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Importance of sowing date optimization for morphological properties and grain yield of maize inbred lines

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Abstract

This study aimed to determine the influence of sowing dates on morphological properties and grain yield. The experiment was conducted during 2018 (Y1) and 2019 (Y2) at one location in Serbia (Zemun Polje). Three inbred lines, produced at the Maize Research Institute (Serbia), were used as the material. Sowing was set in two terms, earlier 1 April (SD1) and optimal 20 April (SD2). Morphological properties of the cob were measured in the laboratory conditions: the ear weight (EW), the cob weight (CW), the cob length (CL), the cob thickness (CT), the 1000 kernel weight (SW), and the grain yield (GY). The sowing date significantly affected the morphological properties of the cob ($p \leq 0,05$). The interaction of factors also had a significant impact on the variability of traits. Three-way analysis of variance indicates that SD1Y1 treatment in combination with ZP1 and ZP3 inbred lines has a higher yield (6.28 t ha^{-1}, 7.05 t ha^{-1}). Further, the 1000-kernel weight in all three genotypes was higher in the SD1, ZP1 (324.35 g), ZP2 (329.78 g), and ZP3 (326.55 g). The earlier sowing date was also favourable for the cob weight. Meteorological conditions can be more or less stressful for field crops. Adverse weather conditions can be avoided or reduced by applying different sowing dates.

Key words: sowing date, maize, grain yield, morphological properties

Introduction

Generally, the sowing date is adjusted to environmental conditions. In the temperate continental climate, it is from the middle to the end of April. With the increase in the average annual temperature and the disturbance of the precipitation pattern, the sowing date tends to be earlier. In addition, lack of water has become a limiting factor for increasing crop production. Finding ways to improve water efficiency has become an urgent task for world agriculture (Liu et al., 2021). The interaction of genotype, soil, and weather conditions is a primary factor that determines the productivity of an area (Khan et al., 2002). Further, the sowing date is an important characteristic for determining the length of the vegetation period, before and after the grain filling, which can be shortened by 6 to 15 days (Lv et al., 2020). As a consequence, grain and biomass yields are reduced. An earlier sowing date could mitigate the effects of high temperatures and disturbed precipitation and grain yields, and in some areas, it is possible to reduce artificial drying (Maresma et al., 2019). New cultivation technologies are based on the use of hybrids with improved vigour in the earlier season and germination resistance at lower temperatures (Khaeim et al, 2022). Management practices to optimize the grain yield of maize (*Zea mays* L.) also include planting on the appropriate sowing date. Low temperatures stop the initiation of germ and root growth, which leads to seed rot and poor germination (Abendroth et al., 2017; Hall et al., 2016). The problem of the sowing date has been documented by Lauer et al., 1999; Tsimba et al., 2013; Abendroth et al., 2017; and others. In these studies, early sowing dates confirmed deficiencies in reducing the accumulation of photosynthetic radiation due to undeveloped leaf surface, but late sowing, due to high temperatures, also has the same effect on the accumulation of photosynthetic radiation. Whether early or late sowing, optimizing the maize sowing date is vital to achieving high yields (Sorensen et al., 2000). Crop technology must be based on the analysis of environmental conditions and the prediction of their changes. This study aimed to analyse early sowing dates in relation to the optimal one, regarding the relationship between the sowing period and the morphological characteristics of the cob and yield.

Material and Methods

Three inbred maize lines produced at the Maize Research Institute (ZP1, ZP2, and ZP3) were selected for testing. The studies were performed for two years (Y1 = 2018 and Y2 = 2019) in one location in Serbia, Zemun Polje- 44°52′00″ N; 20°19′00″ E (L). The soil was slightly calcareous Chernozem, namely Molcal silt loam (coarse-loamy, mixed, superactive, mesic Vitrandic Calcixerolls) (USDA-NRCS, 1999). Soil properties are shown in Table 1.

Tab. 1. Soil properties

	Soil Layer (cm)	pH KCL	pH H_2O	$CaCO_3$ (%)	Organic matter (%)	Total N (%)	P_2O_5 mg/100 g	K_2O mg/100 g
LY1	0–30	7.10	8.10	3.20	2.70	0.19	29.20	20.80
LY2	0–30	7.30	8.40	3.30	2.60	0.19	25.90	25.70

LY1 — Zemun Polje/2018; LY2 — Zemun Polje/2019

Since the beginning of recording temperatures in Serbia (1888), 2018 and 2019 have been considered the two warmest. In 2018, the deviation of average monthly temperatures from the reference period 61-90 was 4.3 ^{o}C , and from 91-20 was 2.1 ^{o}C, while 2019 was marked by one degree lower deviation. The sum of precipitation in 2018 and 2019 was approximately the same, 350 mm, which is about 100 mm less than both reference periods.

During the two-year trial as well as reference period, meteorological data were from the Republic Hydrometeorological Service of Serbia (RHMZ) (Table 2.).

Tab. 2. Meteorological data

	Monthly mean air temperature (^{o}C)							
Year	April	May	June	July	Aug.	Sept.	Oct	Average
2018	18.0	21.7	22.7	23.6	25.7	19.8	15.9	21.1
2019	14.6	15.7	24.2	24.1	25.9	18.6	16.9	20.0
61-90	11.4	16.6	19.6	21.1	20.6	16.9	11.5	16.8
91-20	13.6	18.2	21.9	23.8	23.7	18.5	13.3	19.0
	Monthly sum of precipitation (mm)							
Year	April	May	June	July	Aug.	Sept.	Oct	Sum
2018	24.6	39.0	150.1	61.9	44.0	16.9	20.8	357.3
2019	51.3	129.6	113.7	31.0	19.8	20.6	7.2	350.5
61-90	57.6	69.3	89.3	70.0	54.3	51.3	41.0	433.0
91-20	51.5	72.3	95.4	66.5	53.9	59.8	53.5	452.9

According to the completely randomised design (CRD), a four-replicate trial was set up in 2018-2019. Nine rows were sown in the elementary plot, three rows from each line. During the vegetation, standard cropping practices for maize were applied. The previous crop was wheat. Sowing of inbred lines was performed on two sowing dates: the earlier sowing date 1 April (SD1) and the optimal sowing date 20 April (SD2).

After manual harvesting, the ears used for laboratory analyses were dried to 14% moisture in ovens at the temperature of 35°C.

The samples were taken from the middle row for analysis. Five-cob samples were formed to determine the cob length (CL), thickness (CT), the cob weight (CW), the ear weight (EW) and the 1000-kernel weight (SW). CL and CT were determined by measuring the length and thickness of five ears from each sample with a ruler (0–1000 mm) as well as a calliper (1/10 mm accuracy, 0-150 mm range), and the kernel weight (KW) was measured by the standard method according to the ISTA rules (2020), by counting 4 × 100 kernels and then by measuring them on a digital balance (Tehtnica ET 1111, max-1200.00/120.00). All cobs were harvested from the middle row and then measured to determine grain yield.

All data were processed by the SPSS statistical program. Data were presented using descriptive statistics, and ANOVA analysis of variance to determine the significance of differences between factors.

Results and Discussion

The results of the experiment indicate that the manifestation of the morphological properties of the cob and yield was significantly influenced by the factor genotype, year, and the interaction of the factors ($p \leq 0.01$) ($p \leq 0.05$). By testing the differences between the levels of the sowing date factor, it was determined that there was a significance for the change in the level of the mean values of the CL, CT and SW parameters ($p \geq 0.05$) (Table 3).

Tab. 3. Influence of factors on the morphological properties of the cob and grain yield

	GY	CL	CT	EW	CW	SW
Sowing date	1.314	4.966*	8,658*	0.401	1.712	5.782*
Genotype	21.868**	1.974	3.807*	43.429**	16.101**	0.509
Year	14.819**	7.233*	3.389*	704.901**	5.755*	172.22**
Sowing date× Genotype	6.391*	1.092	0.062	2.498	0.598	0.597
Sowing date× Year	1.624	0.013	0.388	0.007	1.908	9.161*
Genotype× Year	5.004*	1.150	3.021	27.535**	2.390	2.895
Sowing date× Genotype×Year	1.469	0.502	2.486*	0.027	2.895	1.590

*Significant at the 0.05 level, **Significant at the 0.01 level, GY – grain yield, CL – cob length, CT – cob thickness, EW – ear weight, CW – cob weight, SW – 1000 – kernel weight.

Based on the comparison of individual values, the ZP3 genotype had the highest yield (Table 4). In addition, the maximum cob length, cob thickness, and cob weight were determined for this genotype. Temperature conditions, the amount and distribution of precipitation in the first year resulted in better yield and cob length, while in the second year the cob thickness, cob weight, and ear weight were better compared to the first year of production.

The sowing date SD2 for ZP3 was favourable for most properties, as opposed to the earlier sowing date SD1, which affected grain yield (5,77 t ha^{-1}).

All data indicate that SD2 is more optimal for ZP1 and ZP2, except for SW. When it comes to the expression of morphological seed characteristics for ZP3 (EW, CW, SW) and GY, the earlier sowing date SD1 was more suitable. The highest yield GY for the interaction between sowing date and genotype was achieved for SD1ZP3, 7.05t/ha.

In the interaction of SD × Y, earlier sowing (SD1) in the first year (Y1) was better in terms of yield (6.21 t ha^{1}) and CT, while for all other traits the second year (Y2) was more favourable. For the optimal sowing date (SD2), the first year (Y1) was favourable for higher GY, CW, and EW. While in the SD2Y2 variant, significantly higher values were achieved for CL (99.09 cm) and CT (29.17 cm). CT.

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All three factors had the greatest effect in the variant with ZP3 for all traits. The most successful variant for GY and SW was the SD1Y1ZP3 variant, followed by SD1Y2ZP3 for CL and EW, and CT in the SD2Y2ZP3 form (Table 4).

Tab. 4. Mean values of morphological traits of the cob and yield by variants of factor action

		ZP1			ZP2			ZP3			Total	
		Y1	Y2	Total	Y1	Y2	Total	Y1	Y2	Total	Y1	Y2
GY	SD1	6.28	5.26	5.77	5.29	4.20	4.75	7.05	6.56	6.80	6.21	5.34
	SD2	6.06	5.61	5.84	5.84	4.41	5.13	5.49	6.06	5.77	5.80	5.36
	Total	6.17	5.44	5.80	5.57	4.31	4.94	6.27	6.31	6.29		
CL	SD1	78.63	77.84	78.23	88.88	80.74	84.81	78.6	89.11	83.85	82.04	82.56
	SD2	82.09	76.68	79.38	83.88	136.16	110.02	83.33	84.46	83.89	83.10	99.09
	Total	80.36	77.26	78.81	86.38	108.45	97.41	80.96	86.78	83.87		
CT	SD1	21.68	21.23	21.46	21.60	20.27	20.93	22.55	23.10	22.83	21.94	21.53
	SD2	22.48	21.69	22.09	22.56	26.44	24.50	22.15	39.69	30.92	22.40	29.17
	Total	22.08	21.46	21.77	22.08	23.35	22.72	22.35	31.4	26.87		
EW	SD1	133.17	120.62	126.89	139.30	141.79	140.55	150.00	164.98	157.49	140.82	142.46
	SD2	145.53	126.57	136.05	150.10	138.68	144.39	141.77	149.88	145.83	145.80	138.38
	Total	139.35	123.59	131.47	144.70	140.24	142.47	145.88	157.43	151.66		
CW	SD1	22.23	21.97	22.10	24.53	26.07	25.30	24.57	27.32	25.94	23.78	25.12
	SD2	24.93	21.47	23.20	26.23	26.68	26.46	25.33	25.42	25.38	25.50	24.52
	Total	23.58	21.72	22.65	25.38	26.38	25.88	24.95	26.37	25.66		
SW	SD1	319.83	328.88	324.35	328.08	331.48	329.78	331.71	321.39	326.55	326.54	327.25
	SD2	300.82	280.38	290.6	292.00	275.83	283.92	288.21	268.75	278.90	293.68	274.99
	Total	310.33	304.63	307.48	310.04	303.66	306.85	309.96	296.22	303.23		

Y1 – the production year 2018, Y2 – the production year 2019, GY – grain yield, SD1 – earlier sowing date, SD2 – optimal sowing date, EW – ear weight, CW – cob weight, CL – cob length, CT – cob thickness, SW – 1000 kernel weight.

ANOVA pointed out that the application of different sowing dates did not achieve significant differences in values for the morphological characteristics of the cob and yield. Therefore, further analysis of differences in mean values was not performed.

The difference between the parameters in two different environments in the two-year experiments was significant for the grain yield and 1000 kernel weight ($p \leq 0.05$) (Table 5.). The difference is a consequence of the influence of higher precipitation in the June-September period during 2018, the period when plants are in the pheno-phases of fertilisation and grain filling. Grain weight is an indicator of agroclimatic and production conditions of specific years (Bajagić et al., 2021).

Tab. 5. Mean differences in morphological features over two years

Dependent Variable Year	Year		Mean Difference (Y1-Y2)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
	Y1	Y2				Lower Bound	Upper Bound
GY	Y1	Y2	0.651*	0.169	0.000	0.317	0.986
CL	Y1	Y2	-8.264	8.327	0.323	-24.736	8.208
CT	Y1	Y2	-3.233	3.028	0.288	-9.223	2.756
EW	Y1	Y2	2.892	2.232	0.197	-1.523	7.306
CW	Y1	Y2	-0.181	0.420	0.668	-1.012	0.651
SW	Y1	Y2	8.990*	3.443	0.010	2.178	15.801

*The mean difference is significant at the 0.05 level, b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments). Y1- production year 2018, Y2- production year 2019, GY- grain yield, EW- ear weight, CW- cob weight, CL- cob length, CT- cob thickness, SW- 1000 kernel weight.

Depending on genetic factors, and biochemical and physiological abilities of the plant, the duration and degree of grain filling are different, which results in different seed sizes, i.e., yield (Sadras and Egli, 2008). Maize grain yield is the product of mutual compensatory effect of yield components at different stages of vegetation (Kruger et al., 2018).

The correlation between morphological traits indicates a significant relationship between GY and EW, CW as well as SW. Correlations between EW and SW, CL and CT are also important (Table 6.).

Tab. 6. The Pearson Correlation Coefficient for the tested properties

	GY	EW	CW	CL	CT	SW
GY	1					
EW	0.212*	1				
CW	-0.238	0.162	1			
CL	0.161	-0.061	-0.034	1		
CT	0.151	-0.129	-0.086	0.303**	1	
SW	0.188*	-0.635**	-0.149	0.057	0.124	1

*Significant at the 0.05 level, **Significant at the 0.01 level, GY – grain yield, EW – ear weight, CW – cob weight, CL – cob length, CT – cob thickness, SD – 100 – kernel weight.

Genotype × environment interaction often explains the proportion of variation in grain yield better than the effect of the genotype itself. Studying the influence of different environments on one genotype reveals that the main determinant of yield is seed size. Another determinant that affects yield variations is the weather conditions of the production year. This reveals that the year × genotype interaction is significant for grain filling length, the number of grains per plant, and yield (Munaro, et al., 2018). Limited environmental conditions during grain filling can strongly affect yield. Photothermal conditions are important, especially seasons with photothermal imbalances that affect kernel weight and yield (Hisse et al., 2021).

Conclusion

Environmental conditions during the experiment did not contribute to the significance of different sowing dates. Variability of temperature conditions and precipitation levels can be more or less stressful. Analysis of descriptive statistics for individual parameters reveals that the average values of yield and 1000 - kernel weight were higher on the earlier sowing date. Further, positive results in the earlier sowing date were obtained for the cob weight. There is a difference between genotypes in relation with the influence of sowing dates on the manifestation of morphological characteristics of seeds and yield. To achieve the best possible yields, genotypes with greater tolerance for environmental variability should be selected.

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Значај оптимизације рока сјетве за морфолошке особине и принос зрна инбред линија кукуруза

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Сажетак

Ово истраживање је имало за циљ да утврди утицај рокова сјетве на морфолошка својства и принос зрна кукуруза. Експеримент је спроведен током периода 2018 (Y1) и 2019 (Y2) године на једној локацији у Србији (Земун Поље). Као материјал коришћене су три инбред линије, произведене у Институту за кукуруз (Србија). Сјетва је одређена у два рока, раније 1. априла (SD1) и оптимални 20. априла (SD2). Морфолошке особине клипа су мјерене у лабораторијским условима: маса клипа (EW), маса кочанке (CW), дужина клипа (CL), дебљина клипа (CT), маса 1000 зрна (SW) и принос зрна (GY). Датум сјетве је значајно утицао на морфолошка својства клипа (п≤0,05). Значајан утицај на варијабилност особина имала је и интеракција фактора. Трофакторијална анализа варијансе показује да третман SD1Y1 у варијанти са инбред линијама ZP1 и ZP3 имају већи принос (6,28 t ha^{-1}, 7,05 t ha^{-1}). Даље, тежина 1000 зрна у сва три генотипа била је већа у SD1, ZP1 (324,35 g), ZP2 (329,78 g) и ZP3 (326,55 g). Ранији рок сјетве је такође био повољан за тежину клипа. Метеоролошке прилике могу бити мање или више стресне за ратарске усјеве. Неповољни временски услови могу се избјећи или смањити примјеном различитих рокова сјетве.

Кључне ријечи: вријеме сјетве, кукуруз, принос зрна, морфолошке особине

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