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INFLUENCE OF HYBRID AND WEATHER CONDITIONS ON YIELD, PROTEIN AND OIL CONTENTS IN GRAIN OF MAIZE

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Abstract

Considering the role of maize in both animal feed and human consumption, improving the quality of maize grain should be investigated with the same perseverance as the grain yield. The main objectives proposed in this research were to evaluate the influence of the hybrid, weather conditions and their interaction on the yield, protein and oil contents in grain maize, and to investigate the relationships between these traits. Field experiments were performed for two consecutive years at ARDS Șimnic. The results obtained showed that the weather conditions during the study years were the determinant factor of variability in grain yield (88%), and the hybrid was the determinant factor of variability in protein and oil contents (84% and 83%, respectively). In average, in 2018, a significantly higher grain yield (9.05 t/ha) and a significantly lower oil content (4.2%) were registered compared to 2019 (6.08 t/ha and 4.5%, respectively), while the protein content was almost similar in both years (12.5% and 12.3%, respectively). The hybrids P 9903 (7.88 t/ha) and DK 5068 (7.79 t/ha) obtained the highest average grain yields. The hybrid F 376 had the lowest average grain yield (7.03 t/ha) but the highest average protein content (13.4%) and oil content (5.3%). Negative correlations between traits suggested that an increase in the grain yield meant a decrease in the grain quality traits (protein and oil contents).

Key words: *grain protein content, grain oil content, maize yield, weather conditions*

INTRODUCTION

Maize (*Zea mays* L.) is an annual cereal of the family Poaceae (Gramineae) and due to its multiple uses is considered of great importance in ensuring global food security.

Cereals are widely used as feed for animals (feeding chickens, dairy cows, etc.) providing more than 80% of the total concentrated feed [7, 8]. Also, this cereal is an important source of profit for agricultural units with export potential [19, 22, 24].

Romania produces about 10.9 million tons of maize per year in approximately 2.6 million hectares [13].

According to [17], the grain of maize typically contain 73% starch, 10% protein, 4% oil and 10% other constituents.

Protein and oil contents are the most important traits of interest in the maize market [20]. Maize oil is included in the human diet because it has positive health effects, being characterized by high levels of poly-unsaturated fatty acids, especially linoleic acid (24%). It is a good source of vitamin E (21.11 mg ATE/100 g) and tocopherol (14.3 mg/100 g) [28]. Also, the oil content is an important trait of the maize grain when the harvest is used for animal feeding because it has bigger calorific power than starch [1].

Protein is a primary structural and functional component of the living cell. Maize protein can be used in various forms to ensure the protein requirements of different sections of society (infants, the elderly and the disabled, etc.) to prevent malnutrition [18].

Current climate change is adversely affecting crop yields and quality in many parts of the world, and long-term implications of these traits reduction are significant for food security. Evaluations of the impact of global climate changes in Romania emphasize that aridity would increase in the south-western parts of Romania, especially during the crop growing season [23].

The Oltenia region located in the south-western part of Romania is one of the most important agricultural regions but one of the most affected by drought and heat. These phenomena are considered to be some of the major causes of the decline of many crops in the affected areas [5, 9, 10, 11] and therefore of food insecurity.

The rainfalls from sowing to anthesis period and the average temperatures during grain-filling period are dominant climatic factors that explain inter-annual variability of maize yield in this region [6].

The weather conditions of the year are an important factor participating in the yields formation of all crops. Without water, the soil hardens, the roots do not grow sufficiently, and the plants remain underdeveloped affecting production [26].

Therefore, the a proper choice and cultivation of high yielding maize hybrids, that are of good nutritional quality and tolerant to drought stress is a pre-requisite to solving food insecurity. The objectives of this paper were to evaluate the influence of hybrid and weather conditions of the year on grain yield and the quality of maize hybrids and to indentify degree of correlation of these traits.

MATERIALS AND METHODS

Experimental design and plant material

In this experiment, three commercial maize hybrids with a good adaptability to the pedo-climatic conditions in south-western Romania were used, namely: F 376 (NARDI Romania, FAO 500), P 9903 (Pioneer Hi-Bred Services GmbH Austria, FAO 300) and DK 5068 (Monsanto SAS France, FAO 460).

The field trials were conducted in order to investigate the influence of biological material (hybrid/genotype) and weather conditions of the year on yield, protein and oil content in maize grains. The experiments were performed during 2018 and 2019 at the research fields of the Agricultural Research and Development Station (ARDS) Șimnic, Craiova. The site is located on the south-western Romania, in the central part of Oltenia at $44^0$19' N, $23^0$48' E and 182 m altitude. The experiments were established by randomized block method in three repetitions, on a reddish preluvosoil.

Morphologically, the soil presents an Ap 0-29 cm horizon characterized by: pH=5.08, 2.68% humus, 0.072 mg/kg nitrogen, 52.2 mg/kg phosphorus; 125 mg/kg potassium [25].

The principles of conventional technology of maize cultivation were applied (autumn deep ploughing, 55,000 plants/ha). Every year, wheat was the pre-crop. Seeds were sown on April 23 in 2018 and on April 18 in 2019, respectively.

During experiments, nitrogenous fertilizer was utilized within two times of vegetation period: 250 kg/ha N and P_2O_5 kg/ha (20-20-0) before sowing and with 250 kg N/ha (ammonium nitrate) at V8 growth stage. Weeds were controlled by hand weeding and by the use DUAL GOLD 960 1.5 l/ha applied immediately after sowing, and with EQUIP 1.5 l/ha + BUCTRIL 1.0 l/ha in the V6 stage.

Harvesting was carried out in the second decade of September each year.

Grain yield per plot was adjusted to 15.5% grain moisture and was converted to tones/ha.

Chemical composition in maize hybrids, protein and oil contents in grain were determined by infrared spectroscopy technique on the apparatus PERTEN *Inframatic 9140*.

The local weather conditions

The local weather conditions data (precipitations and temperature) were collected from the Weather Station Craiova (Table 1). The year 2018 was considered moderately favourable for maize crop, the precipitation surplus being of +20.7 mm compared to the multiannual average. This year there was a surplus of precipitation in June and July, the rest of the months being dry. The air temperature was higher than the multiannual average, with the exception of July (-1.2°C).

Compared to the multiannual average, 2019 was very dry, the precipitation deficit being of -111.4 mm. All the months of this growing season have been dry, with the exception of June when there was a surplus of precipitation (+62.4 mm). The air temperature was higher, with the exception of July (-1.2°C).

Statistical analysis

Statistical analyses were conducted using analysis of variance (two-factor ANOVA) and means were compared by Fisher's least significant difference (LSD) test at P≤0.05. The relative dependence between the studied traits was defined by correlation analysis (Pearson's correlation coefficients) and linear regression. All these analyses were carried out using the option Data Analysis in the Microsoft Office Excel program.

Table 1. Monthly precipitation and temperature for ARDS Simnic

Month	Multiannual average		Deviation from multiannual average (±)			
			2018		2019	
	P	T	P	T	P	T
April	53.1	12.2	-42.0	+4.4	-11.1	-0.3
May	71.7	17.5	-20.7	+1.7	-39.7	-1.3
June	73.6	21.5	+67.4	+0.1	+62.4	-1.2
July	82.2	23.8	+52.8	-1.2	-23.2	-0.9
August	47.0	22.5	-19.0	+1.2	-38.0	+2.6
September	61.8	17.8	-17.8	+1.4	-61.8	+2.4
Growing season (April – September)	389.4		+20.7		-111.4	

P = Precipitation in mm; T = temperature in °C
Source: Own processing based on data from Weather Station Craiova.

RESULTS AND DISCUSSIONS

Grain yield

Grain yield is the most important character for the maize breeding program. It is a polygenic character that largely depends on both genotypic and agro-ecological factors.

The analysis of variance (ANOVA) for grain yield showed a significant influence of the hybrid, the year and their interaction (P≤0.05) (Table 2). Most of the overall variation, respectively 88%, was due to the year (Figure 1).

Many researchers reported that the genotype and environment fluctuations have a high impact on the maize yield [3, 4, 30].

In this study, we observed that the average grain yield for two years of study was 7.57 t/ha. In 2018, on average for all hybrids tested, a statistically significantly yield was recorded (9.05 t/ha) compared with 2019 (6.08 t/ha) (Table 3). The 32.8% decrease of yield is the result of rainfall deficiency and its rather unfavourable distribution during the growing season.

The highest average yield in the research period was achieved by hybrids P 9903 (7.88 t/ha) and DK 5068 (7.79 t/ha), while hybrid F 376 (7.03 t/ha) achieved the lowest grain yield. The hybrid F 376 had a significantly lower yield in 2018 compared to all tested hybrids, and in 2019 a significantly lower yield compared to only the P 9903 hybrid. In both years, the P 9903 hybrid had a significantly higher yields compared to all hybrids tested (Table 3).

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

Source of variation	**Sum of squares**	**df**	**Mean squares**	**F-value**
Grain yield (t/ha)				
Hybrid (A)	2.649	2	1.324	70.423*
Year (B)	39.457	1	39.457	2,098.146*
Interaction (AxB)	2.636	2	1.318	70.082*
Error	0.236	12	0.019	
Protein content (%)				
Hybrid (A)	9.310	2	4.655	45.048*
Year (B)	0.125	1	0.125	1.210^{ns}
Interaction (AxB)	0.370	2	0.185	1.790^{ns}
Error	1.240	12	0.103	
Oil content (%)				
Hybrid (A)	7.320	2	3.660	66.545*
Year (B)	0.605	1	0.605	11.000*
Interaction (AxB)	0.280	2	0.140	2.545^{ns}
Error	0.660	12	0.055	

*and ^{ns} - significant and non-significant at P≤0.05
Source: Own calculation.

The DK 5068 hybrid had in 2018 a significantly higher yield compared to all tested hybrids but in 2019 this hybrid had a significantly lower yield compared to only the P 9903 hybrid (Table 3).

[16] noted that water stress during the grain-filling stage reduced grain yield by 60%, and [14] also reported a greater reduction in yield under drought stress in the reproductive stage than in the vegetative and grain-filling stage.

Table 3. The average grain yield, protein and oil content of the studied hybrids

Traits	Hybrid (A)	Year (B)		Average per hybrid
		2018	2019	
Grain yield (t/ha)	F 376	8.27	5.78	7.03
	P 9903	9.05	6.71	7.88
	DK 5068	9.81	5.77	7.79
	Average per year	9.05	6.08	7.57
Protein content (%)	F 376	13.5	13.3	13.4
	P 9903	11.8	12.0	11.9
	DK 5068	12.1	11.6	11.9
	Average per year	12.5	12.3	12.4
Oil content (%)	F 376	5.1	5.4	5.3
	P 9903	3.8	3.9	3.9
	DK 5068	3.6	4.3	4.0
	Average per year	4.2	4.5	4.4

Indicator	LSD test	A	B	AxB
Grain yield	5%	0.05	0.06	0.11
Protein content	5%	0.11	0.21	0.28
Oil content	5%	0.08	0.10	0.19

Source: Own calculation.

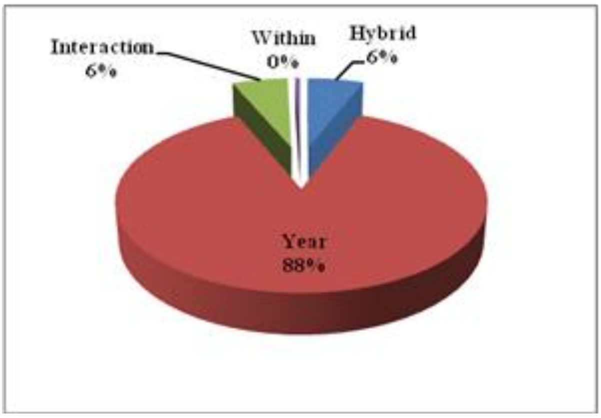

Fig. 1. Share of hybrid, year and their interaction in the variation of grain yield
Source: Own calculation and processing.

Protein content

The ANOVA results for the protein content showed the presence of significant differences in the case of the hybrid (P≤0.05) but non-significant differences in the case of the year and also in the case of the hybrid x year interaction (Table 2).

For protein content, most of the overall variation, respectively 84%, was due to the hybrid (genotype) (Figure 2).

[12] also reported a non-significant effect of the climatic conditions of year on the protein content of maize hybrids, while other authors [4, 27] reported that the protein content was significantly influenced by the genotype and climatic conditions of the year.

[17] found that the grain of maize contain 10% protein. In this study, the average protein content for all hybrids tested was higher (12.4%) compared to this value and almost similar in both years (12.5% and 12.3%, respectively).

The hybrid F376 had, on average, significantly higher protein content (13.4%) compared to the hybrids P 9903 (11.9%) and DK 5068 (11.9%) (Table 3).

Many authors [4, 27, 29] reported that the protein content in maize grain ranged between 8.0-14.0%; 8.05-11.43% and 13.63-15.07%, respectively. These variations were due to genotype and pedo-climatic conditions of study.

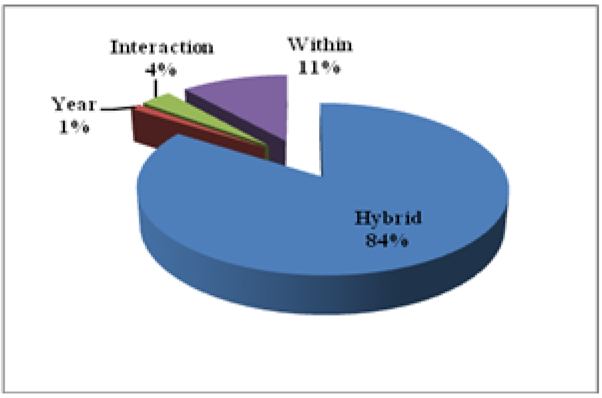

Fig. 2. Share of hybrid, year and their interaction in the variation of protein content
Source: Own calculation and processing.

Oil content

The results of ANOVA indicated that the oil content was significantly different in the case of the hybrids and years, but non-significant in the case of the hybrid x year interaction (Table 2).

The hybrid (genotype) explained most of the overall variation of this trait, respectively 83% (Figure 3).

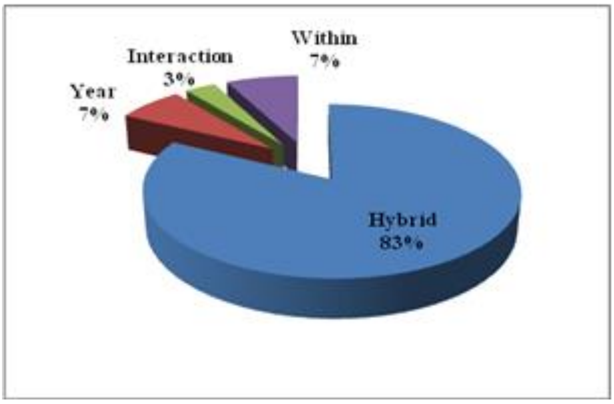

Fig. 3. Share of hybrid, year and their interaction in the variation of oil content
Source: Own calculation and processing.

Similar results for the influence of genotypes and years on oil content were reported by [15].

[17] found that the grain of maize contain 4% oil. In our study, the average oil content for the studied period was 4.4% (Table 3). The results are agreement with findings of [2, 4, 27] which shows that the oil content varied between 2.56-5.57%, 3.72-5.02% and 4.70-5.53%, respectively, depending on the genotype and the pedo-climatic conditions.

For the synthesis of grain oil, the most favourable year was 2019 when significant oil content was reached (4.5%) compared to 2018 (4.2%). These results showed that higher temperatures and lower rainfall during grain-filling stage favoured the oil content.

The highest average oil content in the research period was achieved by the hybrid F376 (5.3%) compared to the hybrids P 9903 (3.9%) and DK 5068 (4%).

Correlations between traits

The estimate of phenotypic correlations between grain yield and the two grain quality traits for 2018 and 2019 are presented in Figures 4, 5, 6 and 7.

In 2018 significant negative correlation was observed between grain yield and protein content ($r=-0.746^*$; $p\leq0.05$), also between grain yield and oil content ($r=-0.910^{**}$; $p\leq0.01$)

The coefficients of determination showed that about 56 % of the variation in the protein content and about 83% of the variation in the oil content are explained by the variation in grain yield of maize (Figures 4 and 5).

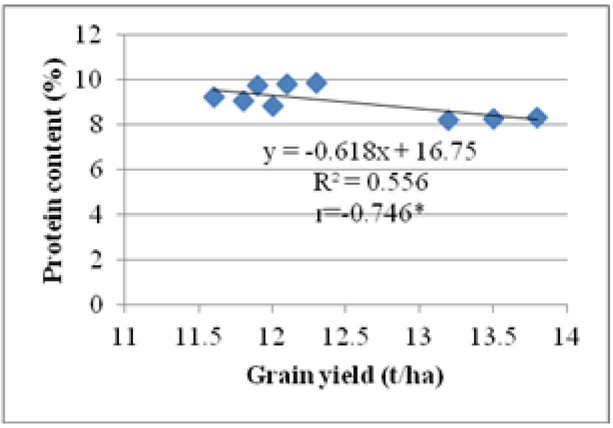

Fig. 4. Regression line and correlation coefficient between grain yield and protein content in 2018
Source: Own calculation and processing.

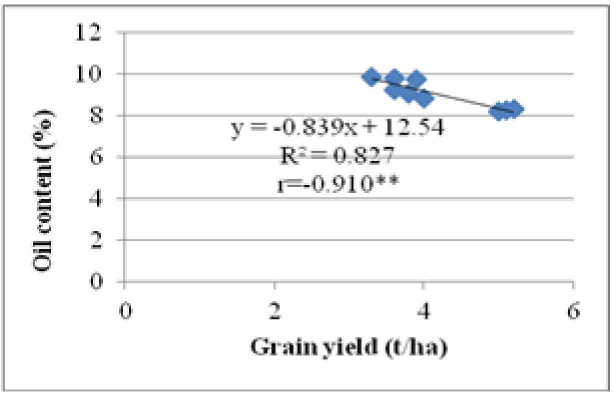

Fig. 5. Regression line and correlation coefficient between grain yield and oil content in 2018
Source: Own calculation and processing.

In 2019 the relations between grain yield and protein content and also between grain yield and oil content were negative but weak ($r=-0.222^{ns}$ and $r=-0.628^{ns}$, respectively).

Only 4.9 % of the variation in the protein content is explained by the variation in the grain yield, also 39.4% of the variation in the oil content is caused by the variation in the grain yield (Figures 6 and 7).

Our results revealed that an increase in yield leads to a decrease in the protein content and oil content in grain of maize. Contrary to these results, [21] reported low relations between yield and both quality traits.

On the other hand, [2] observed a weak negative relation between yield and protein content, but a weak positive relation between yield and oil content.

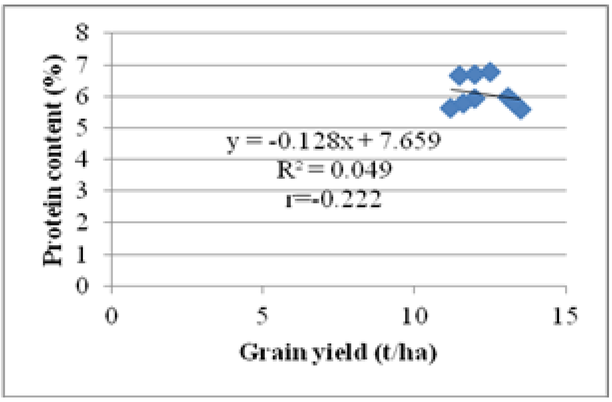

Fig. 6. Regression line and correlation coefficient between grain yield and protein content in 2019
Source: Own calculation and processing.

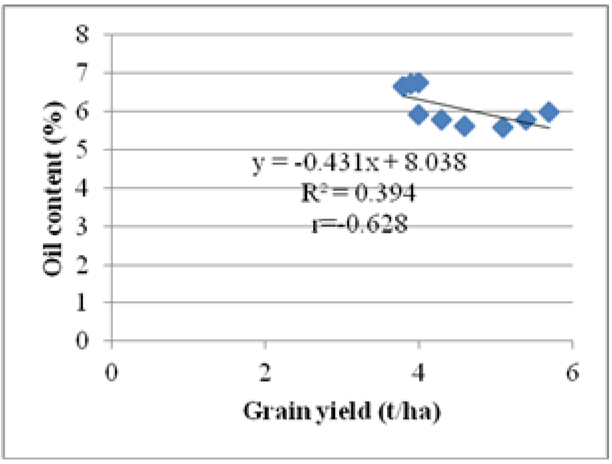

Fig. 7. Regression line and correlation coefficient between grain yield and oil content in 2019
Source: Own calculation and processing.

CONCLUSIONS

The results showed that grain yield was more influenced by the weather conditions of the year.
In the case of grain quality traits viz. protein and oil contents, the determining factor was the hybrid.
The highest grain yield and the lowest oil content in grain of maize were registered in 2018, while protein content was almost similar in both years.
The highest average grain yields were obtained by P 9903 and DK 5068 hybrids, and the highest protein and oil contents were obtained by F376.
The correlations between grain yield and quality traits have been negative in both years, thus breeding for high quality maize hybrids require moderate balance between these traits.

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