Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 2, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

THE INFLUENCE OF SOWING DATE ON DEVELOPMENT OF MAIZE IN THE CONDITIONS OF CENTRAL ROMANIA

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Abstract

Maize, one of our country's most widespread field crops, is also the most exposed to atmospheric and soil drought, which is pronounced in the summer months. The following experimental variants were initiated and tested in this context: early sowing, sowing during the optimal period, and after the optimal period. The evolution of precipitation fluctuated over months and years. The studies focused on the influence of the sowing season on the duration of the growing cycle of maize grains in the area of the Research and Development Station for Cattle Breeding Tg. Mures (R.D.S.C.B. Tg. Mures). According to the data recorded in the 2018-2021 agricultural years, the studied hybrids responded well to early sowing, and each delay reduced the duration of the growing cycle in sowing. Early sowings increased the period from sowing to plant emergence but did not reduce the germination and the population density of the crop. Alternatively, late sowings reduced the number of days to physiological maturity producing higher humidity content in grain at harvest and taller plants.

Key words*: maize, sowing date, germination, growing cycle, plant height.*

INTRODUCTION

Maize (*Zea mays* L.) holds a significant place in Romanian agriculture, by the large area it occupies (on average 30% of arable land), the yields achieved, and the multiple uses of maize grain: food for people, industry, and feed (Ionescu et al., 2020). Therefore, the production and economic efficiency of maize crops are matters of national interest (Sarca et al., 2007).

Many cropping practices have been recommended as sound adaptations to the warming, such as adjusting the sowing date and cropping pattern (Mendelsohn et al., 1994; Rosenzweig and Hillel, 1998; Winters et al., 1998), adopting higher-yielding varieties with heat resistant, and improving management processes (Butt et al., 2005; Njie et al., 2006; Ogden and Innes, 2008).

Plant species have a unique requirement for the core temperature, which is the temperature at which they start growing. Maize, for instance, needs a temperature of 10ºC (Rao Prasada, 2008). Maize seeds germinate 4-5 days after sowing in conditions of heat and humidity, and when the temperature is lower than optimal, 14 to 16 days may be required to emergence (Hussen et al., 2013).

Plants from sowings made in March or early April were not significantly earlier or more productive than plants from sowings made in late April. For grain production, however, any further delay in sowing time usually led to lower yields, even with the earliest varieties tested. In contrast, the final production of dry material from the shoot was higher, on average, from mid-May sowings (Bunting, 1968).

The early sowing of maize is a strategy that farmers can employ to potentially stabilize maize yields, not only in regards to changing climatic conditions but also to avoid adverse conditions such as high temperatures and drought conditions during the grain filling period, phenomena that also occur in the Maize

Belt of the USA (Lauer et al., 1999). Breeding programs have facilitated germination of maize at colder temperatures (Sanghera et al., 2011). Bruns and Abbas (2006) reported technological improvements in maize hybrids such as better early season vigor and tolerance to germination in cool wet soils, better seed treatments to guard against damping off diseases and seedling insect pests, or the advent of herbicides. These factors have contributed to planting maize earlier than it was 30 years ago (Abendroth et al., 2017).

However, early sowing can be conflicted by low spring soil temperatures, which can reduce seed germination, plantar sunrise rate, and final stability (Hayhoe et al., 1996).

The use of the optimal planting window will play a critical role in the future productivity of maize, especially in the context of climate change (Seifert et al., 2017).

The effects of the warming of the Earth's atmosphere are diverse and include the increase in the number and intensity of extreme events such as storms and hurricanes, extreme droughts, floods. Meteorological data show that the last 20 years have been the warmest, and the amplitude between very rainy and very dry years has become much larger (Mircea et al., 2023).

The impact of climate change could be reduced through several technological measures, including the use of biological materials adaptable to less favorable climate and soil conditions, as well as efficient input management.

In this paper, results are presented on the influence of sowing age and climatic conditions on the development of maize crops.

MATERIALS AND METHODS

A four-year experiment (2018-2021) was conducted at the Research and Development Station for Cattle Breeding Tg. Mures (R.D.S.C.B. Tg. Mureș) experimental station at Sângeorgiu de Mureș, Romania, according to the method of subdivided plots, the first factor the sowing date, with 3 gradations: the first sowing date, early sowing was realized when 6ºC were recorded in the soil; the 2nd sowing date, an optimal sowing date when 10ºC was achieved in the soil and the 3rd sowing date, two weeks after the 2nd.

Factor 2 is represented by the 9 tested maize hybrids. Two hybrids from the Agricultural Research and Development Station Turda (A.R.D.S. Turda): Turda 248 (FAO 300), Turda 332 (FAO 380), two hybrids from the company Corteva, P 9900 (FAO 360), P9903 (FAO 360) and two hybrids from the company KWS Semences, KWS 2370 (FAO 290), KWS 4484 (FAO 380).

Was used for sowing a density of 65,000 harvestable plants per ha, with the distance between rows at 70 cm. Fieldwork was done by harrowing in August, deep plowing in the autumn, leveling discs in the spring, and a work with the cultivator to prepare the germinative bed. The application of the whole dose of fertilizers was done after the disk, and their incorporation into the soil was done with the combinator. The amount and type of fertilizer used were $N_{16}P_{16}K_{16}$ 500 kg/ha, and every three years 4 t amendments per ha were applied. The soil on which the experiment was located, was a brown forest soil, weakly podzolic, clay loam texture, with a humus content of 1.9, pH of 5.8, P_2O_2 supply is 17.4 mg/100 g soil, K_2O 21.7 mg/100 g soil and an N index of 1.4. The predecessor plant was soybean. The results of the studies were analyzed according to the climatic conditions of the area, recorded at the weather station in Sângeorgiu de Mureș and presented in Table 1.

The temperature evolution during the vegetation period of the crop, in the four years of the study, did not show significant differences. From the recorded data, it is highlighted that the average monthly temperatures during the vegetation period of the crop (April-October), during the studied years (2018-2021), exceeded the multi-year average. The average temperature during the 2018-2021 vegetation period was 17.1ºC, exceeding the multiannual average for the respective period by 2.2°C. The evolution of precipitation fluctuated over months and years. The average precipitation during the growing season in the studied years was 458 mm, 10 mm below the multiannual average. The wettest months were June with 187.2 mm in 2018 and May 134.45 mm in 2019. The driest month was in August 2018 when only 8.7 mm was recorded.

The height of 10 plants of the central rows was measured about one week after silking in each plot from the base of the crop to the top. The plant density was estimated before harvest, counting the total plants of the two central rows in each experimental plot.

The grain harvest took place during September or October manually, after the plants had reached physiological maturity (Table 3). Grain yield was measured by harvesting two central rows from each plot. A mixed-effects analysis of variance (ANOVA) was carried out to assess the responses to sowing data (SD), with years evaluated as repeated measurements.

Table 1. Mean monthly (T_m) air temperatures and total monthly rainfall at Sangeorgiu de Mures, during the experiment (from 2018 to 2021). Long-term (60 years) mean annual temperature and rainfall values at Sangeorgiu de Mures are 14.9°C and 468 mm, respectively

Month	2018		2019		2020		2021	
	Temperature	Rainfall	Temperature	Rainfall	Temperature	Rainfall	Temperature	Rainfall
	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)	(°C)	(mm)
April	15.6	12.7	12.3	30.3	10.4	21.1	8.6	93.9
May	18.7	53.8	15.3	134.45	14.3	61.4	14.9	95.0
June	20.1	187.2	22.0	49.8	19.6	120.9	19.9	70.4
July	20.7	58.5	21.5	59.9	21.8	99.1	23.0	98.2
August	22.9	8.7	22.1	78.6	22.0	40.9	20.6	77.4
September	16.2	58.8	17.0	50.1	18.3	62.2	17.1	59.8
October	12.5	32.2	12.0	31.6	12.5	74.2	8.7	12.5

RESULTS AND DISCUSSIONS

The number of days when soil temperatures were below 10 degrees and the number of sowing-sowing days fluctuated based on the sowing season and year. Thus, in the early sowing season, there were an average of 14 days with temperatures below 10°C and the number of days sown-rising was 19, in the optimal sowing season there were on average 7 days with temperatures below 10°C, and the number of days sown-rising was 16, the number of days, in the late sowing season there were 2 days with temperatures below 10 degrees C and the number of days sown-rising was 11.

The climatic conditions of 2018-2021 were different, signaling quite long periods, especially in April, with soil temperatures below the minimum germination threshold. The most unfavorable year was 2021 when the number of days with temperatures below the germination threshold reached 20 in the early sowing season, resulting in the extension of the maize growth up to 23 days.

The number of days from sowing to emergence can be influenced by the climatic conditions, the technology applied but also the biological material used, as it resulted from the research carried out by Horablaga et al. (2023) a number of 10-12 days from sowing to emergence of corn depending on the studied germplasm.

So as the number of days with temperatures below 10ºC decreased, the number of days from sowing to emergence also decreased.

In the conditions of the Transylvanian Plateau, during the April-May period, some climatic phenomena such as late frosts (Simon et al., 2023) are quite common, such as late bumblebees or very high-temperature differences between day and night.

Based on previous research (Jones and Thornton, 2003; Lobell and Asner, 2003), it hypothesized that crop development is affected not only by input from factors of production but also by climate change. Therefore, the increase in maize results from the combined action of hours of sunlight, temperature, precipitation, and other environmental factors.

Nielsen et al. (2002) and Parker et al. (2016) pointed out that planting maize too early is associated with potentially suboptimal planting conditions in soil and climate, while planting it too late exposes plants to a short growing season. Tollenaar and Bruulsema (1998), and Shrestha et al. (2018) found that low temperatures prolonged the physiological maturity of maize during late planting. Differences in climate and the length of the growing season can affect the optimal sowing date of maize in different areas (Bruns and Abbas, 2006).

However, the greatest effect of sowing delay was observed in the number of days from sowing to silting, which decreased significantly from 104 days during mid-March sowing to 81 days (22% discount) and to 69 days (33% discount) during mid-April and mid-May sowing (Maresma et al., 2019).

The analysis of % of plants sprouted according to the sowing season highlights the fact that between the optimal sowing season and the early sowing season, there is a significantly positive difference, and compared to the late sowing season there were no significant differences, so we can say that early sowing at temperatures below the minimum germination threshold (10ºC) did not adversely affect germination.
Research conducted by Maresma et al. (2019), showed that early and late sowing has negative effect on plant density, with a number of plants/ha of about 71000 and 75000, respectively compared to normal sowing where the plant density was 78000 plants/ha.
From the statistical analysis on the influence of the years it is found that only in 2021 there was a significantly negative difference due to the non-favorable conditions of April. In the other 3 years the differences were not statistically assured.

Table 2. Soil temperature at sowing depth at 6 a.m. and number of days with suboptimal germination temperatures below 10°C at R.D.S.C.B. Tg.Mures

Sowing date	Year	Date of		No. days btw. sowing-emergence	Emergence plants %	Avg. temp. of soil at 6 a.m.	No. days with suboptimal Temperatures (>10°C)
		sowing	emergence				
Early	2018	April 10	April 21	12	98	8	1
	2019	April 4	April 24	21	98	8.3	17
	2020	April 7	April 24	18	98	7.6	17
	2021	April 10	May 21	23	97	7	20
	Avg.			19	98		14
Optimal	2018	April 24	May 3	10	95	13.5	0
	2019	April 18	May 8	21	99	11	7
	2020	April 21	May 10	20	98	9.6	12
	2021	April 24	May 6	13	97	9.2	8
	Avg.			16	97		7
Late	2018	May 7	May 15	9	95	15	0
	2019	May 5	May 18	14	97	12.4	2
	2020	May 8	May 17	10	98	12	2
	2021	May 7	May 15	9	98	10.2	3
	Avg.			11	97		2

From the analysis of the sowing age, on germplasm sources, it was found that compared to the average of hybrids there was only one hybrid (KWS 4484), at which % the plant emergence was above the average of the hybrids, making a significant positive difference. At the other sources of germplasm, the differences did not have a statistical coverage.
The high maintenance of % of germinated plants and in the years with colder springs we believe is due to the biological value of the seeds and the quality of the phytosanitary products used for treatment.
Another element studied was the plant size which can be influenced by both climatic factors (temperature, precipitation) and applied technologies, previous research has shown that plant size correlates greatly with biomass and production, so it is very often used in production estimation (Yin et al., 2011).
From the analysis of variance, it is found that the date of sowing at temperatures below the minimum threshold of germination had a negative effect on the plant's waist. The difference was very significantly negative in the early sowing season from the optimal sowing season, but this decrease we cannot put entirely on account of sowing below the minimum threshold of germination, but on accumulation of climatic conditions in the sown-flowering interval. Research conducted by Abdel-Rahman et al. (2001) showed that early sowing had a significant effect on the plant's waistline, which is, that the plants with the highest waist are obtained from sowing corn earlier compared to late sowing.
An analysis of the influence of the years on the plant's waist highlights the fact that there are very significant positive differences in 2018 and 2020, but also very significant negative differences in 2019.

From the analysis of variance on germplasm type, it was found that only the T 248 hybrid recorded a significantly negative difference.

The height of the plant is an important growth character directly related to the productive potential of the plant, is very often used in the evaluation of yield (Omotosho and Shittu, 2007; Bendig et al., 2015). Maize is situated in the category of plants with high-temperature claims. In conditions with optimal temperatures, plants can grow between 7 and 14 cm in 24 hours. The hybrid cultivation is made according to the thermal needs of the hybrids for the growth and development processes.

Research by Schitea and Motcă (2013) showed that drought and heat led to a shortening of the growing season, forcing late genotypes to mature.

Table 3. Sowing date (SD) effect on the dates of emergence, silk and black layer appearance, the days happened between sowing and silk and black layer appearance and plant height. Average 2018-2021

Sowing Date (SD)	Emergence plants	Emergence	Silk	Black layer	Plant height
	%	(days)	(days)	(days)	(cm)
Early	97.44	19	92	138	266
2018	97.06	13	75	130	270
2019	97.50	21	94	147	255
2020	97.56	18	101	146	271
2021	97.67	23	98	130	267
Optimal	96.40	16	85	133	278
2018	94.56	10	76	125	288
2019	98.56	20	86	138	263
2020	97.39	20	94	142	284
2021	95.11	13	85	125	279
Late	96.57	10	76	122	288
2018	97.89	9	72	116	303
2019	96.22	14	71	126	269
2020	97.39	9	83	130	295
2021	94.78	9	76	116	284
		ANOVA			
Year (Y)	**	**	**	**	**
Error					
Sowing Date (SD)	*	**	**	**	*
Y*SD	**	**	**	**	**
Error					
Hybrid (H)	**	**	**	**	**
SD*H	**	**	ns	**	**
Y*H	**	**	**	**	**
Y*SD*H	**	**	ns	**	**

Significant at p-value < 0.05; ** Significant at p-value < 0.01; ns = not significant.

The results of measurements on the plant height, by years, depending on the type of germplasm, highlight the fact that the most drastic plant height reductions were recorded in the American germplasm hybrids, 18 And 16 cm, followed by Romanian hybrids with 9 and 10 cm, then with German germplasm of 4 and 14.5 cm, depending on the hybrid.

Analysis of the variance representing the number of days from sowing to silk, in the early sowing season compared to the optimal sowing season, shows that there is a very significant positive difference.

The analysis of the year is highlights a very significant negative difference in 2018, and in 2020 there was a very significant positive difference.

Regarding the germplasm type, there was a distinctly significant difference in the T248 hybrid, and in the other hybrids, the differences did not have statistical assurance.

Most days between sowing and silk, in advance of the optimal era, were achieved in 2018 (15 days), 2019 (5 days), 2020 (6 days) and 2021 (4 days). The average per year and on hybrids is 8 days.

This is in line with the results achieved by Mederski and Jones (1963), who reported a decrease in the number of days from sowing to silting as the soil temperature rises.

The low amount of precipitation correlated with high temperatures makes plants consume more energy to achieve significant yields, with climatic conditions still being the most important factor that determines the yield of a crop (Popa et al., 2021).

Taller plants contribute to obtaining a larger LAI (Leaf Area Index) and intercepting solar radiation better than low-waisted plants.

After analyzing the amount of active temperatures achieved in different years and sowing seasons, it was found that the sum of active temperatures per sowing season was consistent in 2019, while there was a significant variation in the rest of the years due to different climatic conditions. The highest difference in the sum of temperatures was observed in the year 2020. Early sowing has the advantage that it outruns the onset of silkiness and removes the release phase of pollen from the influence of high temperatures that lead to pollen sterility. Post-emergence environmental factors have a significant impact on the yield of a plant (Kimmelshue et al., 2022).

Table 4. The number of days between sowing-silk in the three sowing seasons.
The number of days between the sowing season in the early in addition to the optimal sowing season and 'active temperatures achieved in years and sowing seasons

Year	Hybrid	No. days sowing-silk			Days no. in addition to Sowing season II	∑ active temperatures		
		Sowing season I	Sowing season II	Sowing season III		Sowing season I	Sowing season II	Sowing season III
2018	KWS 2370	73	72	70	14	648	653.4	634
	KWS 4484	80	78	73	12	697	711.4	675.8
	PIONEER 9900	75	72	72	15	661	703	665.6
	PIONEER 9903	76	78	73	16	666	711.4	675.8
	TURDA 332	75	77	72	15	661	703	665.6
	TURDA 248	73	76	71	16	648	694	654.8
	Average	75	76	72	15	663.6	696.0	661.9
2019	KWS 2370	93	83	71	3	688	684	662.7
	KWS 4484	97	88	77	5	724	715.1	724.1
	PIONEER 9900	93	85	76	6	688	696.2	711.5
	PIONEER 9903	92	87	76	8	676	707.9	711.5
	TURDA 332	95	85	75	3	709	696.2	700
	TURDA 248	95	84	73	3	709	690.8	679.8
	Average	94	85	75	5	698.9	698.4	698.3
2020	KWS 2370	97	90	79	6	600	632.2	671.4
	KWS 4484	103	96	86	5	654	694.4	759.9
	PIONEER 9900	104	97	84	6	663	703.7	733.2
	PIONEER 9903	102	93	79	4	644	660.8	671.4
	TURDA 332	98	93	83	8	609	660.8	718.9
	TURDA 248	100	95	86	8	625	682.5	759.9
	Average	101	94	83	6	632.5	672.4	719.1
2021	KWS 2370	98	86	76	4	676	700.8	697.3
	KWS 4484	97	83	74	5	661	654.2	678.5
	PIONEER 9900	99	86	76	5	691	700.8	697.3
	PIONEER 9903	101	88	83	5	721	724.6	785.5
	TURDA 332	98	86	77	4	676	700.8	708
	TURDA 248	94	81	72	4	614	621.8	649.1
	Average	98	85	76	5	672.9	683.8	702.6
	Average 2018-2021	92	85	76.5	8	667.0	687.6	695.5

Another element studied was the variability of the number of days from sowing to physiological maturity. From the statistical analysis of the data, it follows that between the early and optimal sowing seasons, there are very significant positive differences. The analysis of the variance on the influence of the years revealed a very significant negative difference between 2018 and 2021 and a very significant positive difference between 2019 and 2020.

An analysis of germplasm sources shows that there was a very significant negative difference for the KWS 2370 hybrid and very significant positive and distinctively significant positive differences in the American germplasm hybrids. In Romanian hybrids, the results did not have a statistical coverage.

Of particular importance of early sowing is the date of physiological maturity. From the table presented it follows that the number of days in advance at physiological maturity is between 9 and 3 days. From the analysis by year it follows that the highest advance was made in 2018 (8 days) and the lowest in 2019 (3 days). Early sowing leads to an advance maturation of hybrids, economically desirable goal, eliminating the drying stage, shattering the berries and favoring the filling of the berries and the growth of the MMB.

Table 5. Number of days between sowing-physiological maturity in the three sowing seasons. The number of days between sowing-physiological maturity in the early in addition of the optimal sowing seasons and ∑ of the active temperatures achieved in sowing years and sowing seasons

Year	Hybrid	No. days sowing-black layer			Days no. in addition to Sowing season II	∑ active temperatures		
		Sowing season I	Sowing season II	Sowing season III		Sowing season I	Sowing season II	Sowing season III
2018	KWS 2370	126	121	114	10	1230.9	1255.3	1209.5
	KWS 4484	133	126	115	7	1320.9	1319.9	1221.4
	PIONEER 9900	133	124	116	7	1320.9	1294.4	1232.4
	PIONEER 9903	134	128	117	7	1334.5	1343.5	1244.1
	TURDA 332	132	127	119	9	1307.9	1331.6	1269.6
	TURDA 248	127	122	115	8	1245.1	1268.5	1221.4
	Average	131	125	116	8	1293.3	1302.2	1233.1
2019	KWS 2370	143	135	120	5	1242.1	1275.2	1256.6
	KWS 4484	148	138	125	3	1308.2	1327.2	1308
	PIONEER 9900	146	136	127	3	1281.7	1288.3	1329.9
	PIONEER 9903	147	137	129	4	1294.6	1313.8	1352.4
	TURDA 332	150	140	128	3	1347.6	1348.1	1342.2
	TURDA 248	151	141	126	3	1360.2	1356.8	1318.2
	Average	148	138	126	4	1305.7	1318.2	1317.9
2020	KWS 2370	140	136	122	9	1094.9	1176.2	1177.7
	KWS 4484	142	138	130	9	1113.7	1192.4	1256.8
	PIONEER 9900	151	125	144	6	1214.5	1329.7	1364.5
	PIONEER 9903	149	140	126	4	1198.3	1210	1214.9
	TURDA 332	144	138	126	7	1133.5	1192.4	1214.9
	TURDA 248	151	144	130	6	1214.5	1247.2	1256.8
	Average	146	137	130	7	1161.6	1224.7	1247.6
2021	KWS 2370	138	134	134	9	1158.7	1210.2	1328.2
	KWS 4484	139	131	131	7	1165.5	1194.5	1285.1
	PIONEER 9900	142	137	128	5	1182.8	1234.8	1246.6
	PIONEER 9903	149	139	133	7	1222.9	1258.2	1318.3
	TURDA 332	146	135	131	3	1206.2	1223.2	1285.1
	TURDA 248	137	124	126	3	1151.3	1152.4	1222.4
	Average	142	133	131	6	1181.2	1212.2	1281.0
	Average 2018-2021	92	85	76.5	8	667.0	687.6	695.5

CONCLUSIONS

There were situations when the temperature remained below the germination threshold for several days, the studied hybrids germinated after 20-23 days, but without affecting the germination. There were no differences between germplasm sources, but there were differences between the years studied. The coldest year was 2021 when the plants emergence after 22-24 days without affecting the germination.

Early sowing did not adversely affect % of the plants sprouted compared to the optimal sowing season.

The date of the silk appearance was advanced by up to 17 days compared to the optimal sowing season. The differences were different depending on the year and the hybrid. The highest reduction was achieved in 2018, and depending on the germplasm, the biggest advance was made in hybrids with American germplasm. Early sowing has the advantage of eliminating the overlap of the flowering and silky phase appearance over high temperatures which can lead to poor fertilization.

Early sowing also outpaced physiological maturity by 3-9 days, positively influencing the filling of the berries.

Early sowing led to a reduction in the plant's waist by up to 13 cm, the difference is very significantly negative.

From the obtained results we consider that sowing of maize at temperatures below the minimum germination threshold can be a process of removing critical phases of the plant from the stressful influence of climate change during the summer, provided that the seed has superior quality indices.

Sowing at temperatures below the minimum germination threshold remains a solution until genomic biotypes with superior characteristics on climate change are developed.

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