricultural Research and Development Station (ARDS) Simnic located in southwestern Romania, an area characterized by a temperate continental climate with sub-mediterranean influences. The trials were designed as randomized block experiments with four maize hybrids in three replications on a reddish preluvosoil.

Standard technological practices for maize cultivation have been applied. Sowing was carried out in the last decade of April (22 and 23, respectively) in 2016 and 2018 or in the first decade of April (10) in 2017.

Harvesting was carried out in the first decade of August each year.

The grain yield per plot was adjusted to 15.5% grain moisture and was converted to tones per hectare.

The protein content and oil content of the maize grains was determined by PERTEN Inframatic 9140.

The precipitation and temperature data were collected from Weather Station Craiova (Table 1).

Table 1. Monthly average precipitation and temperature in the experimental years (ARDS Simnic, 2016, 2017 and 2018)

Year	**Deviation from multiannual average (±)**					
	April	**May**	**June**	**July**	**August**	**April-August**
Precipitation (mm)						
2016	+19.6	+16.6	+31.5	-28.8	-12.0	-12.3
2017	+10.4	+0.1	-50.5	+25.2	-40.6	-55.4
2018	-42.5	-19.9	+66.5	+52.2	-21.6	+34.7
Multiannual average	53.6	70.9	74.5	82.8	49.6	331.4
Temperature (°C)						
2016	+2.7	-1.3	+0.5	+0.1	+0.8	
2017	-0.5	-0.3	+1.8	+0.4	+2.7	
2018	+4.0	+1.6	+0.2	-1.2	-1.4	
Multiannual average	12.1	17.6	21.4	23.8	22.3	

The year 2016 was considered moderately favorable for maize crop, the deficit being small (-12.3 mm) compared to the multiannual average. In this year April, May and June were wet with frequent rainfall but July and August were dry.

The year 2017 was characterized as an unfavorable year with severe drought stress in June and August, the deficit reaching -55.4 mm compared to the multiannual average. During these periods, the heat was more intense. April and May were optimal for plants, June was extremely dry, July was wet and August was very dry.

In 2018, April, May and August were dry, while June and July were very wet, the year being considered moderately favorable for maize crop.

Effects of experimental year and hybrid (genotype) were evaluated by analyses of variance (two-factor ANOVA) with interaction. Significant differences between averages were reported using the Least Significant Difference (LSD) at the $p \leq 0.05$ level. Relative dependence was defined by correlation analysis and obtained coefficients were tested for significance level of 0.05% and 0.01% (Săulescu & Săulescu, 1967). All analyses were carried out using Microsoft Office Excel program.

RESULTS AND DISCUSSIONS

Grain yield

Grain yield is one of the complex characters controlled by several interacting genotypic and environmental factors. Few yield components are less complex, highly inherited and less influenced by the environmental changes (Kashiani & Saleh, 2010).

According to Heidari et al. (2019), a considerable range of variations for the tested traits provide a good opportunity for selection to identify superior genotypes and to use them as a genetic source for breeding purposes versus yield improvement and the introduction of commercial varieties, especially in conditions of drought stress.

For grain yield, ANOVA results showed significant differences between years and hybrids (P≤0.01) (Table 2).

Several researchers have reported that environment fluctuations have a high impact on maize yield (Haş et al., 2010; Barutcular et al., 2016; Bonea, 2016).

The maize yield varied considerably during the research period, depending on the amount and distribution of precipitation during the growing season (Table 3).

On average, in 2018 there was a significantly higher yield (8.90 t/ha) compared to 2017 (5.07 t/ha) and 2016 (8.61 t/ha). The highest yield in 2018 was achieved by the hybrid F376 (10.31 t/ha), and in 2016 was achieved by the hybrids F423 (9.48 t/ha) and F376 (9.28 t/ha). In the very dry year 2017, the best yields were given by the hybrids F376 (5.61 t/ha) and F423 (5.36 t/ha), while the hybrid Oituz had the lowest yield of 4.32 t/ha (Table 3).

Table 2. ANOVA for grain yield, protein and oil content

Source of variation	df	SS	MS	F
Grain yield (t/ha)				
Hybrid	3	15.64	5.21	113.80**
Year	2	109.46	54.73	1194.33**
Interaction	6	7.83	1.30	28.48**
Error	24	1.10	0.05	
Protein content (%)				
Hybrid	3	3.63	1.21	12.0**
Year	2	18.73	9.37	92.90**
Interaction	6	6.16	1.03	10.19**
Error	24	2.42	0.10	
Oil content (%)				
Hybrid	3	1.13	0.37	7.39**
Year	2	1.23	0.62	12.14**
Interaction	6	0.84	0.14	2.77*
Error	24	1.22	0.05	

*and ** = significant at P≤0.05 and P≤0.01, respectively

The average yield for tested hybrids was 7.53 t/ha. The highest average yield in the research period 2016-2018 was achieved by the hybrid F376 (8.40 t/ha) followed by the hybrid F423 (7.70 t/ha), and the lowest average yield was achieved by the hybrid Oituz (6.56 t/ha).

The interaction between the analyzed factors (experimental year x hybrid) had a significant effect on grain yield (P≤0.01) (Table 2).

In 2017 and 2018, the F376 hybrid had a significantly higher yield compared to all tested hybrids (P≤0.05), and in 2016 the Oituz and F376 hybrids had significantly higher yields compared to all tested hybrids.

Protein content

The quality of the maize yield is a complex trait that is formed during ontogenesis representing the phenotypic expression of genotype x environment interaction (Bonea, 2016).

ANOVA results for protein content showed significant differences between years and hybrids (P≤0.01) (Table 2). On average, the protein content was significantly higher in the very dry year 2017 (15.5%) compared to 2016 (14.1%) and 2018 (13.5%) (Table 3).

Table 3. The average grain yield, protein and oil content under field conditions from ARDS Șimnic (2016, 2017 and 2018)

Traits	Hybrid (A)	Year (B)			
		2016	2017	2018	Average per hybrid
Grain yield (t/ha)	Oituz	6.89	4.32	8.46	6.56
	Iezer	8.79	4.98	8.58	7.45
	F376	9.28	5.61	10.31	8.40
	F423	9.48	5.36	8.26	7.70
	Average per year	8.61	5.07	8.90	7.53
Protein content (%)	Oituz	15.0	15.8	13.5	14.8
	Iezer	13.2	15.6	13.7	14.2
	F376	13.6	15.3	13.4	14.1
	F423	14.7	15.1	13.5	14.8
	Average per year	14.1	15.5	13.8	14.5
Oil content (%)	Oituz	5.5	5.4	4.7	5.2
	Iezer	4.9	5.1	4.8	4.9
	F376	5.3	5.5	5.4	5.4
	F423	5.0	5.4	4.7	5.0
	Average per year	5.2	5.4	4.9	5.1

Indicator	LSD test	A	B	A x B
Grain yield	5%	0.13	0.15	0.25
Protein content	5%	0.19	0.22	0.38
Oil content	5%	0.13	0.15	0.27

Many researchers have noted that high air temperature increased protein content (Halford et al., 2015; Mayer et al., 2016).

According to Prasanna et al. (2001), the protein content in maize ranges between 6-14% depending on genotype and environment. In this study, the average value of protein content for the researching period (2016-2018) was 14.5%. The highest average protein content was achieved by the hybrids F423 and Oituz (14.8%), and the lowest content by Iezer (14.2%) and F376 (14.1%). These results are in agreement with those obtained by Bonea (2016).

The year x hybrid interaction also had a significant effect on protein content (P≤0.01) (Table 3). In 2016, the hybrid Iezer had significantly lower protein content compared to all hybrids tested but in 2017 this hybrid had a significantly higher yield compared with the tested hybrids (except the Oituz hybrid). This difference may be due to the low temperature during grain-filling stage, which may be detrimental to protein synthesis (Ahmed & Fayyazul, 2015).

Our results are consistent with the results of several researchers who stated that the protein content is characteristic of the genotype but strongly influenced by the environment (Mikhaylenko et al., 2000; Haş et al., 2010; Popovic et al., 2013),

A different range of variation (8.22 and 13.94%) was observed by Abou-Deif et al. (2012), and Oliveira et al. (2006) found that the averages of total protein content in dent and flint populations were 9.67% and 10.51%, respectively, and the average of their hybrid combinations was 11.86%.

Oil content

The results of ANOVA have indicated that the oil content differed significantly between years and hybrids (P≤0.01) (Table 2).

On average, a significantly higher oil content (5.4%) was recorded in 2017 compared to 2016 (5.2%) and 2018 (4.9%) (Table 3).

The highest average oil content in the research period was achieved by hybrid F376 (5.4%) followed by Oituz (5.2%), and the lowest oil content by the hybrid Iezer (4.9%).
Interaction between year x hybrid had a statistically significant effect on the oil content ($P \leq 0.05$). In 2018, the Oituz hybrid had a significantly lower oil content compared to F376 but in 2016 this hybrid had a significantly higher yield compared to Iezer and F423.
These results are in agreement with those obtained by Bonea (2016). Mittelmann et al. (2006) reported similar results for the average oil content in 10 maize genotypes and their hybrids, which varied from 4.22% to 4.94%. Abou-Deif et al. (2012) showed average values of 7.67% and 11.56% in inbred lines of maize, and the value for crosses were between 9.27 to 11.29%. According to Laurie et al. (2004), the kernels of a modern maize hybrid contain ~ 4% oil, 9% protein, 73% starch, and 14% other constituents (mostly fiber). Normal maize kernels contain 3-4% oil, while high oil genotypes have about 6% oil (Singh et al., 2014).
Large variations in the grain yield, protein and oil content indicated that these traits were affected by agro-ecological factors, in addition to genetic factors and management practices.

Correlations analysis

The dependence between grain yield and protein and oil contents were determined by correlation analysis (Table 4).
The correlation coefficients between grain yield and protein content for the individual year were negative and non-significant in 2016 and 2018 ($r = -0.486$; $r = -0.538$, respectively), but in 2017 the correlation coefficient was negative and significant ($r = -0.687^{0}$).
The combined three years of data showed that grain yield was significantly negatively correlated with protein content ($r = -0.838^{00}$; $p \leq 0.01$).
On the contrary, Prakash et al. (2006) reported that grain yield was significantly positively correlated with protein content. Aliu et al. (2012) reported a negative and non-significant correlation between yield and protein content, but a positive and non-significant correlation with oil content.
Different relationships were observed between grain yield and oil content depending on the experimental year. The 2016 results indicated a negative and non-significant correlation ($r = -0.559$). Opposite correlations were found in 2017 and 2018, when the dependence between grain yield and oil content was slightly positive ($r = 0.200$) and significantly positive ($r = 0.788^{**}$; $p \leq 0.01$), respectively. These changes may be due to the total amount of precipitation in July, which favored both the yield and the oil content.

Table 4. Correlations between traits

Trait	Grain yield	Protein content	Oil content
2016			
Grain yield	1		
Protein content	-0.486	1	
Oil content	-0.559	0.323	1
2017			
Grain yield	1		
Protein content	-0.687^{0}	1	
Oil content	0.200	0.061	1
2018			
Grain yield	1		
Protein content	-0.538	1	
Oil content	0.788**	-0.321	1
Three years average			
Grain yield	1		
Protein content	-0.838^{00}	1	
Oil content	-0.352^{0}	0.394*	1

$*,^{0}$ Significant at 0.05 probability level, $**,^{00}$ Significant at 0.01 probability level

The average yield for the research period (2016-2018) was negative and significantly correlated with the oil content ($r = -0.352^{0}$, $p \leq 0.05$). Also, the protein content was positive and significantly correlated with the oil content ($r = 0.394^{*}$, $p \leq 0.05$).
Zdunic et al. (2012) observed a low relationship between yield and oil content in two testcross populations of maize. According to Singh et al. (2014), maize oil content is negatively correlated with grain yield and it is influenced by both genetic makeup and environmental conditions.

CONCLUSIONS

It was concluded that year, hybrid, and hybrid x year interaction cause statistically significant differences in the grain yield, protein and oil contents of the maize hybrids tested.
The average yields were significantly higher in 2018 (8.90 t/ha) compared to the 2016 and 2017 yields.

The very dry year 2017 was the best year for the synthesis of protein and oil from maize grain (15.5% and 5.4%, respectively).

The F376 hybrid had the highest average grain yield and oil content but the lowest protein content. The F423 hybrid also had a significant average grain yield.

Oituz and F423 hybrids obtained the highest average protein content compared to the other hybrids tested. The Oituz hybrid also had the highest average oil content, excep F376.

The combined three years of data showed that grain yield was significantly negatively correlated with protein and oil contents.

It can be recommended that growing F376 or F423 hybrid in order to obtain maximum grain yield, growing Oituz or F423 hybrid for maximum protein content, and growing F376 or Oituz hybrid for maximum oil content under the environmental conditions of southwestern Romania.

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