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ADAPTABILITY OF MAIZE HYBRIDS IN THE CENTRAL PART OF OLTENIA, ROMANIA, UNDER COMBINED DROUGHT AND HEAT CONDITIONS

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Abstract

Due to climate modifications, extremely dry years are becoming more frequent in Romania, the Oltenia region being one of the most affected areas. In this context, farmers must choose the most suitable hybrids for their farm, because the level of grain yield and its quality depend on this choice. This study was designed to compare the phenology, grain yield and associated traits of some maize hybrids belonging to two different maturity groups (4 semi-early and 4 semi-late), under the combined effect of drought and heat in 2022. Experiences were placed under field conditions at Agricultural Research and Development Station (ARDS) Simnic, the Oltenia region, Romania in a randomized block design on a reddish brown soil. The obtained results showed that the maize hybrids from the semi-early maturity group outperformed maize hybrids from the semi-late maturity group with a grain yield advantage of 865 kg/ha (+30%). The semi-early hybrids Magnus (4,334 kg /ha) and DKC 4598 (3,814 kg/ha), closely followed by HSF 1180-17 (3,719 kg/ha) were superior for grain yield compared to other hybrids, showing a good adaptability to extreme drought conditions in the central part of Oltenia.

Key words**:** *drought, growth stages, heat, yield***.**

INTRODUCTION

One of the basic cereals worldwide, including in Romania, is maize (*Zea mays* L.) crop, which plays an important role in ensuring food security.

For human nutrition, maize along with wheat and rice provides about 30% of the food calories for 4.5 billion people [23]. Globally, it is considered that about 56% of dry grain production is used for feed, 13% for food, and a fifth for non-food uses [9].

Although Romania occupies a constant place among the largest maize producers in the European Union, due to drought, heat and limited irrigation, the maize harvest fluctuates significantly [11, 20]. For example, in Romania, at the level of 2021 (a favorable year for maize crop), the national production of maize reached a level of 14.82 million tons, but in 2022, due to the extreme drought, the level decreased to 8.03 million tons [10].

Maize is a very sensitive plant to drought due to its high water requirements, but also its inability to reduce/stagnate growth under water stress conditions [19].

The simultaneous occurrence of drought and heat in the fields of farmers in Romania has become more and more common. The most recent extremely dry years from 1900-2022 were 2007, 2015, 2019, 2020, 2022, and the summer of 2022 was the third warmest summer since 1961 to date, with high temperatures associated with insufficient precipitation exacerbating the drought stress [16]. The variation of weather from one area to another and from one year to another is very different, presenting serious risks to the production of agricultural crops. In this context of current climate changes, emphasis is placed on improving the ability of maize to adapt to adverse climatic conditions [12].

Oltenia is an agricultural region in southwestern Romania, important for maize crops. The frequent occurrence of drought in this area has shown serious consequences on maize yield [2, 3, 8].

Grain yield is the objective with the greatest contribution to the economic efficiency of maize crop, to its increase contributing the tolerance to abiotic, biotic and technological factors, balanced development of plants, and expression of yield traits [7].

Depending on the time of occurrence, duration and intensity of the drought, yield losses in maize vary between 15-70% [2, 3, 17]. Therefore, information is needed on the evaluation of maize hybrids to select the best adapted to drought.

The Romanian market includes a wide range of maize hybrids and the choice of the right ones for each crop area represents a real challenge for farmers, because the level of yield and its quality depends on their choice.

The increase in the frequency of extremely dry years in most areas of Romania has attracted the attention of researchers from research institutes, to develop and transfer to farmers improved maize hybrids for drought and heat tolerance.

Previous studies have shown that a viable and sustainable strategy from an economic point of view is the development and expansion in cultivation of earlier maize hybrids (depending on the cultivation area), hybrids that have a better adaptation capacity to the conditions of drought and heat [13, 14, 19].

Based on these considerations, this study aimed at the behavior of some maize hybrids belonging to two different maturity groups (semi-early and semi-late) in terms of growth stages, grain yield and some related attributes, with implications for agricultural practice in the central part of Oltenia area.

MATERIALS AND METHODS

This study was carried out at ARDS Simnic, Craiova (the central part of Oltenia, Romania), in the combined drought and heat conditions of 2022 (Figure 1).

The biological material tested consisted of eight maize hybrids belonging to two groups of different maturity: FAO 301-400 (Oituz, Magnus, DKC 4598, HSF 1180-17) and FAO 401-500 (F 423, Felix, P0216, P0023).

The experiment was carried out in a randomized block with two replications having a net plot size of 6.72 m^2, on reddish-brown soil.

Complex fertilizers (NPK 20:20:20) were applied before sowing with 250 kg/ha and ammonium nitrate at the stage of 10-12 leaves with 150 kg/ha.

Sowing was carried out on April 12, 2022, at a density of 55,000 plants/ha.

For chemical protection against diseases and pests, Dual Gold 1 l/ha was applied in pre-emergence and at the 6-8 leaf stage, as well as the herbicides Click Pro 2-2.3 l/ha and Crew Ace 0.8 l/ha. Also, 2 mechanical and one manual hoeing were done. Harvesting was done on August 31, 2022.

Data were collected for plant height (cm), ear height (cm), days to 75% emerged plants, days to 50% flowered and silked, days to physiological maturity, grain yield (kg/ha) adjusted to 15.5% moisture, sterile plants (%), 1000-grain weight (g) and test weight (kg/hl).

Data collected for yield were statistically analyzed with analysis of variance (ANOVA) and Duncan multiple range test (p=0.05), first separately for each maturity group and then combined, for both groups.

Weather data (precipitation and temperatures) comes from Craiova Meteorological Station [6].

Fig. 1. View from the experimental field, ARDS Simnic, 2022
Source: Original.

RESULTS AND DISCUSSIONS

For Romania, the summer of 2022 was the third driest and warmest since 1961 until now [16].

The climatic factors (precipitation and temperatures) recorded for the study area (Craiova, Oltenia region from southwest Romania) during the maize growing period (April-August) of 2022, showed an extreme, long-lasting drought with many hot days and nights (Figures 2 and 3).

From April to July, precipitation was below the multiannual average, the lowest precipitation being recorded in June and July (-55.5 mm, respectively, -36.6 mm) (Figure 2).

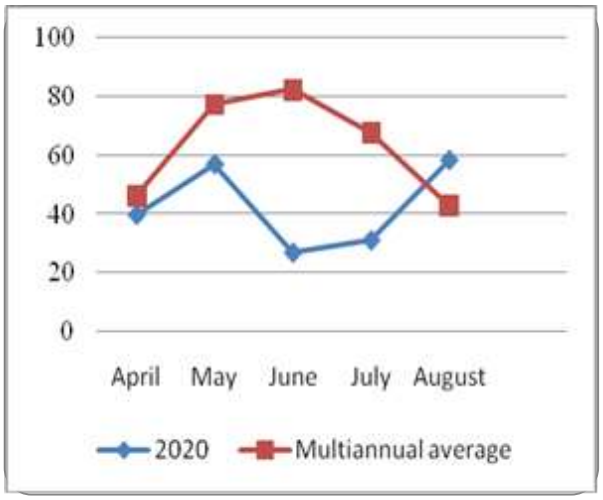

Fig. 2. Monthly precipitation durind the maize growing period (April-August) at ARDS Simnic, 2022.
Source: Own design and processing based on the data from [6].

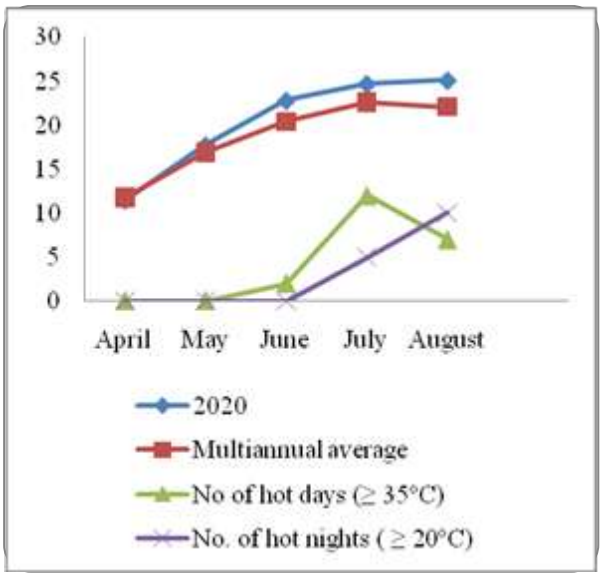

Fig. 3. Average monthly temperatures during the maize growing period (April-August) at ARDS Simnic, 2022
Source: Own design and processing based on the data from [6].

Average monthly temperatures throughout the growing period, except for May, exceeded the multi-year average. The high number of hot days (≥ 35°C) and hot nights (≥ 20°C) in June, July and August combined with low amounts of precipitation exacerbated drought (Figure 3).

Therefore, at ARDS Simnic, drought and heat set in from June (the most critical period for maize/flowering and silking) and continued throughout all reproductive stages.

Insufficient precipitation and high and long-lasting temperatures during the flowering and reproductive stages negatively affected the grain yield of the hybrids studied, which was an average of 3320 kg/ha. From FAOSTAT data [10] it can be seen that it is almost at the same level as the national average yield obtained in 2022 (3,298 kg/ha), but it is lower than that of 2021 (5,801 kg/ha).

Previous studies have shown that combined stress (drought and heat) had a greater impact on maize grain yield than individual stresses [25, 26], and maize is more sensitive to stress in the reproductive stages compared to the vegetative growth stages [5, 21, 22].

According to [18], high temperatures between 33°C-36°C during pre-flowering and post-flowering reduce grain yield by 10-45%. Maize yield reduction percentages due to high temperatures (above 30°C) are of 1% under optimal precipitations conditions, of 1.7% under drought conditions and up to 40% under combined drought and heat conditions [17].

In our study, the results of the analysis of variance for grain yield showed significant differences between hybrids both within maturity groups and between groups ($P<0.05$) (Table 1). From the semi-early maturity group (FAO 301-400), the Magnus hybrid achieved the highest grain yield (4,334 kg/ha) being at the same level of significance as the DKC 4598 hybrid (3,814 kg/ha), while the old hybrid Oituz (released in 1999) achieved the lowest yield (3,142 kg/ha).

From the semi-late maturity group (FAO 401-500), the P0216 and Felix hybrids achieved the highest yields (3,166 and 2,954 kg/ha, respectively), while the F 423 hybrid achieved the lowest yield (2,560 kg/ha).

Combined analysis of variance for grain yield showed that the hybrids Magnus and DKC

4598, closely followed by HSF 1180-17 were superior compared to other hybrids.

The group of semi-early hybrids exceeded the group of semi-late hybrids by 865 kg/ha (+30%) (Table 1, Figure 4).

The Magnus maize hybrid is a modern hybrid, recently released (2021) by NARDI Fundulea (Romania) that has been improved for drought tolerance [15].

Modern maize hybrids improved for drought tolerance together with improved field management represent the best solutions for managing drought losses [15].

Table 1. Grain yield of the maize hybrids studied at ARDS Simnic, 2022

Hybrid	Grain yield				
	kg/ha	% to average group	Duncan test	% to general average	Duncan test
1. FAO 301-400 group (semi-early hybrids)					
Oituz	3,142	-16.3	C	-5.4	C
Magnus	4,334	+15.5	A	+30.5	A
DKC 4598	3,814	+1.6	AB	+14.9	A
HSF 1180-17	3,719	-0.9	B	+12.0	B
Average group 1	*3,752*				
LSD5%	529	14.1			
2. FAO 401-500 group (semi-late hybrids)					
F423	2,560	-11.3	B	-22.8	D
Felix	2,954	-2.3	A	-11.0	CD
P0216	3,166	+9.7	A	-4.6	C
P0023	2,867	-0.7	AB	-13.6	CD
Average group 2	*2,887*				
LSD 5%	353	12.2			
General average	*3,320*				
LSD 5%	623			18.7	

The same letter shows that there is no significant difference based on the Duncan test α = 5%
Source: Own calculation.

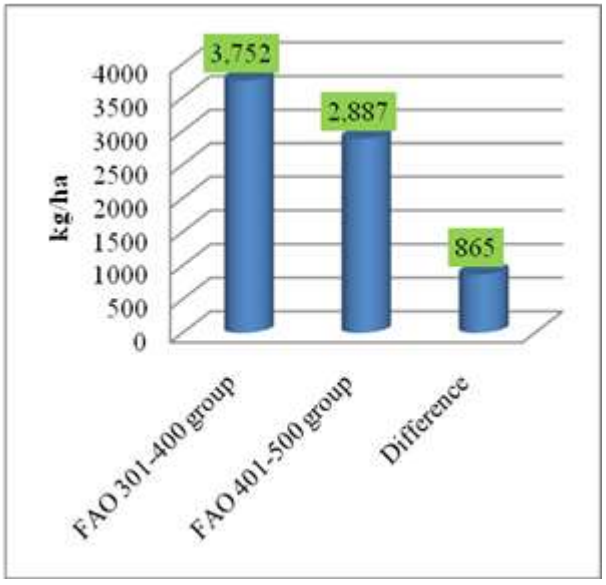

Fig. 4. Yield difference (kg/ha) between maturity groups, ARDS Simnic, 2022
Source: Own calculation.

The number of days to emergence, for most hybrids, was 22 days. Regarding the precocity of flowering, the group of semi-early hybrids recorded an advance of 4 days compared to the group of semi-late hybrids (Table 2).

According to [5], maize plants exhibit three mechanisms of resistance to combined drought and heat conditions, namely, avoidance, escape and tolerance, and hybrids precocity is one of the responses related to escape.

There was no difference between the two maturity groups regarding the attainment of physiological maturity (118 days), but the number of days from silking to physiological maturity (the period of grain filling) was lower for the semi-late maturity group, the group that recorded a lower grain yield.

Our results were consistent with previous studies that showed that grain yield is closely related to grain filling duration [4, 21].

Table 2. Growth stages of the maize hybrids studied at ARDS Simnic, 2022

Hybrid	Growth stages (days from sowing to)				
	emergence	Flowering	silking	physiological maturity	silking-physiological maturity
1. FAO 301-400 group (semi-early hybrids)					
Oituz	22	76	79	116	37
Magnus	21	76	78	119	41
DKC 4598	21	76	78	116	38
HSF 1180-17	22	76	78	121	43
Average group 1	*22*	*76*	*78*	*118*	*40*
2. FAO 401-500 group (semi-late hybrids)					
F 423	22	80	82	118	36
Felix	22	79	82	119	37
P0216	22	80	84	118	34
P0023	24	80	84	118	34
Average group 2	*22*	*80*	*83*	*118*	*35*

Source: Own calculation.

Plant height is an important trait for both grain yield and green and dry matter production. This is determined by the expression and interaction of several genes but also by climatic conditions [3].

In our study, the plant height had a general average of 203 cm, the Magnus and P0216 hybrids recording the maximum plant height of 210 cm (+3%), and the Felix hybrid the minimum plant height of 193 cm (-5%) (Table 3).

Table 3. The agronomic traits of the maize hybrids studied at ARDS Simnic, 2022

Hybrid	Plant height		Ear height		Sterility		1,000-grain weight		Test weight	
	cm	% to general average	cm	% to general average	%	% to general average	g	% to general average	kg/hl	% to general average
1. FAO 301-400 group (semi-early hybrids)										
Oituz	206	100	103	116	1	20	200	105	65.4	99
Magnus	210	103	87	98	7	140	210	110	66.4	100
DKC 4598	207	102	93	105	0	0	171	90	66.6	100
HSF 1180-17	203	100	88	99	0	0	184	96	71.6	108
Average group 1	*207*		*93*		*2*		*191*		*67.5*	
2. FAO 401-500 group (semi-late hybrids)										
F 423	193	95	70	79	13	260	205	107	67.0	101
Felix	198	97	89	100	7	140	166	87	65.7	99
P0216	210	103	94	106	3	60	208	109	63.8	96
P0023	198	97	89	100	9	180	186	97	63.2	95
Average group 2	*200*		*86*		*8*		*191*		*65.0*	
General average	*204*	*100*	*89*	*100*	*5*	*100*	*191*	*100*	*66.3*	*100*

Source: Own calculation.

Ear height between 70 and 103 cm, with a general average of 89 cm, makes hybrids suitable for mechanized harvesting. According to [1], a very high ear height could be susceptible to stock and root lodging. The percentage of sterility was higher in the semi-

late maturity group (8%) compared to the semi-early group (2%). The highest percentage of sterility was recorded in F 423 (+160%) compared to the general average (Table 3).

A previous study found that the drought and heat during flowering led to an increase in the number of sterile plants and also to a reduction in yield [2] .

For 1,000-grain weight, the values were similar for the two maturity groups (191 g), the HSF 1180-17 hybrid registering the highest value of 210 g (+10%) compared to the general average. The weight of the grains is an important component of the yield having a decisive role in highlighting the production potential. Our results were consistent with previous studies that showed that high temperatures (heat) during the reproductive stages shorten the duration of grain filling leading to a reduction in the number of grains, their size and weight [1, 24].

CONCLUSIONS

The preliminary results obtained in combined conditions of drought and heat throughout the flowering and reproductive stages showed a different response of the studied hybrids from the two maturity groups. This difference between hybrids is due to both genetic variation and their difference in adaptability to combined drought and heat conditions.

Maize hybrids from the semi-early maturity group (FAO 301-400) outperformed maize hybrids from the semi-late maturity group (FAO 401-500) with a grain yield advantage of 865 kg/ha (+30%).

Three semi-early hybrids namely, the modern hybrid Magnus released in 2021 (4,334 kg/ha) and DKC 4598 (3,814 kg/ha), closely followed by the perspective hybrid HSF 1180-17 (3,719 kg/ha) were superior for grain yield, compared to other hybrids. These better-adapted maize hybrids can be a solution to the problems caused by extreme drought for farmers in the Oltenia region.

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