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COMPARATIVE PERFORMANCE AND STABILITY OF SOME MAIZE HYBRIDS IN THE AGROCLIMATIC CONDITIONS OF CRAIOVA, DOLJ COUNTY, ROMANIA

Ioana Claudia DUNĂREANU[1], Dorina BONEA[2]

[1]Agricultural Research and Development Station Șimnic – Craiova, 54 Bălcești Road, Dolj County, Romania, E-mail: claudia.borleanu@yahoo.com
[2]University of Craiova, Faculty of Agronomy, 19 Libertății Street, Dolj County, Romania, E-mail: dbonea88@gmail.com

Corresponding author: dbonea88@gmail.com

Abstract

Profitable and sustainable maize production is based on the use of stable and performing hybrids, suitable for contrasting environmental conditions. This paper presents the behaviour of three commercial maize hybrids at ARDS Șimnic- Craiova, Dolj County, in the period 2017-2020. The results of the ANOVA showed that the hybrid, year, and interaction H Y had significant effects on grain yield. The major variation of grain yields (80%) was caused by the year, the highest yields being obtained in 2018 and 2020, while the lower grain yields were obtained in 2017 and 2019. Average grain yields, variation coefficients (CV), regression coefficients (b), intercept values (a) and determination coefficient values (R^2) of hybrids were examined as stability parameters. The yield stability analysis indicated that the Iezer hybrid has a good adaptability to unfavourable environmental conditions from the study area, the P 0216 hybrid has a good adaptability to favourable environmental conditions, and the P 9637 hybrid has a good adaptability to contrasting environmental conditions.

Key words: *grain yields, intercept value, regression coefficient, variation coefficient*

INTRODUCTION

In 2020, maize *(Zea mays* L.) was the second most produced crop in the world (after wheat) with a cultivated area of 201.9 million hectares, and the most produced cereal in Romania (1st place) with a cultivated area of 2.6 million hectares [5]. This is due to the fact that maize has a wide range of uses such as animal feed, food industry, pharmaceutical industry, obtaining biodiesel, etc.

Romania plays an important role in the international cereal market [15, 16] and its performance in maize cropping is based on the use of high-yielding hybrids with a grain quality required for processing and with resistance to biotic and abiotic stresses [18].

Obtaining maize hybrids adapted to the specific conditions from the Oltenia area and sustainable maize production raises some particular problems determined by the drought and heat that occur frequently [2, 3, 25]. Thus, maize breeding activity to obtain high-yielding and stable hybrids is very important for crop management in this area.

Current climate changes and the use of older registered maize hybrids reduce genetic progress in grain yield [8].

The more recently registered cultivars (after 2000) are more tolerant to climate changes, especially through the improved yield traits following the selection of these genotypes under stress conditions [9].

Seed Companies and Research Institutes own maize hybrids with high genetic potential for grain yield. For increase stability, these hybrids must combine a genetically high yield potential and a good resistance to different environmental conditions [19].

The determination of yield stability and the degree of expression of improved traits is done by testing maize hybrids in comparative cultures located in different pedoclimatic conditions [20].

Evaluation of the interaction of each cultivar with environmental factors (year, location, soil type, applied technology, etc.) is a very important aspect for plant breeders.

This paper presents the behavior of three commercial maize hybrids in terms of yield performance and stability in different climatic conditions from ARDS Simnic-Craiova.

MATERIALS AND METHODS

In the experimental field of Maize Breeding Laboratory from Agricultural Research and Development (ARDS) Șimnic - Craiova, in the 2017-2020 period, multiple maize tests were carried out in order to identify the most adapted and performing genotypes, so as to reduce genetic vulnerability and obtain the highest and most stable yields. The site is located in the center of Oltenia region.

The data in this paper comes from comparative cultures with maize hybrids.

The trials were carried out according to the randomized blocks method in three repetitions and placed on a reddish preluvosoil with pH = 5.6; humus = 1.8, medium supplied with NPK. The technology applied was specific to maize cropping for non-irrigated conditions from the Craiova area. The previous plant was wheat. The commercial hybrids evaluated were: Iezer (hybrid created by NARDI Fundulea, FAO 401-500), P 0216 (created by PIONEER Company, FAO 450) and P 9537 (created by PIONEER Company, FAO 350). These maize hybrids were widely cultivated by farmers in the Oltenia region and in Dolj county, respectively. They were analyzed in each of the four years, both from the point of view of the grain yield, as well as some yield and quality traits (hectoliter weight, 1000-grain weight, plant height, protein content and oil content). Protein and oil contents were determined with the apparatus PERTEN Inframatic 9140. Characterization of hybrid stability for the grain yield was achieved using the following statistics parameters: average grain yields and coefficients of variation (CV) according to [7]; regression coefficients (b) and intercept values (a) according to [6]; and coefficients of determination (R^2) according to [17].

The obtained data for grain yield were processed by the analysis of variance (ANOVA).

All statistical analyses were performed using the Microsoft Office Excel.

Precipitation and temperature data for studied period were collected from Weather Station Craiova (Table 1).

In the study period (2017-2020) during the maize growing season (April-September) there was a great variation in the water and thermal regime.

Table 1. Deviations from the multiannual average of precipitations and temperatures recorded in the period 2017-2020 at ARDS Simnic-Craiova

Year	April	May	June	July	August	September	April-September
Precipitation (mm)							
2017	+10.9	-0.7	-49.6	+25.8	-38	-12.8	-64.4
2018	-42	-20.7	+67.4	+52.8	-19	-17.8	+20.7
2019	-11.1	-39.7	+62.4	+23.2	-38	-61.8	-111.4
2020	-53.1	-0.7	-2.6	+7.8	-21	-59.8	-129.4
Multiannual average	53.1	71.7	73.6	82.2	47	61.8	389.4
Temperature (°C)							
2017	-0.6	-0.2	+1.7	+0.4	+2.5	+7.2	
2018	+4.4	+1.7	+0.1	-1.2	+1.2	+1.4	
2019	+0.3	-1.3	+1.2	-0.9	+2.6	+2.4	
2020	-0.2	-1.3	-0.2	-0.6	+2	+4.8	
Multiannual average	12.2	17.5	21.5	23.8	22.5	17.8	

Source: Own processing based on data from Craiova Weather Station.

Thus, in 2017, larger precipitation deficits were recorded in the months of June (-49.6 mm), August (-38 mm) and September (-12.8 mm), also in the months of June, July, August and September, the temperatures were above the multiannual average by +1.7°C, by +0.4°C, by +2.5°C and by +7.2°C, respectively.

In 2018, precipitation deficits were recorded more in the vegetative period, in the months of April (-42 mm), May (-20.7 mm) and less in the reproductive period (August with -19 mm), and the temperatures exceeded the multiannual average in April (+4.4°C), May (+1.7°C), August (+1.2°C) and September (+1.4°C).

The year 2019 recorded precipitation deficits in April, May, August and September (-11.1 mm, -39.7 mm, -23.2 mm, -38 mm and - 61.8 mm, respectively, also the temperatures in the months of June, August and September were above the multiannual average by +1.2°C, by +2.6°C, and by +2.4°C, respectively.

The year 2020 recorded a larger precipitation deficit in the months of April, August and September (-53.1 mm, -21 mm and -59.8 mm, respectively) and temperatures above the multiannual average in August (+2°C) and September (+4.8°C).

RESULTS AND DISCUSSIONS

The fluctuations of the environmental factors during the four years of testing determined a large variability of grain yield from one year to another and from one hybrid to another. The amount of precipitation and temperatures during the critical periods of maize growth, namely the flowering-pollination and grain-filling stages, had a major role on grain yield levels. Similar results were reported by [9] for the ARDS Turda area.

Combined analysis of variance (ANOVA) for grain yield showed statistically significant differences ($p<0.05$) between years (Y) and between hybrids (H). Also grain yield was significantly affected by HY interaction (Table 2).

The proportion of the explained sum of squares showed that the variation of the grain yield was determined, in the first place by the effect of the year (80%), then by the effect of the hybrid (15%) and in the end by the effect of the HY interaction (3%) (Figure 1).

The small influence of the HY interaction shows that these hybrids are part of the category of modern hybrids that tolerate climate changes, especially through improved yield traits following the selection of these genotypes under stress conditions [9].

Table 2. Analysis of variance (ANOVA) for grain yield

Source of variance	Degrees of freedom	Sum square	F test
Hybrid (H)	2	17201896	106.2*
Year (Y)	3	93408191	384.5*
Interaction H x Y	6	3717698	7.6*
Erorr	24	1943223	

* = significant at 5% probability level, by F test
Source: Own calculation.

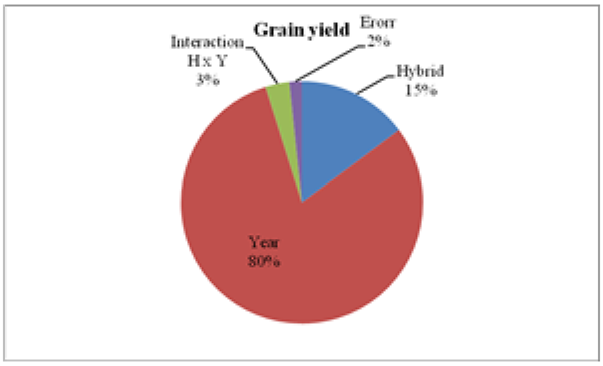

Fig. 1. Share of genotype, year and their interaction in the variation of grain yield
Source: Own design and processing.

The highest grain yields were obtained in 2018, followed by 2020, when drought and heat occured at the end of the grain-filling stage and the distribution of precipitation was more uniform. The low grain yields were obtained in 2019 and 2017 when drought and heat were more severe (Table 3).

According to [12], drought stress in one week before and two weeks after flowering cause yield losses of 20% to 50%, and drought stress in the grain-filling stage cause a yield loss of 10%.

In the dry year 2017, the average yield was 5,744 kg/ha (control), noting the hybrid P 0216 with a grain yield of 6,180 kg/ha and a significant difference of +436 kg/ha, and the hybrid P 9537 with a grain yield of 6,075 kg/ha and a significant difference of +331 kg/ha compared to the control. The Iezer hybrid obtained the lowest grain yield of 4,977 kg/ha with a significant difference of -767 kg/ha compared to the control.

In 2018, an average yield of 9,486 kg/ha was obtained, the hybrid P 9537 being noted with a grain yield of 10,489 kg/ha and a significant difference of +1,003 kg/ha compared to the control. The hybrid P 0216 obtained a grain yield of 9,890 kg/ha statistically similar to the control, and hybrid Iezer obtained the lowest grain yield of 8,079 kg/ha and a significant difference of -1,407 kg/ha compared to the control.

Table 3. The grain yields of the maize hybrids during the testing period, 2017-2020, at ARDS Șimnic-Craiova

Hybrid	2017		2018		2019		2020	
	kg/ha	±difference to control	kg/ha	±difference to control	kg/ha	±difference to control	kg/ha	±difference to control
Iezer	$4,977^{0}$	-767	$8,079^{0}$	-1,407	$4,699^{0}$	-664	$6,212^{0}$	-725
P 0216	6,180*	+436	$9,890^{ns}$	+404	$4,918^{ns}$	-445	$6,935^{ns}$	-2
P 9537	6,075*	+331	10,489*	+1,003	6,478*	+1,115	7,664*	+727
Average (control)	5,744		9,486		5,363		6,937	
LSD 5%		176		850		492		548

* = significant positive; ^{0} = significant negative; ns = non-significant, at 5% probability level
Source: Own calculation.

The lowest average yield, namely 5,363 kg/ha, was obtained in 2019, a year characterized by severe drought in July and August (during the flowering and grain-filling stages). The hybrid P 9537 was noted with a grain yield of 6,478 kg/ha and a significant difference of +1,115 kg/ha compared to the control. The hybrid Iezer obtained the lowest grain yield (4,699 kg/ha) with a significant difference of - 664 kg/ha compared to the control, and the hybrid P 0216 obtained a grain yield of 4,928 kg/ha statistically similar to the control.

In 2020, the average yield was 6,937 kg/ha, the hybrid P 9537 being noted, which achieved a grain yield of 7,664 kg/ha and a significant difference of +727 kg/ha. The lowest grain yield of 6,212 kg/ha and a significant difference of -725 kg/ha compared to the control was obtained by the hybrid Iezer, and the hybrid P 0216 obtained a grain yield of 6,935 kg/ha statistically similar to the control. Many reports showed that drought stress decreased significantly grain yield of maize and yield traits [2, 14, 21].

On average over the four years of testing, the grain yield obtained by the three commercial hybrids studied was 6,883 kg/ha. The hybrid P 9,537 was noticed with an average yield of 7,655 kg/ha, significantly higher than the control. Hybrid P 0216 obtained an average yield of 6,981 kg/ha statistically similar to the control, and hybrid Iezer obtained an average yield of 5,992 kg/ha significantly lower than the control (Table 4).

The maximum level of grain yields (10,689 kg/ha) was recorded for the hybrid P 9537 in 2018, and the minimum level of grain yields (4,428 kg/ha) was recorded for the hybrid Iezer in 2019. The biggest difference in grain yield in contrasting environmental conditions (5,864 kg/ha) was recorded in the P 0216 hybrid, and the smallest difference (4,069 kg/ha) was recorded in the Iezer hybrid (Table 4). Regarding the coefficients of variation, they showed a high yield variability in the studied hybrids (<30%), according to [23]. The lowest coefficients of variation were recorded in the hybrids P 9537 (23.5%) and Iezer (23.6%) Grain yield stability estimated by combining the use of coefficient of variation and average grain yields (Figure 2) according to [7], showed that the hibrid P 9537 is located in the group I of stability (with hight yield and small variation), the hybrid P 0216 is located in the group II of stability (with hight yield and large variation), and the hybrid Iezer is located in the group III of stability (with low yield and small variation).

Yield stability evaluated by regression coefficients (b) according to [6], showed that the hybrid Iezer is adapted to unfavorable environmental conditions (b<1), and the hybrids P 0216 and P 9537 are adapted to favorable environmental conditions (b>1). Also, the higher R^2 value for the hybrid Iezer (R^2=0.994) indicate its favorable response to environmental changes, according to [17] (Table 4).

Table 4. Maximum, minimum and mean yields and stability parameters to the variation of environmental conditions, ARDS Şimnic-Craiova, 2017-2020

Hybrid	Average (kg/ha)	Minimum (kg/ha)	Maximum (kg/ha)	Amplitude (kg/ha)	Stability parameters			
					Coefficient of variation (CV%)	b	a	R^2
Iezer	5,992^0	4,428	8,497	4,069	23.6	0.82	+315.5	0.994
P 0216	6,981^{ns}	4,597	10,461	5,864	27.7	1.18	-717.8	0.972
P 9537	7,677*	5,957	10,689	4,732	23.5	1.05	+409.7	0.971
Average experiment (control)	6,883				24.9			
LSD 5%	3,692							

* = significant positive; ^{0} = significant negative; ns = non-significant at 5% probability level
Source: Own calculation.

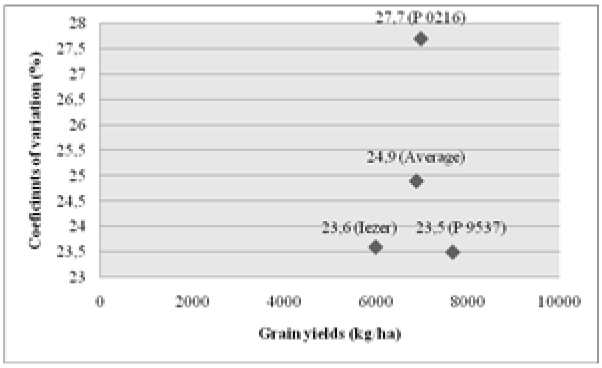

Fig. 2. Grain yields and yield stability expressed by the coefficient of variation
Source: Own design and processing based on the Francis and Kannenberg model [7].

The parallel analysis of both the regression coefficients (b) and the intercept values (a) allows a better characterization and also an identification of genotypes with wide adaptability to different environmental conditions [13, 26, 27].

According to [10], a genotype is adapted to unfavorable environmental conditions when the regression coefficient b<1 and "a" (intercept) has positive values; it is adapted to favorable environmental conditions when b>1 and "a" has negative values; it is adapted to contrasting environmental conditions when b>1 and "a" has positive values.

Therefore, based on these two parameters, the three studied hybrids can be classified as follows:

- the hybrid Iezer is a maize hybrid well adapted to unfavorable environmental conditions (b<1, "a" with positive values);
- the hybrid P 0216 is a maize hybrid well adapted to favorable environmental conditions (b>1, "a" with negative values);
- the hybrid P 9537 is a maize hybrid with wide adaptability to contrasting (different) environmental conditions (b>1, "a" with positive values).

The cultivation of genotypes with wide adaptability to contrasting environmental conditions can reduce the risks of yield reduction in unfavorable years [13].

Along with the analysis of the behavior of the three commercial maize hybrids in terms of grain yield, other productivity and nutritional value traits were followed, namely: hectoliter weight, 1,000-grain weight, plant height, protein content and oil content.

The grain yields of the maize hybrids were influenced by the values of these agronomic traits. Thus, we observed that in the hybrid P 9537, the high grain yield was influenced by hight 1,000-grain weight (278 g), by high hectoliter weight (69.3 kg/ha) and by high plant height (233.3 cm), these yield traits having coefficients of variability with low values (<10%) or with medium values (<20%) (Table 5). However, [19] showed that the hectoliter weight does not have a great influence on the grain yield. According to [22], 1,000-grain weight is a fundamental grain yield contributing trait and the genetic potential of a particular genotype can be judged by this trait. Previous findings have also reported that hybrids having highest plant height produced higher yield [11].

Regarding the nutritional value, we noticed that the hybrid Iezer which obtained the lowest grain yields during the years of testing, had a better nutritional quality due to the higher protein content (14.4%) and oil content

(5%) compared to the others two hybrids. Numerous researchers have confirmed that grain yield correlates negatively with protein and oil content [1, 4, 24].

Table 5. The values of the yield and quality traits and the coefficients of variation (CV),

Hybrid	Hectoliter weight		1,000-grain weight		Plant height		Protein content		Oil content	
	Average (kg/hl)	CV (%)	Average (g)	CV (%)	Average (cm)	CV (%)	Average (%)	CV (%)	Average (%)	CV (%)
Iezer	68.3	1.4	222.0	8.8	224.5	7.8	14.4	8.0	5.0	3.0
P 0216	67.8	2.2	247.3	19.9	220.5	11.4	13.3	5.6	4.3	9.3
P 9537	69.3	2.7	278.0	14.2	233.3	12.2	12.9	7.0	4.4	4.1

Source: Own calculation.

CONCLUSIONS

The major variation of grain yield in maize (80%) was caused by the year (different climatic conditions from the years of testing)

On average over the four years of study (2017-2020), the hybrid P 9537 obtained the highest grain yield (7,677 kg/ha) showing a good adaptability to the contrasting environmental conditions from ARDS Simnic – Craiova, Dolj County.

The Iezer hybrid, even if it obtained the lowest average grain yield (4977 kg/ha), had the best grain quality (protein content of 14.4% and oil content of 5%) and showed a good adaptability to the unfavourable environmental conditions that occur frequently in the study area .

The hybrid P 0216 obtained a good average grain yield (6,981 kg/ha), showing good adaptability to favourable environmental conditions in the study area.

The grain yields obtained were determined by the values and the specific variation of the yield and quality traits to the fluctuation of environmental conditions.

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