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THE INFLUENCE OF SOWING DATE AND PLANT DENSITY ON MAIZE YIELD AND QUALITY IN THE CONTEXT OF CLIMATE CHANGE IN SOUTHERN ROMANIA

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Abstract

Yield and quality are affected by several plant characters, environment and cultural practices. The researches were performed during the 2018-2020, in the experimental field of NARDI Fundulea and the aim of this study was to evaluate the effect of sowing date, plant density and climatic conditions on the yield and quality of maize. The experience comprised three different sowing dates (I - April 1, II – April 15 and III- May 1), using three maize hybrids (Iezer, Mostistea and F423) and three plant density (50 000, 60 000 and 70 000 plants/per hectare). The annual rainfall varied from year to year and the maximum production and quality of maize was maximized from medium plant density and earlier sowing dates, depending on the hybrid. The early sowing date led to increase of quality values, which was depending on climatic conditions. The results showed that yield and quality from maize was very significantly affected by year conditions, sowing date, plant density and hybrids, as well as by most interactions between these factors.

Key words*: maize, sowing dates, plant density, yield and quality, climatic conditions.*

INTRODUCTION

Maize (*Zea mays*) is one of the most important crops and ranks second in the world, cultivated on 160 million ha and producing about 800 million tons of grain (www.fao.org). In Romania, maize is cultivated on 2.7 million ha (www.madr.ro).

The results of various researches show the role of sowing time and plant density on increasing maize production in different climatic conditions. The sowing season is a very important technological link to maximize the yield of maize (Van Roekel and Coulter, 2012) and therefore research is concentrated about the response to maize yield at sowing (Paraschivu et al., 2017; Abendroth et al., 2017).

The optimal time for sowing crops can vary from one agricultural area to another due to differences in soil and climatic elements (Paraschivu et al., 2015; Burns and Abbas, 2006, Tsimba et al., 2013). Maize seed needs positive soil temperatures to germinate and grow (Abendroth et al., 2017), but early sowing is now widely applied by farmers to take advantage of solar radiation (Fabian & Gomoiu, 1981). Research has shown that early planting leads to increased yields during photosynthesis and avoids stagnation of seed germination and degradation of their quality (Lauer et al, 1999). However, in conditions of too low temperatures in the soil, the seeds have the ability to absorb water, but will delay the growth of roots, which leads to the installation of seed rot and a problematic emergence (Abendroth et al., 2017; Hall et al., 2016). The availability of water in the soil is one of the limiting factors that affects the optimal density of plants and implicitly the yield of maize. The amount and distribution of rainfall, soil water and plant density interact and directly influence the period of active crop growth (Lobell and Burke, 2008; Huzsvai & Nagy, 2005). Yield differences between hybrids are determined by the genetic characteristics of the hybrid, environmental conditions, nutritional space, soil fertility and applied technology (Partal & Paraschivu, 2020; Paraschivu et al, 2019; Bene et al., 2014). The impact of climate change on agricultural yields can have various consequences from one area to another (Donatelli et al., 2012). Thus, in this paper we present the results recorded in the last three years on the influence of sowing time, plant density and climatic conditions on maize yield and quality.

MATERIALS AND METHODS

The field tests were established in the period 2018 - 2019 - 2020, on a specific soil for southern Romania (cambic chernozem). Regarding the physical characteristics of the soil, the humus content is higher in the first 15 cm due to the former bedding and gradually decreases to depth.

The soil consists of several horizons:

- Ap+Aph - 0-30 cm, clay-clay-dust with 36.5% clay and permeability 492, pH 5.9.
- Am - 30-45 cm, clay-clay with 37.3% clay, compacted, DA 1.41g / cm^3, pH 5.9.
- A/B (45-62 cm), Bv1 (62-80 cm), Bv2 (82-112 cm), Cnk1 (149-170 cm), Cnk2 (170-200 cm).

Depending on the agricultural year, the water supply of the soil is favorable for field crops, groundwater at 10-12 meters.

The experimental material included three maize hybrids (Iezer, Mostistea and F423), developed at the National Institute for Agricultural Research and Development in Fundulea. Hybrids were sown at three different dates (SD I - April 1, SD II - April 15 and SD III - May 1) and at three plant density (50 000, 60 000 and 70 000 plants / hectare). The size of the plot was 56.0 m^2 (with 20 m long, 4 rows, 70 cm distance between rows). The cultivation of maize followed the wheat, in the rotation of 4 years.

In terms of quality, samples were taken from each repetition and variant and determined:

- The mass of 1000 grains was weighed with the Kern precision electronic scale.
- The hectolitre weight was determined with the special cylinder, followed by weighing on the Kern scale.

Using the electronic device INFRATEC 1241 Grain Analyzer, the elements of seed analysis were determined: - Starch content (%) - Protein content (%) - Fat content (%).

The dynamics of water loss of cereals in the studied hybrids was performed directly in the experimental field during the last month of the vegetation period.

The data were statistically evaluated using analysis of variance procedure - ANOVA, using MSTATC software. The significant differences among means of variant was tested by Duncan's multiple range test.

RESULTS AND DISCUSSIONS

Climatic aspects

The 2018 was a dry year. Temperatures recorded average values 1.0ºC higher than the multiannual average. The variation of temperatures differs from one year to another, so that in 2018, the high temperatures of the period of intense vegetation associated with the deficit of precipitation led to a significant decrease in yields.

In 2019, the months with the lowest amounts of precipitation were September with 6.2 mm, compared to 50.9 mm multiannual average and August with 12.6 mm compared to 51.5 mm multiannual average. The highest amounts of precipitation were recorded in July with 87.4 mm, about 14.7 mm above the multiannual average. Regarding the thermal regime, in the period June - September, the registered values show that the average monthly temperatures were higher than the multiannual average, in June by 3ºC above the multiannual average.

The year 2020 was a dry one, with accentuated water deficit and high temperatures, compared to the multiannual average. The months with the lowest rainfall were 14 mm compared to 44.6 mm on average, August with 5.4 mm compared to 49.7 mm on average and July with 34.2 mm compared to 71.4 mm on average. In May and June there were precipitation amounts close to normal, 57.8 mm and 68.4 mm, respectively. The precipitation deficit affected the installation and development of crop plants in the first phases after emergence, which had a negative impact on the final production. Higher than average annual temperatures have exacerbated the drought. In July and August, due to the severe drought, the development of maize crop was affected. The average temperatures recorded in the agricultural year 2020 were 20.6ºC, compared to the multiannual average of 18.5ºC and an increase was 2.1ºC.

In order to establish the influence of the climatic elements, on the evolution of the maize culture, the values obtained in different phenological phases of the plants with the final production were analyzed and corroborated, in terms of quantity and quality.

Table 1. The meteorological parameters in the experimental period (Fundulea, 2018–2020)

	Years/Months	April	May	June	July	August	September	Total/Average
Precipitations (mm)	2018	2.4	34.0	120.6	84.9	2.8	28.6	273.3
	2019	51.4	124.2	74.6	87.4	12.6	6.2	356.4
	2020	14.0	57.8	68.4	34.2	5.4	68.6	248.4
	50 years average	**44.0**	**60.0**	**73.0**	**72.7**	**51.5**	**50.9**	**352.1**
Temperatures (°C)	2018	15.8	19.3	22.6	22.8	24.2	19.0	20.4
	2019	11.2	17.2	23.6	22.9	24.7	19.3	19.8
	2020	12.4	16.8	21.8	25.1	25.5	20.8	20.6
	50 years average	**11.1**	**16.9**	**20.7**	**22.7**	**22.1**	**17.3**	**18.5**

Production and Quality

The yields registered significantly different values from one year to another, depending on the evolution of precipitations and temperatures, the sowing dates, the density of the plants and the characteristics of the hybrid.

Thus, in 2018, considered a dry year, with a rainfall deficit of 78.8 mm compared to the multiannual average and a negative distribution in May, July and August and temperatures above the multiannual average, the yield of maize recorded values between 3.1 – 6.5 to/ha, the best technological variant was registered at the association between the sowing date I, the density of 60 0000 plants/ha and the F423 hybrid or the Mostistea hybrid. The lowest value of the yield was at the associated variant between the sowing date III, the density of 70 0000 plants/ha and the hybrid Mostistea, with 3.1 to/ha (Figure 1).

In 2019, a year considered normal, with an average rainfall of 356.4 mm, the yield of maize recorded values between 4.6 – 9.4 to/ha, depending on the technological variant. The variations were between 6.3 – 9.4 to/ha at the sowing date I, of 5.3 – 7.0 to/ha at the sowing date II and 4.6 – 6.5 to/ha at the sowing date III. The best technological variant was registered at the association between the sowing date I, the density of 60 0000 plants/ha and the F423 hybrid or the Mostistea hybrid.

In 2020, considered a dry year, with a precipitation deficit of 103.7 mm compared to the multiannual average and with an average temperature of 2.1°C above the multiannual average, the maize yield recorded the highest value, of 3.9 to / ha, for the F423 hybrid in the technological variant with the sowing date II and with a density of 60 0000 plants/ha, followed equally by the Mostistea and Iezer hybrids with 3.8 to/ha in the same technological variant.

The sowing date I had yield values of 3.6 to/ha for the F423 hybrid and 3.5 to/ha for the Mostistea hybrid, both at a density of 60 000 plants/ha. The lowest value of the yield was for the technological variant with the sowing date III, the density of 70 000 plants/ha and the hybrid Mostistea, followed by the technological variant with the sowing date III, the plant density of 50000 plants/ha for the Iezer and Mostistea hybrids (Figure 1).

The analysis of variance shows a very significant influence of the climatic conditions on sowing dates (SD), plant density, hybrids and interactions of these factors (Table 2).

The average number of days from sowing to emergence of plants was a maximum of 19 at sowing date I and decreased to 14 and 11 days for sowing date II and III. The sowing date was distinctly significant positive for the final production, the harvest index and the moisture at seed harvest. The highest average value of the productions was registered at the second sowing date, with 7.40 to/ha, followed by the value from the first sowing date I with 4.70 to/ha.

The associated influence of year, hybrid and sowing date was significantly positive for final production and grain humidity at harvest. As the research data show, the height of maize plants increases with late sowing dates. Thus, the height of maize plants increased significantly (7%) from an average of 2.20 m for sowing date I to 2.35 m for sowing date III.

The variation recorded was due to the influence of climatic conditions, warm weather can stimulate plants to develop large vegetative mass. Hybrids showed differences in plant height as an average over three years, so that F423 recorded the highest value of 2.40 m followed by Iezer hybrid with 2.32, in the favorable years.

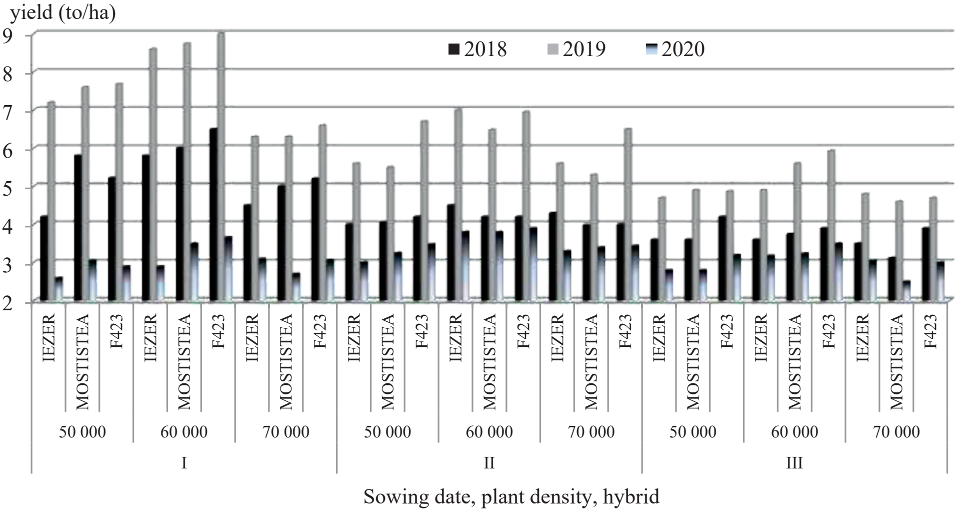

Figure 1. Yields obtained to maize hybrids under experimental conditions during 2018-2020

Table 2. ANOVA for sowing date (SD), grain yield, humidity, the emergence days and plant height – average the years 2018-2020

Sowing Date (SD)	Grain Yield	Harvest Index	Grain Humidity	Emergence	Plant Height
	(to/ha)		(%)	(days)	(m)
2018	6.10	0.59	17.2	21	2.22
2019	4.30	0.57	16.8	19	2.26
2020	3.80	0.60	14.1	20	2.12
Average SD I	**4.70**	**0.58**	**16.0**	**19**	**2.20**
2018	8.90	0.53	17.6	13	2.30
2019	6.80	0.52	17.4	13	2.33
2020	6.50	0.50	14.6	16	2.14
Average SD II	**7.40**	**0.52**	**16.5**	**14**	**2.26**
2018	3.40	0.50	19.5	10	2.35
2019	3.80	0.49	20.4	12	2.40
2020	5.50	0.47	19.0	12	2.31
Average SD III	**4.20**	**0.49**	**19.6**	**11**	**2.35**
ANOVA / SEMNIFICATIONS					
Year (Y)	**	*	**	**	**
Error					
Sowing date (SD)	**	**	**	*	*
SD*Y	*	*	*	**	*
Error					
Hybrid (H)	*	ns	**	ns	*
H*SD	*	ns	**	ns	ns
Y*H	ns	ns	ns	ns	*
Y*H*SD	*	ns	*	ns	ns

*- Significat at P-value <0.05; ** Significat at P-value <0.01; ns – not significat;

The hectolitric weight registered an average of 76.7 kg / hl at the sowing date I with values between 74.0 – 80.0 kg / hl, an average of 76.8 kg/hl at the sowing date II with values between 74.0 – 79.4 kg/hl and the last average of 75.7 kg/hl at the sowing date III with values between 72.6 – 79.4 kg/hl.

The highest value of the hectoliter weight was registered in 2019, with 80.0 kg/hl, at the sowing date I, and the lowest in 2020, with 72.6 kg/hl, at the sowing date III (Table 3).

The weight of one thousand grains (WTG) recorded an average of 287.2 g at the sowing date I with values between 260.1 – 316.0 g, an average of 296.1 g at the sowing date II with values between 257.9 – 332.1 g and an average of 281.8 g at the sowing date III with values between 252.4 – 306.9 g.

The protein content registered an annual average of 7.9% at the sowing date I with values between 7.1 - 8.8%, an average of 8.6% at the sowing date II with values between 7.6 - 9.7% and an average of 7.8% at the sowing date III with values between 7.2 - 8.9%. The highest value of protein content was registered in 2020, with 9.7%, at the sowing date II, and the lowest in 2019, with .71%, at the sowing date I.

The starch content registered an average of 68.7% at the sowing date I with values between 64.3 - 72.3%, an average of 69.2% at the sowing date II with values between 65.4 - 72.5% and an average of 68.2% at the sowing date III with values between 63.7– 72.1%. The highest value of the starch content was registered in 2020, with 9.7%, at the sowing date II, and the lowest in 2019, with 7.1%, at the sowing date I.

The fat content in the grain registered an average of 4.2% at the sowing date I with values between 4.0 - 4.5%, an average of 4.2% at the sowing date II with values between 3, 9 - 4.5% and average of 3.9% at the sowing date III with values between 3.6 - 4.3%. The highest value of fat content in grain was registered in 2020, by 4.5%, at the sowing date I, and the lowest in 2018, by 3.6%, at the sowing date III (Table 3).

The correlation between the values of the starch content is negatively correlated with the values of the protein and fat content, due to the climatic characteristics of the agricultural year.

The values of the variants were very significantly positive when associating the year with the sowing date for the starch content and the fat content in the grain.

The influence of the year was very significantly positive for the hectolitric weight, the protein content, the starch content and the fat content in the grain.

The influence of the hybrid was insignificant for the weight of a thousand grains and the starch content.

The dynamics of grain water loss in the studied hybrids: F423, Iezer and Mostistea was decisively influenced by the climatic evolution, the technological elements and the characteristics of the hybrid (Figures 2 and 3).

Table 3. ANOVA for hectoliter weight (HW), weight thousands grain (WTS) and the protein, starch and fat content – average 2018-2020

Years	HW	WTG	Proteine	Amidon	Fat content
	(kg/hl)	(g)	(%)	(%)	(%)
2018	76.1	285.5	7.8	69.5	4.0
2019	80.0	316.0	7.1	72.3	4.0
2020	74.0	260.1	8.8	64.3	4.5
Average SD I	**76.7**	**287.2**	**7.9**	**68.7**	**4.2**
2018	77.1	298.5	8.5	69.6	3.9
2019	79.4	332.1	7.6	72.5	4.1
2020	74.0	257.9	9.7	65.4	4.5
Average SD II	**76.8**	**296.1**	**8.6**	**69.2**	**4.2**
2018	75.0	286.0	7.5	69.0	3.6
2019	79.4	306.9	7.2	72.1	3.8
2020	72.6	252.4	8.9	63.7	4.3
Average SD III	**75.7**	**281,8**	**7.8**	**68.2**	**3.9**
ANOVA / SEMNIFICATIONS					
Year (Y)	**	*	**	**	**
Error					
Sowing date (SD)	*	*	*	*	*
SD*Y	*	*	*	**	**
Error					
Hybrid (H)	*	ns	*	ns	*
H*SD		ns	*	ns	ns
Y*H	*	*	*	*	*
Y*H*SD	*	*	*	*	*

*- Significat at P-value <0.05; ** Significat at P-value <0.01; ns – not significat;

At the sowing date I, the F423 hybrid had a humidity percentage of 23%, and the Mostiştea hybrid had 2.2% more, a difference that was maintained on September 13th.
At the sowing date II, the F423 hybrid had a humidity percentage of 24%, and the Mostiştea hybrid had 1.7% more, a difference that was maintained on September 15th. At the sowing date III, the F423 hybrid had a humidity percentage of 22%, and the Iezer hybrid had 2.2% more, a difference that was maintained on September 21st. For the all sowing dates, the Iezer hybrid recorded intermediate values, compared to other hybrids.
At the time of harvest, the moisture of the grains became uniform, the difference between hybrids being insignificant, between 14.3% and 15.2%, regardless of the sowing season.

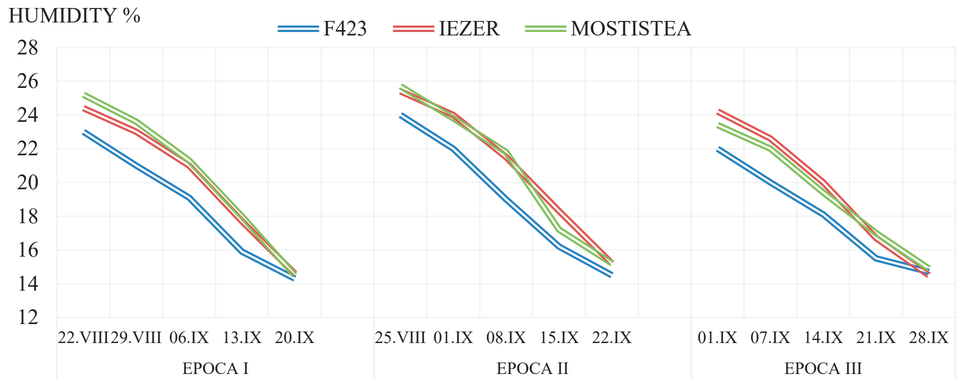

Figure 2. Dynamics of grain water loss in the hybrid F423, Iezer and Mostistea, sowing in the optimal year – average 2019

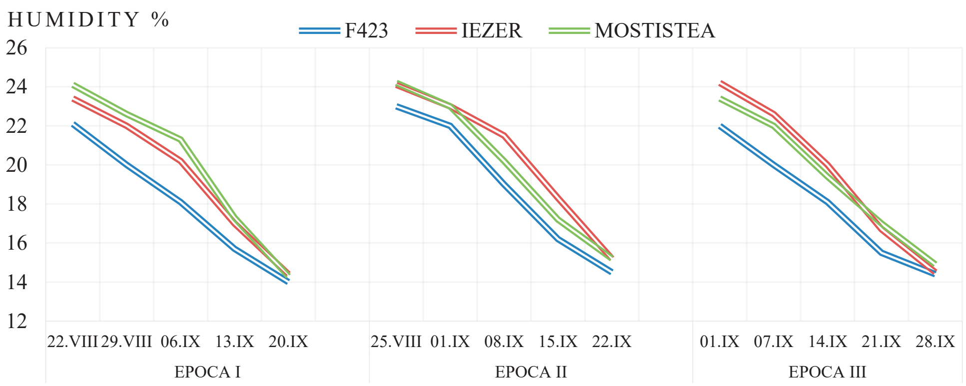

Figure 3. Dynamics of grain water loss in the hybrid F423, Iezer and Mostistea, sowing in the dry year – average 2020

CONCLUSIONS

The results study and analyses shown in this paper showed that sowing date and plant density interact with water supply and affect quantity and quality of the maize yield.
Climatic conditions affect maize plants in any phase of vegetation, with a negative impact on the final production and its quality. The drought phenomenon influences by intensity and duration, sometimes up to the compromise the crop and in this case the drought resistance of the hybrid has a decisive role. In the year 2020, the drought afected the final productions no matter the technological links applied.

Early sowing data (SD I) increased the number of days from sowing to plant emergence, which reduced the density of crop plants and is closely dependent on soil temperature that conditions of the germination process. Late sowing data (SD III) reduced the number of days from sowing to the appearance of plants, increasing the moisture content of cereals at harvest.

The highest yields were obtained in the normal climatic year and in the associated technological variant of the sowing date I, the plant density of 60 000 plants/ha and the hybrid F423 or Mostistea.

The yield quality registered high values in a normal climatic year and in the associated technological variant of the sowing date II and the plant density of 60 000 plants/ha.

The dynamics of water loss of grains in the studied hybrids highlighted the hybrid F423 which recorded lower values compared to the hybrids Mostistea and Iezer, by 1.7 - 2.2%, depending on the sowing date. The humidity in the grain was influenced by the climatic evolution, the technological elements and the characteristics of the hybrid.

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