

Influence of genotype, climatic factors and sowing time on maize yield and water release rate

Vera RAJIČIĆ¹, Jelena STOJILJKOVIĆ², Vera POPOVIĆ^{3,4*},
Milan BIBERDŽIĆ⁵, Dragan TERZIĆ¹, Kristina LUKOVIĆ²,
Mirela MATKOVIĆ STOJŠIN⁶, Nenad ĐURIĆ^{2*}

¹University of Niš, Faculty of Agriculture, Kosančićeva 4, 37000 Kruševac,
Serbia; verarajic74@gmail.com; terzic.dragan@junis.ni.ac.rs

²Institute for Vegetable Crops, Karadorđeva 71, 11420 Smederevska Palanka, Serbia;
jstojiljkovic@institut-palanka.rs; klukovic@institut-palanka.rs; nenad.djuric@outlook.com

³Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia; drvpopovic@gmail.com

⁴University of Bijeljina, Faculty of Agriculture, Pavlović put bb, 76300 Bijeljina, Bosnia and Herzegovina; vera.popovic@ifvcns.ns.ac.rs
(*corresponding author)

⁵University of Priština-Kosovska Mitrovica, Faculty of Agriculture, Kopaonička bb, 38228 Lešak, Serbia; mbiberdzic@gmail.com

⁶"Tamiš" Research and Development Institute, Novoseljski put 33, 26000 Pančevo, Serbia; matkovic.stojšin@institut-tamiš.rs;

Abstract

The objective of this paper was to determine the optimal sowing periods for maize in alluvial soil in the semiarid conditions of the southern of Serbia during two successive growing seasons of six maize genotypes from three FAO ripening groups and three sowing periods. Different climatic conditions, temperatures, and amounts of precipitation levels during the examined research period, as well as different sowing periods, had a significant effect on grain yield and yield characteristics variation. The 2014 growing season was more favorable due to a well-distributed rainfall pattern during the critical stages of maize growth, which positively affected thousand-kernel weight and grain yield. Grain yield was significantly higher in 2014 compared to 2015, which was less favorable due to high temperatures and reduced rainfall during the critical growth stages. The genotypes NS 5051 and ZP 555 demonstrated the greatest stability in the number of grains per cob during the second sowing period in the 2014 season. The greatest stability in thousand-kernel weight was achieved by genotype NS 6030 in all three sowing periods in the 2014 season. The genotypes NS 5051 and ZP 555 showed the highest stability of grain yield in all three sowing periods in 2014, and positive interaction with the environment was achieved during the second sowing period in 2015. The results indicate the need for a localized approach when selecting hybrids and adjusting optimal sowing periods to mitigate the negative effects of climate change and to get maximize yield.

Keywords: maize; sowing period; yield; physiological maturity; technological maturity

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Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world, alongside with wheat and rice. It is grown extensively in temperate, tropical, and subtropical regions. Maize grain is a valuable source of protein (6-13%), oil (2-5%), starch (70-85%), sugar (1-3%), vitamins, and minerals, including vitamins A, E, B3, B6, B12, iron, calcium, potassium, phosphorus, and sulfur (Shah, 2007; Popović, 2010). Maize is a very important agricultural crop not only in the Republic of Serbia but also globally, with significant potential for further expansion, and it has an increasingly important place on the market. In Serbia, maize has been the most represented field crop for years. In 2023 in the Republic of Serbia, maize was sown on 922.980 ha, with an average grain yield of 7.2 t ha⁻¹ (SORS, 2023). Maize is a plant with a very high biological fertility potential, and it belongs to the group of plants with the highest production of organic matter per unit area. The fact that all above-ground parts of the plant can be used gives special economic importance to maize (Đurić *et al.*, 2015; Milenković *et al.*, 2015). Environmental limitations, such as temperature and drought, have caused a decline in maize production levels in recent decades. This decline is expected to worsen with climate change (Meeks *et al.*, 2013). The production potential and crop quality are correlated with, and strongly influenced by environmental factors such as temperature, amount of precipitation, and soil water reserves (Butts-Wilmsmeyer *et al.*, 2019; Markoski *et al.*, 2023; Simić *et al.*, 2023). Therefore, it is necessary to reduce undesired outcomes using innovative or adapted crop cultivation methods. Sowing during optimal periods to ensure proper plant growth and development of plants, as well as using hybrids with different vegetation periods, are just a few potential strategies to reduce the adverse effects of climate change on agricultural production (Lupu and Pırşan, 2017).

Despite its high genetic yield potential, maize yields vary significantly under different weather conditions, which is one of the reasons for the suboptimal utilization of maize fertility. Maize yield depends on several yield components such as cob length, cob diameter, number of grains per row and the thousand-kernel weight (Gokmen *et al.*, 2001; Božović *et al.*, 2018). Maize yield is highly affected by the number of grains of rows and thousand-kernel weight of maize, with various meteorological factors such as precipitation and temperature playing a significant role in yield formation (Sarcevic-Todosijevic *et al.*, 2016; Yang *et al.*, 2022; Brozović *et al.*, 2023). Partali *et al.* (2021) indicated that the maize yield and quality are significantly influenced by the conditions of the year, sowing period, plant density, type of hybrid, as well as interactions between these factors.

Maize, unlike other agricultural crops, shows great diversity in terms of vegetation length, and of all external factors, temperature has the greatest influence on this characteristic. Over the years, maize yield have fluctuated. The large variation in yield is due to the amount and distribution of precipitation and other factors, such as soil fertility, lower availability of nutrients, the water-air regime in the soil, smaller plots, and less commercially oriented, predominantly precipitation-dependent production systems (Pavlov and Crevar, 2014; Dugalić *et al.*, 2024). Oscillations in yield can be attributed to production in dry farming systems, so unfavorable weather conditions during the growing season very often led to the reduction of grain yield (Branković-Radojčić *et al.*, 2017; Urechean and Bonea, 2017). Hybrids with shorter growing seasons flower earlier and fill grain, enabling them to avoid the June and August droughts that often occur in our region. One of the central issues the world faces is the risk of significant climate change, which represents an environmental problem across all economic sectors (Hong *et al.*, 2019). The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) states that global temperatures are expected to increase by 1.5 °C or more within the next 20 years, with extreme weather events becoming more frequent and severe (Levin *et al.*, 2021). The increase in temperatures and the lack of precipitation during July and August are consequences of global warming, which could result in a decrease in maize yields (Levin *et al.*, 2021).

Biberdžić *et al.* (2018b) point out that the sowing period is one factor that significantly impacts maize yield. Zhang *et al.* (2019) state that the optimal sowing period can be defined as the sowing time that ensures

maize emerges at the most favorable moment, maximizing the use of growing season conditions to achieve the highest possible yield. Sowing at the optimal time increases maize yield and avoids the need for artificial drying, thus increasing its profitability. Additionally, new hybrids, as well as advancements in agronomic technologies and crop protection, significantly increase maize production (Srivastava *et al.*, 2018; Maresma *et al.*, 2019).

To achieve high and stable yields, numerous researchers have studied the vegetation length of individual maize hybrids in different weather conditions from emergence to maturation, because not all hybrids can be grown equally successfully in all production areas. The duration of the vegetative growth period and the grain filling period both influence crop yield (Anapalli *et al.*, 2022; Wu *et al.*, 2023; Wang *et al.*, 2024). Despite the significant differences in vegetation length by year, no major differences were observed in the sum of effective temperatures for the same hybrid, regardless of the years or sowing period (Biberdžić *et al.*, 2018a). For a hybrid to be accepted in the market, in addition to its genetic potential for high yields, it must exhibit good adaptability and stability, quickly release moisture from the grain, and have good resistance to economically significant pests and plant disease agents (Božović *et al.*, 2018; Bocianowski *et al.*, 2019). The dynamics of moisture release is a quantitative feature characterized by high heritability and additive gene action. Liu *et al.* (2020) point out that the moisture content of the grain at the time of harvesting depends on the rate of water loss during ripening, that is, after physiological maturity. Therefore, the selection of maize should continue to focus on developing genotypes that are characterized by rapid grain moisture release (Mitrović *et al.*, 2015; Popović *et al.*, 2024).

Due to the insufficiently clear influence of climatic conditions, sowing period, and genotypes belonging to different FAO ripening groups (400, 500, and 600) on certain productive and physiological properties of maize, two-year research was conducted in the Jablanica district. The goal was to assess the influence of climatic conditions and sowing period on the number of grains per cob, thousand-kernel weight, maize yield, and the percentage of water released from the maize grains.

Materials and Methods

Experimental design

The examination of the morphological and productive characteristics of maize was conducted under field conditions in the vicinity of Leskovac, at 43°01'476" N 21°56'126" E, altitude 225 m (RHIS, 2016). The studies were carried out on alluvial-type soil during 2014 and 2015. In both years, the pre-crop was winter wheat. Soil cultivation began with autumn plowing at a depth of 30 cm, with the introduction of 500 kg ha⁻¹ of NPK fertilizer (16:16:16). Pre-sowing preparation was carried out immediately before seeding with a two-pass disc. The experiment was setup in a randomized block design with three replications.

Six genotypes from three FAO ripening groups (400, 500, and 600), developed at the Zemun Polje Maize Institute and the Institute of Field and Vegetable Crops in Novi Sad were used for research. The following hybrids were used: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5) and NS 6030 (G6). Each genotype was sown in three sowing periods: SPI (beginning of April), SPII (mid-April), and SPIII (end of April), with a 15-day interval between sowing dates. FAO group 400 hybrids were sown with a plant spacing of 20 cm, FAO 500 with a spacing of 25 cm, and FAO 600 with a spacing of 30 cm. Four rows of each hybrid were sown to a length of 7 m, so the size of the basic plot was 19.6 m².

The recommended amount of nitrogen fertilizer for top dressing (200 kg ha⁻¹ KAN) was divided into two top applications. The first feeding was done when the plants were at the 3-4 leaf stage, with 60% of the recommended amount applied. The second application was made with the remaining amount of KAN when the maize was at the 7-8 leaf stage.

Crop protection against weeds began after sowing and before crop emergence, by treating the soil surface with herbicides (Basar, application rate 1.4 l ha⁻¹ + Rezon, application rate 1.5 l ha⁻¹). When the crop reached

the 6-leaf stage, it was protected against weeds using herbicides (Motivell in the amount of 0.75 l ha⁻¹ + Callisto 0.25 l ha⁻¹).

In the experiment, the following properties were analyzed: number of grains in the cob (NGC), thousand-kernel weight (TKW), maize grain yield (GY), water content at physiological maturity (WCPM), and water content in technological maturity (WCTM). Yield was determined by measuring the cobs of the two inner rows of each elementary plot across all repetitions and variants, and converted to grain yield in t ha⁻¹ based on 14% grain moisture. After that, a sample was taken for analysis of the number of grains per cob and thousand-kernel weight. To determine these values, 12 plants were sampled from each repetition and variant. The number of grains per cob and the thousand-kernel weight were determined using an automatic seed counter. Thousand-kernel weight was measured in the laboratory of Agricultural Advisory and Professional Service in Leskovac and expressed in grams, with two decimal places. The stage of physiological maturity was determined when a black layer appeared at the base of the grain in 50% of the plants (Dainard and Duncan, 1969). From the moment of physiological maturity, every seven days until technological maturity, sampling of the cobs of all hybrids and sowing periods was carried out, and grain moisture was measured with a Dickey-John moisture meter, and the values for water release from maize kernels were presented in percentages. The average water content of grain at physiological and technological maturity was determined, as well as the percentage of drying depending on the hybrid and sowing date by period (every 7 days from the moment of physiological maturity to technological maturity) and the correlation between the rate of grain water release and the sowing period, for each hybrid.

Meteorological conditions

The Leskovac Basin is one of the largest basins in Serbia, with a width of 45 km. It has an oval shape and a low altitude, reaching up to 300 m. It is surrounded by mountains of medium height, and numerous river courses have contributed to the formation of a specific climate. The climate in this area is significantly different than that of the neighboring regions. It is located in the central part of the South Morava River Basin. In addition to the main course of the South Morava, the basin also contains the courses of four other rivers (the Veternica, the Jablanica, the Vlasina, and the Pusta Reka), collectively known as the Leskovac Five Rivers. The basin is divided into smaller units by the river courses, with the central part occupied by the Leskovac Field. The position, shape, and size, along with other geographical factors, made the Leskovac Basin quite distinct from the neighboring Vranjska Basin, which is located further south (Milentijević *et al.*, 2018).

Examining the data from Figure 1, we can see that during the two-year research period, both average temperatures and precipitation varied. Differences were observed in the total amount of precipitation during the growing season, as well as in the monthly distribution of precipitation. The total precipitation during the growing season in 2014 was 464.1 mm, with an average temperature of 17.77 °C. Notably, 197 mm of precipitation fell in June, July, and August, which is 42.71 mm more than the multi-year average for the same period (Figure 1a). This period is particularly important in terms of precipitation amounts and distribution, and temperatures for maize yield formation. Based on the data on precipitation and average temperatures, it is evident that 2014 was favorable for maize production. In 2015, during the growing season, 255.9 mm of precipitation fell, which is 208.2 mm less than in 2014 (Figure 1a), while the average monthly temperature during the growing season was 19.31 °C, which is 1.54 °C higher than in 2014 (Figure 1b).

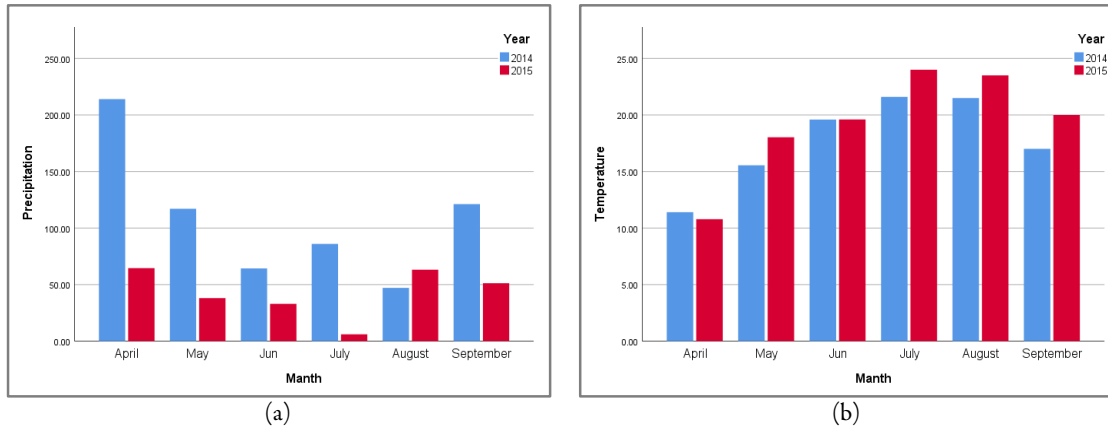


Figure 1. Amount of precipitation (mm) and mean air temperature (°C) by month in Leskovac, during the study: (a) Mean amount of precipitation in 2014 and 2015; and (b) Mean air temperature in 2014 and 2015

A particularly unfavorable period occurred during June, July, and August, with 102.8 mm of precipitation (Figure 1a), during these three months, which classifies 2015 as an extremely unfavorable year maize production. In the ecological conditions of Serbia, high temperatures and water deficit in July and August lead to reduced yields and deterioration of technological properties of maize (Maksimović *et al.*, 2018; Biberdžić *et al.*, 2018b; Ljubičić *et al.*, 2023).

Soil conditions

Before starting the experiment, soil samples were collected for agrochemical analysis. The analysis of the soil was done in the laboratory of the Agricultural Advisory and Expert Service in Leskovac immediately prior to the commencement of the experiment. Soil acidity was determined electrometrically using a pH meter, where the voltage created by the activity of hydrogen ions in the soil suspension was measured in a normal KCl solution (pH in nKCl), using the Kappen method. The humus content was determined according to the Kozman method, based on the oxidation of carbon from the organic matter in the soil using a potassium permanganate solution (0.1n KMnO_4), followed by titration with oxalic acid. The nitrogen content was calculated from the humus content and is expressed as a percentage. Easily accessible phosphorus ($\text{mg P}_2\text{O}_5$ per 100 g^{-1}) and potassium ($\text{mg K}_2\text{O}$ per 100 g^{-1}) were determined using the Al-method (according to Egner-Riehm) with the reading of the optical density of phosphorus on a spectrophotometer and of potassium on a flame photometer. The phosphorus and potassium contents in the soil are expressed in milligrams per 100 grams of soil.

Soil analysis did not determine the presence of carbonates (Životić and Gajić, 2023; Gajić *et al.*, 2023). Table 1 presents the availability of nutrients in the soil on which the research was conducted.

Table 1. Chemical properties of the soil

Depth (cm)	pH		Humus (%)	Nitrogen (%)	Available ($\text{mg } 100 \text{ g}^{-1} \text{ soil}$)	
	H_2O	KCl			P_2O_5	K_2O
0-30	7.74	5.78	2.65	0.13	17.56	34.00
30-60	7.20	6.10	2.10	0.06	8.90	21.76

Observing the results of the agrochemical analysis of the soil from Table 1, it can be concluded that the soil on which the two-year study was conducted belongs to the group of moderately acidic soils (Belić *et al.*, 2014), being that the pH in KCl was 5.78. The established content of humus in the arable layer (2.65%) places this soil in the group of those that are poorly provided with humus and moderately provided with total nitrogen (0.13%). Based on the same results, it can be concluded that the soil is optimally provided with readily available

phosphorus (17.56 mg 100 g⁻¹ of soil) and highly provided with potassium (34.00 mg 100 g⁻¹ of soil) in Table 1.

The Leskovac area has significant opportunities when it comes to land as a natural resource. Long-term soil testing in the laboratories of Agricultural Advisory and Professional Service in Leskovac, has shown that, compared to the results of analyses from twenty years ago, the acidity of the soil has improved by 0.2 to 0.3 units, while the percentage of humus in the soil has decreased. Furthermore, there was a decrease in phosphorus and potassium, which shows that the quality of the soil has been degraded by intensive production and improper cultivation. Most soil types have a medium-heavy mechanical composition and are moderately porous. Based on the chemical composition of the soil, it is mostly acidic, with a low content of humus and a modest level of physiologically active phosphorus and potassium.

Statistical analysis

Statistical data processing and analysis were performed using GenStat (2013) for PC/Windows 7. In the paper, Pearson's correlation analysis was used to test the association between independent samples, and a two-factor analysis of variance (ANOVA) was used to test the difference between groups. Significance levels of 0.05 and 0.01 were used as threshold values.

An AMMI (Additive Main Effects and Multiplicative Interaction) analysis was conducted using GenStat software, Trial Version 18.1.0.17005, to analyze genotype-by-environment interactions for the analyzed traits (GenStat, 2021). This analysis combines ANOVA (Analysis of Variance) and PCA (Principal Component Analysis) to decompose the complex interactions between genotypes and environments. The AMMI model identifies main effects (genotypes and environments) as well as interaction effects, providing valuable insights into genotype performance and environmental adaptability (Zobel and Gauch, 1998). Each corn genotype was evaluated across various environments, such as three sowing periods and two seasons, allowing for the assessment of how genotypes perform under different conditions. Furthermore, AMMI 1 (interaction principal components axes 1 [IPCA₁] × mean value of the analyzed trait) and AMMI 2 (interaction principal components axes 1 [IPCA₁] × interaction principal component axes 2 [IPCA₂]) biplots were constructed to visually represent the genotype-environment interactions.

Results

Agronomic parameters and stability performance of analyzed genotypes

The research examined whether there is a significant difference in the number of grains per a maize cob, thousand-kernel weight, grain yield, and grain water release rate depending on the year of production, genotypes, sowing period, and environment interaction.

According to the results of the ANOVA test shown in Table 2, it can be noticed that there is a highly significant difference during the two-year period in the number of grains per the maize cob concerning the genotype and the sowing period. However, there was no mutual influence of the genotype and the sowing period on the number of grains per the maize cob.

The FAO group 600 genotypes, G5 and G6 (ZP 666 and NS 6030) had a significantly higher number of grains compared to the other tested hybrids in 2014, while the genotype NS 6030 (G6) had a significantly lower number of grains compared to the other genotypes in 2015.

The number of grains in 2014 in the SPI (507.51) was significantly lower than in the SPII (578.72) and SPIII sowing periods (546.93), while in 2015 the number of grains in the SPIII (377.55) was significantly lower than in the SPI (416.90) and SPII (414.25) sowing periods (Table 2). Based on the results of the two-year research, we can conclude that in 2014, the highest number of grains was achieved by FAO group 600 genotypes in the SPII and SPIII sowing periods. During the 2015 production year, all examined genotypes from different FAO ripening groups had a lower number of grains compared to 2014. In the case of FAO group 600 genotypes

in the SPII and SPIII sowing periods in 2015, there was a decrease in the number of grains, while the highest number of grains per the cob was found in the genotypes ZP 555 and NS 5051 in the SPI sowing period (Table 2).

Table 2. The number of grains in a maize cob concerning the genotype and the sowing date

A- genotype	B – sowing period							
	2014				2015			
	I	II	III	Average	I	II	III	Average
G1	435.37	522.72	495.38	484.49	412.50	413.50	385.55	403.85
G2	446.37	522.83	502.36	490.48	410.89	412.62	382.09	401.86
G3	515.55	564.32	546.13	551.06	442.95	440.30	399.16	427.47
G4	516.45	585.19	551.54	551.06	433.44	450.64	385.13	423.07
G5	560.45	631.05	589.37	593.62	416.35	400.34	369.81	395.50
G6	570.85	646.22	596.80	604.62	385.29	368.12	343.58	365.66
Average	507.49	578.72	563.59		416.90	414.25	377.55	
	F		P		F		P	
A	137.067		0.000**		16.981		0.000**	
B	137.410		0.000**		33.472		0.000**	
A × B	1.610		0.143		0.918		0.143	

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: I (beginning of April), II (mid-April), and III (end of April); ²F-values of F-test, * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively

The results of the AMMI analysis of six maize genotypes sown in three sowing periods over two growing seasons are presented in Table 3. Based on AMMI analysis in Table 3, a highly significant influence of genotype, sowing date, and environment on the number of grains per maize cob was noticed. The AMMI analysis showed a highly significant effect of the interaction between genotype and environmental factors (GEI-Genotype by Environment Interaction) on the number of grains per maize cob, which varied among different environments. The AMMI model showed that Genotype + Environment (GE), has a highly significant effect on the number of grains per maize cob explaining 87.13% of the total variation. The principal components of genotypes and environment's account for 6.03% and 81.10% of the variation, respectively (Table 3).

Table 3. AMMI ANOVA for the number of grains in a cob of six maize genotypes sown in three sowing periods across two seasons

Source of variation	Df	SS	MS	F - value	P - value	The share of total variation %
Total	107	758170	7086	-	-	-
Treatments	35	742855	21224	100.33**	0.000	97.98
Genotypes	5	44771	8954	42.33**	0.000	6.03
Environments	5	602433	120487	551.29**	0.000	81.10
Block	12	2623	219	1.03 ^{ns}	0.431	0.35
Interactions	25	95650	3826	18.09**	0.000	12.88
IPCA ₁	9	92551	10283	48.61**	0.000	96.76
IPCA ₂	7	2238	320	1.51 ^{ns}	0.181	2.34
IPCA ₃	5	806	161	0.76 ^{ns}	0.581	0.84
Residuals	4	55	14	0.07 ^{ns}	0.992	0.01
Error	60	12692	212	-	-	-

*Notes: **-Highly significant at $p < 0.01$ probability level; *-Significant at $p < 0.05$ probability level; ^{ns}-Not significant; Df-Degree of freedom; SS-Sum of squares; MS-Mean Squares; F-F value calculated; P-P value calculated; IPCA₁-The first-interaction principal components axes; IPCA₂-The second-interaction principal components axes; IPCA₃-The third-interaction principal components axes

In the analysis of variance, the complex nature of the Genotype \times Environment interaction (GEI), which accounts for 12.88% of the total sum of squares of the trial, had a much higher contribution to Genotype \times Environment interaction effects than the Genotype effect (6.03%). The interaction principal components axes 1 (IPCA₁) participated in the GEI variation with 96.76%, while the interaction principal components axes 2 (IPCA₂) participated in the GEI variation with 2.34%, both with highly significant effects on the GEI variation. The IPCA, as an additional analysis of the GEI, pointed out the high significance of the two main principal components (IPCA₁ and IPCA₂), while the residual accounted for only 0.01% of the total sum of squares in Table 3.

By creating an AMMI 1 biplot (IPCA₁ \times mean value), the interaction between genotype and the external environment, i.e., the multivariate effect of the variability of the number of grains per cob, was observed in more detail (Figure 2).

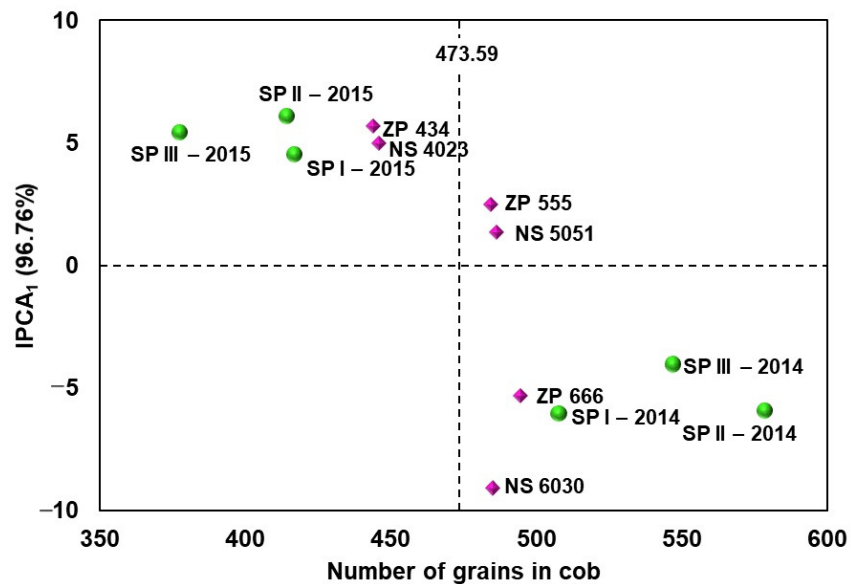


Figure 2. AMMI 1 (IPCA₁ \times mean value) biplot for six maize genotypes across six environments (three sowing periods \times two seasons) for the number of grains in cob
*Notes: SP-sowing period (I-beginning of April, II-mid-April, and III-end of April)

According to this AMMI 1 biplot, the genotypes NS 5051 and ZP 555 from FAO group 500 achieved the greatest stability in terms of the number of grains per cob, while the genotype NS 6030 from FAO group 600 achieved the greatest instability. All the mentioned genotypes had a mean value of the number of grains per cob, which was slightly higher than the average during for the experiment.

According to the AMMI 1 biplot (Figure 2) and the average values (Table 4) based on the points for the sowing periods (SPI, SPII and SPIII), it can be observed that the tested maize genotypes had higher average values for the number of grains per cob in the first growing season in 2014. In all three sowing periods during the 2015 season, the below-average value for the number of grains per cob was recorded (Figures 2 and 3).

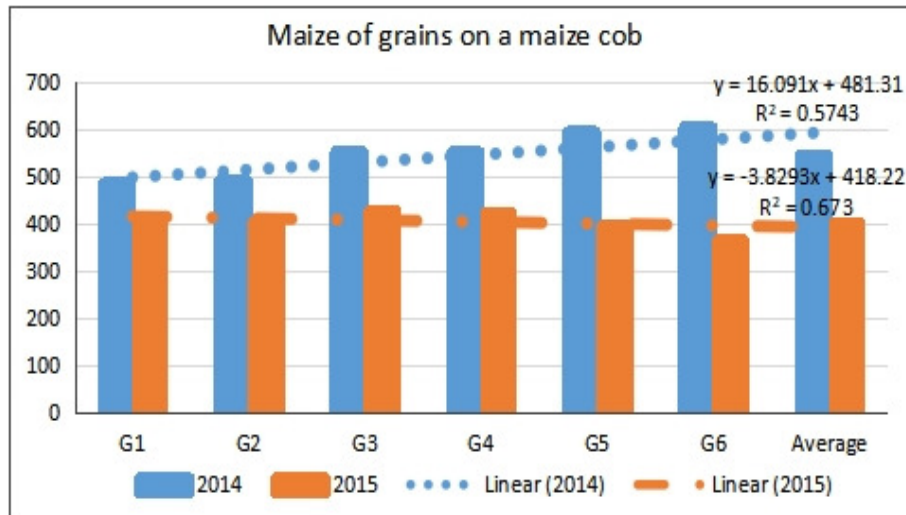


Figure 3. Effect of genotype and year of the number of grains per maize cob

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6)

According to the AMMI 1 biplot based on the sowing date points (SPI, SPII, and SPIII), it can be noticed that the maize genotypes ZP 434 and NS 4023, from FAO group 400, had a positive interaction with the mentioned environments (Table 4; Figure 2). In contrast, in all three sowing periods in the 2014 season, the recorded value of the number of grains per cob was above average, with the highest value at the second sowing period (SP II). Genotypes from FAO group 600 had a positive interaction with these environments. Thus, the analyzed environments (vegetation seasons) differ more in additive than in non-additive (multivariate) sources of variation, while the variation of genotypes is significantly influenced by additive and non-additive effects of variation.

Table 4. First four AMMI selections per environment for the number of grains in cob of maize

No.	Environment	Mean	IPCA ₁ Score	Rank of genotypes			
				1	2	3	4
5	SPII-2015	414.3	6.084	G3	G3	G1	G2
6	SPIII - 2015	377.6	5.441	G3	G1	G4	G2
4	SPI -2015	416.9	4.534	G3	G4	G5	G2
3	SPIII - 2014	546.9	-4.066	G6	G5	G4	G3
2	SPII-2014	578.4	-5.933	G6	G5	G4	G3
1	SPI - 2014	507.5	-6.060	G6	G5	G4	G3

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: SPI (beginning of April), SPII (mid-April), and SPIII (end of April)

The analysis of variance in Table 5 revealed a highly significant influence of genotypes and sowing dates on the thousand-kernel weight of maize for both production years. The mutual influence of genotypes and sowing date on the thousand-kernel weight in the maize cob in 2015 was highly significant, while in 2014 it was not significant.

Genotype NS 6030 (G6) from FAO group 600 had significantly higher thousand-kernel weight than hybrids from FAO groups 400 and 500 in 2014, while genotypes of FAO group 500 (ZP 555 and NS 5051) had significantly higher thousand-kernel weight than those from FAO group 600 in 2015 in Table 5. Thousand-kernel weight in 2014 differed significantly across all sowing periods. The highest achieved thousand-kernel weight in 2014 was achieved in the SPII sowing period, and the lowest in the SPI sowing

period, while in 2015 the thousand-kernel weight in the SPIII sowing period (286.82 g) was significantly lower than the SPI (334.88 g) and SPII sowing periods (343.63 g), as shown Table 5.

Table 5. Thousand-kernel weight (g) of maize grains depending on the genotype and sowing period

A- genotype	B – sowing period							
	2014				2015			
	I	II	III	Average	I	II	III	Average
G1	353.08	393.59	373.70	373.45	306.27	338.60	288.56	311.14
G2	355.54	388.93	367.78	370.75	293.89	315.85	277.39	295.71
G3	360.69	395.97	379.89	378.85	344.45	370.68	305.94	340.35
G4	364.62	397.39	378.35	380.22	321.70	385.72	290.47	332.63
G5	373.48	405.36	379.23	386.02	378.86	325.53	289.90	331.43
G6	376.55	407.82	388.09	390.82	364.13	325.37	268.70	319.40
Average	363.99	398.17	377.84		334.88	290.98	286.82	
	F		p		F		p	
A	6.626		0.000**		9.833		0.000**	
B	69.189		0.000**		67.910		0.000**	
A × B	0.338		0.964		7.576		0.000**	

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: I (beginning of April), II (mid-April), and III (end of April); ²F-values of F-test, * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively

Based on the AMMI analysis of six maize genotypes sown in three sowing periods during two growing seasons (Table 6), a highly significant influence of genotype, sowing time, and environment on the thousand-kernel weight was observed. The AMMI analysis showed a highly significant influence of the interaction between genotype and environmental factors (GEI) on thousand-kernel weight, which varied among different environments.

Table 6. AMMI ANOVA for the thousand-kernel weight of six maize genotypes sown in three sowing periods across two seasons

Source of variation	Df	SS	MS	F - value	P - value	The share of total variation %
Total	107	181317	1695	-	-	-
Treatments	35	169623	4846	29.40**	0.000	93.55
Genotypes	5	10275	2055	12.47**	0.000	6.06
Environments	5	135848	27170	180.81**	0.000	80.09
Block	12	1803	150	0.94 ^{ns}	0.541	1.06
Interactions	25	23501	940	5.70**	0.000	13.85
IPCA ₁	9	16730	1859	11.28**	0.000	71.19
IPCA ₂	7	5038	720	4.37**	0.000	21.44
IPCA ₃	5	1603	321	1.95 ^{ns}	0.100	6.82
Residuals	4	129	32	0.20	0.939	0.08
Error	60	9890	165	-	-	-

*Notes: **-Highly significant at $p < 0.01$ probability level; *-Significant at $p < 0.05$ probability level;

^{ns}-Not significant; Df-Degree of freedom; SS-Sum of squares; MS-Mean Squares; F-F value calculated; P-P value calculated; IPCA₁-The first-interaction principal components axes; IPCA₂-The second-interaction principal components axes; IPCA₃-The third-interaction principal components axes

The AMMI model, which was used to determine the number of principal components and the contribution of each of them in Genotype + Environment analysis (GE), indicated that both components

explained 86.15% of the GE variation (Table 6). The first and second principal components accounted for 6.06% and 80.09% of the variation, respectively. In the analysis of variance the complex nature of the Genotype \times Environment interaction (GEI), which accounted for 13.85% of the total sum of squares of the trial, had a much higher contribution to Genotype \times Environment interaction effects than Genotype effects. The interaction principal component axes (IPCA), as an additional analysis of the GEI, pointed out the statistical significance of the two main principal components (IPCA₁ and IPCA₂), while the residual accounted for only 0.08% of the total sum of squares in Table 6. The interaction principal component axes 1 (IPCA₁) participated in the GEI variation with 71.19%, while the interaction principal component axes 2 (IPCA₂) participated in the GEI variation with 21.44%, both with highly significant effects on the Genotype \times Environment interaction (GEI). The 2014 growing season was more favorable with the proper distribution of rainfall in the critical stages of maize growth, thus having a positive effect on the thousand-kernel weight, which was significantly higher compared to the 2015 growing season.

Based on the AMMI 1 biplot (Figure 4a) and the average values (Table 7) for six maize genotypes across six environments (three sowing periods \times two seasons) it can be noticed that greater stability for the thousand-kernel weight was achieved in the 2014 growing season across all three sowing periods. Greater variability was recorded in the second year of the experiment (2015), both in the mean values and in terms of stability (Figure 5; Table 7).

According to this AMMI 1 biplot (Figure 4a), the greatest stability was achieved by genotype NS 4023 from FAO group 400, which had a thousand-kernel weight below the general average, and the greatest instability was observed in NS 5051, NS 6030, and ZP 666. Genotypes and environments differed from each other in both the additive and multivariate parts of the variation.

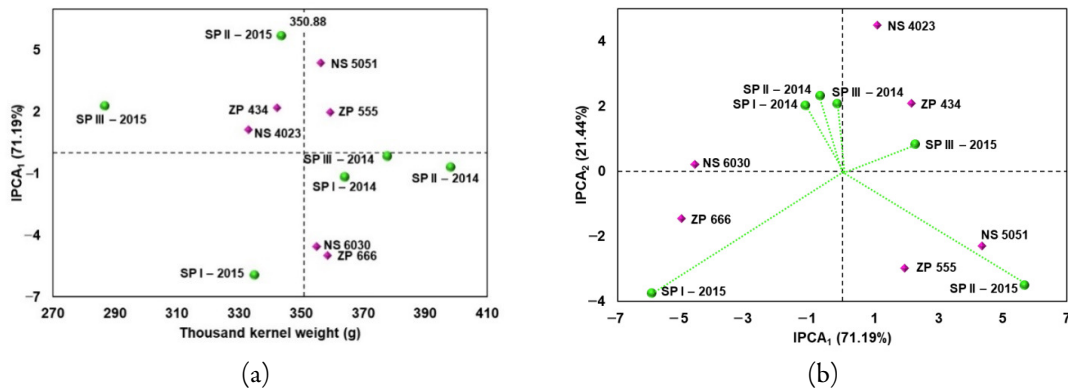


Figure 4. (a) AMMI 1 (IPCA₁ \times mean value) biplot for six maize genotypes across six environments (three sowing periods \times two seasons) for the estimation of main and multivariate (GEI) effects for the thousand kernel weight; (b) AMMI 2 (IPCA₁ \times IPCA₂) biplot for six genotypes across six environments (three sowing periods \times two seasons) for the thousand kernel weight

*Notes: SP-sowing period (I-beginning of April, II-mid-April, and III-end of April)

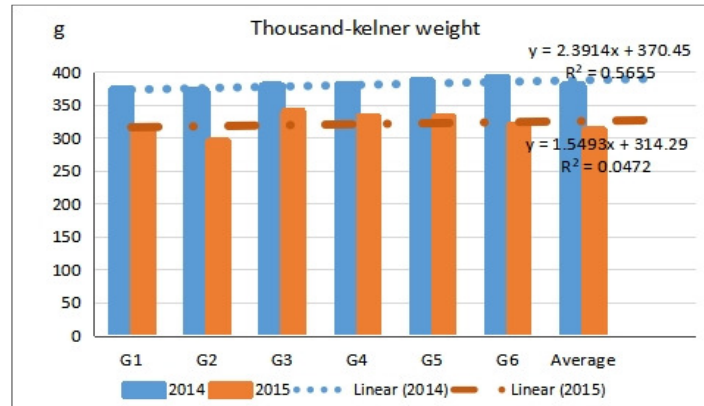


Figure 5. Effect of genotype and year on maize thousand-kernel weight (g) of grains

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6)

Table 7. First four AMMI selections per environment for thousand grain weight

No.	Environment	Mean	IPCA ₁ Score	Rank of genotypes			
				1	2	3	4
5	SPII-2015	343.6	5.684	G4	G3	G1	G2
6	SPIII-2015	286.8	2.273	G3	G4	G5	G1
4	SPIII-2014	377.8	-0.161	G6	G5	G4	G3
3	SPII-2014	398.2	-0.699	G6	G5	G3	G4
2	SPI-2014	364.0	-1.149	G6	G5	G4	G3
1	SPI-2015	334.9	-5.947	G5	G6	G3	G4

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: SPI (beginning of April), SPII (mid-April), and SPIII (end of April)

The AMMI 2 model explains 71.19% of the sum of squares of the Genotype × Environment interaction (GEI) for the thousand-kernel weight in the tested maize genotypes in Figure 4b. The vectors of all three sowing periods in the 2014 season are placed within the first quadrant of the biplot, which means that the climatic conditions in the 2014 season enabled the genotypes to be ranked equally. According to this AMMI 2 biplot, the greatest stability was achieved by genotype NS 6030, suggesting it consistently had the highest thousand-kernel weight, and a positive interaction with these environments. The vectors of sowing periods in the 2015 season were placed in three different quadrants of the biplot, meaning that they differed in terms of the stability of the thousand-kernel weight (Figure 4b).

Positive interaction with the vector of the first sowing period in the 2015 season was achieved by genotype ZP 666, in the second sowing period by genotypes NS 5051 and ZP 555, and in the third sowing period by genotype ZP 434, in Figure 4b.

By creating an AMMI 2 biplot (IPCA₁ × IPCA₂), the interaction between genotype and the external environment, i.e. the multivariate effect of the variability in thousand-kernel weight, was further explained by the second axis of interaction (IPCA₂), in Figure 4b.

Based on the results shown in Table 8, it can be noted that there is a highly significant difference for both production years in the yield of maize grains concerning the genotype and the sowing period and a highly significant influence of the interaction of the genotypes and the sowing period on the grain yield in the maize cob in 2015.

The highest grain yield in 2014 was achieved by genotypes NS 6030 (11.068 t ha⁻¹) and ZP 666 (10.868 t ha⁻¹) from FAO group 600, which had significantly higher yields compared to genotypes ZP 434 (9.144 t ha⁻¹) and NS 4023 (8.991 t ha⁻¹) from FAO group 400, while in 2015, the grain yield of genotypes NS 6030 (4.980 t ha⁻¹) and ZP 666 (5.306 t ha⁻¹) from FAO group 600 was significantly lower compared to genotypes FAO group 400 and 500, as shown in Table 8.

Table 8. Maize grain yield (t ha⁻¹) concerning on the genotype and sowing period

A- genotype	B – sowing period							
	2014				2015			
	I	II	III	Average	I	II	III	Average
G1	9.144	10.245	9.716	9.701	7.250	8.171	6.938	7.453
G2	8.991	9.998	9.467	9.485	6.916	7.846	6.912	7.224
G3	9.655	10.735	9.988	10.126	7.973	8.241	6.135	7.449
G4	9.526	10.508	10.057	10.030	7.708	8.413	5.725	7.282
G5	9.850	10.868	10.141	10.286	7.608	6.660	5.306	6.524
G6	9.977	11.068	10.248	10.431	6.842	6.443	4.980	6.088
Average	9.523	10.570	9.936		7.382	7.629	5.998	
	F		p		F		p	
A	82.012		0.000**		16.077		0.000**	
B	357.132		0.000**		77.802		0.000**	
A × B	1.487		0.184		5.464		0.000**	

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: I (beginning of April), II (mid-April), and III (end of April); ²F-values of F-test, * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively

The grain yield of the tested maize genotypes in 2014 differed significantly by sowing period, where the highest achieved yield was found in the SPII sowing period (10.570 t ha⁻¹), and the lowest in the SPI sowing period (9.524 t ha⁻¹). In 2015, grain yield in the SPIII sowing period (5.999 t ha⁻¹) was significantly lower than in the SPI (7.383 t ha⁻¹) and SPII sowing periods (7.629 t ha⁻¹), as shown in Table 8.

Based on AMMI data for six maize hybrids sown in three sowing periods during two growing seasons (Table 9), a highly significant influence of genotype, sowing period, and environment on grain yield was noticed. AMMI analysis showed a highly significant influence of the interaction between genotype and environmental factors (GEI) on grain yield, which varied across different environments.

The AMMI model, which was used to determine the number of principal components and the contribution of each of them in Genotype + Environment analysis (GE), indicated that both components had highly significant effects on grain yield explaining 91.52% of GE variation in Table 9. The first and second principal components accounted for 1.16% and 90.36% of the variation, respectively. In the analysis of variance, the complex nature of the Genotype × Environment interaction (GEI), which accounted for 8.48% of the total sum of squares of the trial, had a much higher contribution to Genotype × Environment interaction effects than the Genotype effect (1.16%). The interaction principal component axes (IPCA), as an additional analysis of the GEI, pointed out the high significance of the two main principal components (IPCA₁ and IPCA₂), while the residual accounted for only 0.02% of the total sum of squares (Table 9). The interaction principal component axes 1 (IPCA1) explained 81.96% of the GEI variation, while the interaction principal component axes 2 (IPCA2) explained 14.74% of the GEI variation, both with highly significant effects on the GEI variation in Table 9.

Different climatic conditions, temperatures, and amounts of precipitation during the study period, as well as different sowing periods, significantly impacted the variation in the sum of squares across environments, showing that the investigated growing seasons differed significantly, and all this affected the high grain yield variation. The 2015 growing season was less favorable due to high temperatures and less rainfall in the critical stages of maize growth (vegetative growth, grain filling, and grain water release), which caused a decrease in yield.

Based on the AMMI 1 biplot (Figure 6a) and the average values (Table 10) for six maize genotypes in six environments (three sowing periods × two seasons), it can be observed that greater stability for the grain yield was achieved in the 2014 growing season at all three sowing periods.

Table 9. AMMI ANOVA for the grain yield of six maize genotypes sown in three sowing periods across two seasons

Source of variation	Df	SS	MS	F - value	P - value	The share of total variation %
Total	107	318.83	2.980	-	-	-
Treatments	35	311.90	8.911	79.36**	0.000	97.82
Genotypes	5	3.61	0.722	6.43**	0.000	1.16
Environments	5	281.84	56.367	3455.87**	0.000	90.36
Block	12	0.20	0.016	0.15 ^{ns}	0.999	6.41
Interactions	25	26.45	1.058	9.42**	0.000	8.48
IPCA ₁	9	21.68	2.408	21.45**	0.000	81.96
IPCA ₂	7	3.90	0.556	4.96**	0.000	14.74
IPCA ₃	5	0.81	0.163	1.45 ^{ns}	0.219	3.06
Residuals	4	0.07	0.017	0.15 ^{ss}	0.963	0.02
Error	60	6.74	0.112	-	-	-

*Notes: **-Highly significant at $p < 0.01$ probability level; *-Significant at $p < 0.05$ probability level; ^{ns}-Not significant; Df-Degree of freedom; SS-Sum of squares; MS-Mean Squares; F-F value calculated; P-P value calculated; IPCA₁-The first-interaction principal components axes; IPCA₂-The second-interaction principal components axes; IPCA₃-The third-interaction principal components axes

Table 10. First four AMMI selections per environment for grain yield

No.	Environment	Mean	IPCA ₁ Score	Rank of genotypes			
				1	2	3	4
5	SPIII-2015	6.00	0.953	G1	G2	G3	G4
6	SPII - 2015	7.63	0.872	G4	G3	G1	G2
4	SPI - 2015	7.38	-0.097	G3	G4	G5	G6
3	SPIII - 2014	9.94	-0.474	G6	G5	G3	G4
2	SPI-2014	9.52	-0.623	G6	G5	G3	G4
1	SPII - 2014	10.57	-0.629	G6	G5	G3	G4

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: SPI (beginning of April), SPII (mid-April), and SPIII (end of April)

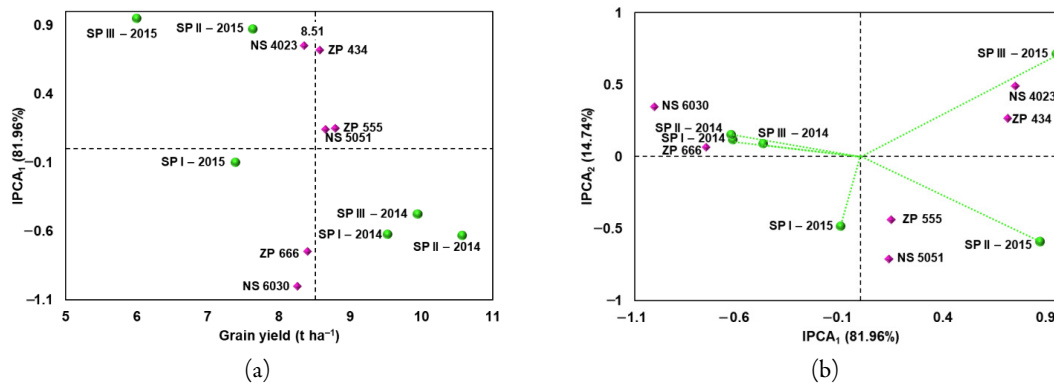


Figure 6. (a) AMMI 1 (IPCA₁ × mean value) biplot for six maize genotypes across six environments (three sowing periods × two seasons) for the estimation of main and multivariate (GEI) effects for the grain yield; (b) AMMI 2 (IPCA₁ × IPCA₂) biplot for six maize genotypes across six environments (three sowing periods × two seasons) for the grain yield; *Notes: SP = sowing period (I = beginning of April, II = mid-April, and III = end of April).

According to this AMMI 1 biplot, the genotypes NS 5051 and ZP 555 from FAO group 500 demonstrated the highest stability, with a mean grain yield within the general average, while genotypes NS 6030, NS 4023, and ZP 434 showed the highest instability (Figure 6a; Table 10). Regarding environmental factors, the highest grain yield stability was recorded in the first sowing period in the second season (2015), with values below the average for the entire experiment. In the 2014 season, the grain yield was above the average value in all three sowing periods, with a medium stable reaction of the genotypes.

According to the AMMI 1 biplot (Figure 6b) and the average values (Table 10), based on the points of the sowing periods (SPI, SPII, and SPIII), it can be observed that the examined maize genotypes had higher average grain yields in the first 2014 growing season. The AMMI 2 biplot for the yield of the tested maize hybrids from different FAO ripening groups showed that the first principal component (IPCA₁) accounted for 81.96% of the interaction between genotype and external environment. The vectors for the sowing periods in season 2014 are positioned in the first quadrant of the biplot, overlapping at a sharp angle, which means that the climatic conditions in the 2014 season enabled the genotypes to be ranked equally.

According to the AMMI 2 biplot (Figure 6b), based on the points for the sowing periods (SPI, SPII, and SPIII), it can be observed that the maize genotypes ZP 666 and NS 6030 from FAO group 600 exhibited a positive interaction with the respective environments. The vectors of sowing periods in the 2015 season were placed in three different quadrants of the biplot, meaning that they differed in terms of the stability of the yield (Figure 6b).

A positive interaction during the second sowing period in the second season was achieved by hybrids belonging to FAO group 500 (NS 5051 and ZP 555), while during the third sowing period of the second season a positive interaction with the environment was achieved by hybrids belonging to FAO group 400 (NS 4023 and ZP 434) in Figure 7.

The research examined whether there were significant differences in the number of grains per maize cob, thousand-kernel weight, grain yield, and grain water release rate over the entire period and each term, especially concerning the year of sowing in Table 11.

Based on the results of the t-test of independent samples shown in Table 11, it can be noted that there is a highly significant difference in the number of grains per cob, thousand-kernel weight, yield of grains, and the rate of water release from grains with respect to the year of sowing, where better results were achieved in 2014 for every observed parameter, except for the rate of water release from the grain, which was noted in 2015.

Table 11. Influence of the examined factors concerning the year of sowing

Sowing period	NGC		TKW (g)		GY (t ha ⁻¹)		RWR (%)	
	2014	2015	2014	2015	2014	2015	2014	2015
I	507.49	416.90	363.99	334.88	9.52	7.38	0.28	0.42
II	578.39	414.25	398.18	343.62	10.57	7.62	0.27	0.41
III	546.93	377.55	377.84	286.83	9.93	5.99	0.26	0.37
Aver.	544.27	402.90	380.00	321.78	10.01	7.00	0.27	0.40
	t	p	t	p	t	p	t	p
I	6.49	0.000**	3.45	0.002**	13.61	0.000**	-6.28	0.000**
II	11.91	0.000**	7.37	0.000**	13.01	0.000**	-7.13	0.000**
III	15.17	0.000**	19.07	0.000**	18.54	0.000**	-6.20	0.000**
Aver.	16.17	0.000**	10.39	0.000**	18.59	0.000**	-11.14	0.000**

*Notes: ¹Number of grains in the cob (NGC), thousand-kernel weight (TKW), corn grain yield (GY), and rate of water release (RWR); ²T-values of t-test, * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively

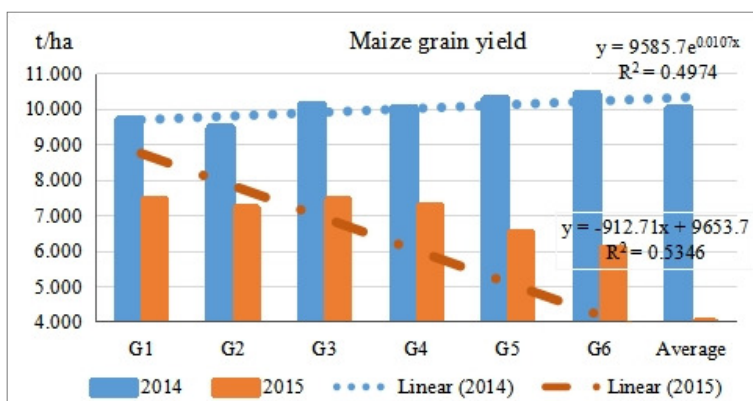


Figure 7. Effect of genotype and year of grain yield of maize genotypes

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6)

Water content in physiological and technological maturity

Table 12 presents the results of descriptive statistics of all six maize hybrids across all sowing periods, during the two-year research, for grain water content at both physiological and technological maturity.

Table 12. Water content in grain (%) at physiological and technological maturity during two vegetation seasons

Parameter	2014		2015	
	WCPM (%)	WCTM (%)	WCPM (%)	WCTM (%)
Mean	33.363	19.819	27.428	14.770
Median	33.300	19.800	26.700	14.950
Mode	31.7	16.1	26.7	16.4
Std. Deviation	1.378	2.830	3.517	3.368
Variance	1.897	8.006	12.371	11.341
Minimum	30.9	15.1	21.7	9.0
Maximum	35.7	24.2	33.0	20.6

*Notes: WCPM-Water content in physiological maturity (%), WCTM-Water content in technological maturity (%)

Based on the performed analysis presented in Table 12, we can observe that the average grain water content at physiological maturity was 33.363% in 2014 and 27.428% in 2015. The average grain water content at technological maturity in 2014 was 19.819%, while in 2015 it was 14.770%.

Table 12 presents the mean values for the grain water content at physiological maturity and grain at harvest/technological maturity for each tested hybrid. Based on the analysis, we can notice that the genotype NS 6030 (G6) had the highest grain water content at physiological maturity in both production years.

Average values in grain water content at physiological and technological maturity in the tested maize genotypes in 2014 and 2015 are present in Table 13. In 2014, the physiologically mature grain water content of genotype NS 6030 (G6) was 35.322%, and in 2015 it was 31.189%. The lowest grain water content at physiological maturity in both years of the study was found in genotype ZP 434 (G1), with 31.489% in 2014, and 23.978% in 2015, as shown in Table 13.

The genotype NS 6030 (23.546%; 19.022%) had the highest grain water content in the harvest in 2014 and 2015, as shown in Table 13. The lowest water content at technological maturity was found in genotype ZP 434 (G1), which was 16.156% in 2014, and 11.344% in 2015 (Table 13).

Table 13. Grain water content (%) at physiological and technological maturity in relation in maize genotypes

Traits	Year	G1	G2	G3	G4	G5	G6
Water content in physiological maturity (%)	2014	31.489	32.533	32.800	33.444	34.589	35.322
	2015	23.978	24.289	26.644	28.733	29.733	31.189
Water content in technological maturity (%)	2014	16.156	16.944	19.200	20.800	22.267	23.546
	2015	11.344	11.778	13.589	15.400	17.489	19.022

*Notes: Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6)

According to the data shown in Table 14, it can be observed that there is a highly significant difference in the rate of grain water release per day in relation to the genotype, and a significant difference in the sowing period in both production years. However, there is no significant difference in the interaction of the genotype \times sowing period (A \times B) on the rate of grain water release.

Table 14. The rate of water release (%) from grains per day depending on the genotypes and sowing period

A- genotype	B – sowing period							
	2014				2015			
	I	II	III	Average	I	II	III	Average
G1	0.37	0.37	0.34	0.36	0.46	0.45	0.36	0.42
G2	0.37	0.37	0.35	0.36	0.45	0.44	0.35	0.41
G3	0.32	0.32	0.31	0.32	0.49	0.43	0.39	0.44
G4	0.32	0.29	0.29	0.30	0.44	0.39	0.40	0.41
G5	0.30	0.28	0.27	0.28	0.37	0.38	0.37	0.37
G6	0.28	0.27	0.27	0.27	0.35	0.41	0.35	0.37
Average	0.33	0.32	0.31	0.32	0.43	0.42	0.37	0.40
	F		p		F		p	
A	75.166		0.000**		5.480		0.001**	
B	4.575		0.017**		5.033		0.012**	
A \times B	0.719		0.702		0.673		0.742	

*Notes: ¹Genotypes: ZP 434 (G1), NS 4023 (G2), ZP 555 (G3), NS 5051 (G4), ZP 666 (G5), and NS 6030 (G6), and three sowing periods: I (beginning of April), II (mid-April), and III (end of April); ²F-values of F-test, * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively

In 2014, across all hybrids and sowing periods, the average rate of water release per day was 0.32%. During 2014, at all three sowing periods, the genotypes G6 (0.27%) and G5 (0.28%) from FAO group 600 had a significantly lower daily grain water loss compared to the genotypes G1 and G2 (0.36%) from FAO group 400 and hybrids G4 (0.30%) and G5 (0.32%) from FAO group 500. Genotypes G1 and G2 from FAO group 400 had a significantly higher rate of grain water release compared to hybrids FAO group 500 and 600 in Table 14.

In 2015, the average rate of water release was 0.40% per day. Genotypes G6 (0.37%) and G5 (0.37%) from FAO group 600 had a significantly lower rate of grain water release per day compared to genotypes G2 (0.41%) and G1 (0.42%) from FAO group 400 and genotypes G4 (0.41%) and G3 (0.44%) from FAO group 500. During the SPI sowing period in 2014, the rate of grain water release per day was 0.33%, which was more significant compared to the SPIII period (0.31%) in Table 14. In 2015, the rate of water release per day in the SPI sowing period was 0.43%, which was more significant compared to the SPIII period, where the daily loss of water from the grains was 0.37% per day.

The average rate of grain water release during the two-year study (2014 and 2015) depended on the genotypes, sowing period, and year of the study (Table 14). Hybrids from FAO ripening group 400 had a higher grain water release rate (0.39% per day) compared to hybrids from FAO ripening groups 500 and 600 (0.38

and 0.32% per day). The rate of water release from grains in 2014 was 0.32% per day, while in 2015 the daily grain water loss was 0.40%, as shown in Table 14.

Correlations between the analyzed traits

The research examined whether there was a significant correlation between the characteristics of maize in relation to the year and the sowing period. The results of the analysis presented in Table 15 showed that the correlation coefficients between individual traits varied significantly depending on the year of the study. This variation was attributed to different climatic conditions during the examined periods, with 2015 being a dry year, characterized by limited and poorly distributed precipitation, especially during the period of dry matter accumulation and during the ripening period, compared to 2014, which was favorable for maize production.

Based on the results of the correlation analysis in Table 15, it can be concluded that for each year there was a significantly strong positive correlation between the number of grains, thousand-kernel weight, and grain yield. The correlation coefficient between the tested maize characteristics was higher in 2014 compared to 2015, which showed a stronger correlation between the mentioned maize characteristics in 2014.

During 2014, a significant high negative correlation was observed between grain water release per day and other characteristics, based on which it can be observed that with an increase in the number of grains, thousand-kernel weight, and yield, the daily loss of water from the grain decreases (Table 15).

In 2015, a significantly high positive correlation of grain water release with the number of grains ($r = 0.56^{**}$) and grain yield ($r = 0.51^{**}$) was noticed, while no significant correlation was noted with thousand-kernel weight ($r = 0.16$). The amount of water released from grains during 2015 increased with the increase in the number of grains and grain yield, as shown in Table 15.

Table 15. Correlation of maize characteristics about the two years and three sowing periods

Traits	2014				2015			
	NGC	TKW	GY	RWR	NGC	TKW	GY	RWR
NGC	-				-			
TKW	0.76 ^{**}	-			0.58 ^{**}	-		
GY	0.86 ^{**}	0.85 ^{**}	-		0.78 ^{**}	0.65 ^{**}	-	
RWR	-0.83 ^{**}	-0.42 ^{**}	-0.61 ^{**}	-	0.56 ^{**}	0.16	0.51 ^{**}	-
Sowing period I								
NGC	-				-			
TKW	0.78 ^{**}	-			-0.05	-		
GY	0.83 ^{**}	0.61 ^{**}	-		0.62 ^{**}	0.18	-	
RWR	-0.94 ^{**}	-0.70 ^{**}	-0.96 ^{**}	-	0.64 ^{**}	-0.62 ^{**}	0.36 ^{**}	-
Sowing period II								
NGC	-				-			
TKW	0.64 ^{**}	-			0.63 [*]	-		
GY	0.89 ^{**}	0.53 ^{**}	-		0.78 [*]	0.61 ^{**}	-	
RWR	-0.93 ^{**}	-0.55 ^{**}	-0.86 ^{**}	-	-0.05	-0.22	0.38 ^{**}	-
Sowing period III								
NGC	-				-			
TKW	0.59 ^{**}	-			0.44 ^{**}	-		
GY	0.81 ^{**}	0.66 ^{**}	-		0.54 ^{**}	0.19	-	
RWR	-0.91 ^{**}	-0.59 ^{**}	-0.87 ^{**}	-	0.46 ^{**}	0.45 ^{**}	-0.13	-

*Notes: ¹Number of grains in the cob (NGC), thousand-kernel weight (TKW), maize grain yield (GY), and rate of water release (RWR); ²Within years and the sowing period, the values in each column followed differently; * and ** represent significant differences at $p < 0.05$ and $p < 0.01$, respectively.

According to the results of the correlation analysis shown in Table 15, it can be concluded that there was a significant connection between the characteristics of maize and the sowing period in 2014, with the results for each period being relatively similar to those for the entire vegetation period. In contrast, the correlation results for maize characteristics across each sowing period in 2015 differed considerably from those for the entire year.

In the first sowing period, a significantly high correlation was established between the thousand-kernel weight with the number of grains ($r = 0.78^{**}$) and yield ($r = 0.61^{**}$) in 2014, while in 2015 no significant correlation was established between the tested traits. In the second sowing period, a significantly high correlation was established between the thousand-kernel weight and the number of grains ($r = 0.64^{**}$) and yield ($r = 0.53^{**}$) in 2014, while there is a highly significant correlation between the thousand-kernel weight and yield ($r = 0.61^{**}$), and a significant correlation between the number of grains and thousand-kernel weight ($r = 0.63^{*}$) established in 2015. In the third sowing period, a significantly high correlation was established between the thousand-kernel weight with the number of grains ($r = 0.59^{**}$) and yield ($r = 0.66^{**}$) in 2014, while in 2015 no significant correlation was established between the thousand-kernel weight and grain yield ($r = 0.19$), as shown in Table 15.

According to the results of the correlation analysis shown in Table 15, it can be concluded that a significant connection between the thousand-kernel weight and grain water release was observed in the first and third sowing periods.

Discussion

Agronomic parameters and stability performance of analyzed genotypes

Yield is an important indicator for assessing the impact of agrotechnical measures and growing conditions, reflecting the ability to grow, develop, and tolerate adverse conditions, as well as adapt to external conditions (Fischer, 2015; Vasileva *et al.*, 2023; Brozović *et al.*, 2023; Popović *et al.*, 2024). Maize yield mostly depends on variations in the number of grains in the harvest (Cirilo and Andrade, 1994). Based on the results of the two-year study, we can state that in 2014, which had a favorable distribution of precipitation during the growing season, the highest number of grains was achieved by hybrids from FAO group 600 in the second and third sowing period. In 2015, which was unfavorable for maize production in terms of the amount and distribution of precipitation, all tested hybrids from different FAO ripening groups had a lower number of grains compared to 2014. The genotypes ZP 666 (593.62) and NS 6030 (604.62) from FAO group 600 had a significantly higher number of grains compared to the other tested hybrids in 2014, while genotypes NS 5051 (423.07) and ZP 555 (427.47) had a significantly higher number of grains compared to the other genotypes in 2015. Mandić *et al.* (2024), found that the number of grains per year ranged from 230.0 in 2017 to 712.5 in 2016 (AS 534), with an average of 525.1. In the case of hybrids from FAO group 600 in the second and third sowing periods in 2015, there was a decrease in the number of grains, while the highest number of grains per cob was recorded in the hybrid from FAO group 500 in the 2014 sowing period. These differences between the hybrids examined over different sowing periods were due to differences in their genetic constitution. Fabris *et al.* (2023) point out that the later maize sowing can result in weaker plant structure, a less developed root system, and poorer absorption of nutrients, all of which negatively affect the ability to achieve maximum yields.

Examining the influence of weather conditions on the number of grains per cob, Wang *et al.* (2023) stated that maize is highly sensitive to environmental conditions during the threshing stage, and if that period is characterized by a lack of water or other unfavorable climatic conditions, such as excessive rainfall, humidity, low temperatures, or a lack of nutrients, poorer corn set occurs, which leads to a shortage of grains per cob, which is in agreement with the results of our research. The mass of grains per maize cob is an important component of grain yield, and it is most influenced by weather conditions during the grain filling phase, the

sowing period, as well as other agrotechnical measures (Carter *et al.*, 2016; Biberdžić *et al.*, 2018a; Božović *et al.*, 2018).

The flowering stage is particularly sensitive to heat and drought stress, leading to a reduction in grain number and grain weight (Butts-Wilmsmeyer *et al.*, 2019). High temperatures during the grain filling stage shorten the filling time and ultimately reduce grain weight and yield (Cheabuet *et al.*, 2018; Shao *et al.*, 2021; Yasin *et al.*, 2022). Climatic conditions, especially during the growing season, have a significant impact on crop yield, particularly when the interaction between multiple parameters is manifested (Butts-Wilmsmeyer *et al.*, 2019; Simon *et al.*, 2023; Petrović *et al.*, 2023; Mazibuko *et al.*, 2024). A highly significant difference in the number of grains, thousand-kernel weight, grain yield, and rate of grain water release compared to the year of sowing was achieved in 2014, a year with favorable weather conditions, especially a regular and consistent amount of precipitation during the flowering and grain formation periods in the tested maize hybrids from different FAO ripening groups. Qi *et al.* (2022) state that even if the amount of precipitation during the vegetation period of the crop corresponds to the value necessary for good plant development, irregular precipitation during important stages of development can lead to a significant decrease in yield. The highest need for water occurs during the flowering and grain formation periods in July–August, as well as 7–10 days before flowering, 10–20 days after flowering, and during milk maturity (Qi *et al.*, 2022). Maize production in the coming period will significantly depend on the selection of suitable hybrids (with different vegetation lengths, tolerance to water and nitrogen deficiency in the soil, and tolerance to high temperatures), sowing periods, and appropriate production technology (Carter *et al.*, 2016; Mastrodomenico *et al.*, 2018; Simon *et al.*, 2023).

The thousand-kernel weight plays a significant role in determining the maize grain yield, and understanding its basic genetic mechanisms is crucial for improving its overall performance (Božović *et al.*, 2022; Nowosad *et al.*, 2023). The results of the AMMI analysis show a highly significant influence of the interaction between genotype and environmental factors (GEI) on the thousand-kernel weight that varied between different environments. The results of our research align with those of Nowosad *et al.* (2023) who, in their ten-year experiment, identified significant effects of genotype, climatic conditions, and GEI on the thousand-kernel weight. Nowosad *et al.* (2023), examined 26 doubled-haploid maize lines and found that the highest variability (15.50%) in thousand-kernel weight was observed in the first year (2013) of conducting the study, while the lowest variability in thousand-kernel weight was observed in 2020 and 2022 (7.27% and 7.65%, respectively). Božović *et al.* (2022), during their two-year research (2017 and 2018) conducted at two localities, in Zemun Polje and Pančevo, Serbia, reported that the genotype accounted for the largest share of the total phenotypic variance for thousand-kernel weight (64.70%), while the share of year, locality, and treatment was 8.42% and the total interaction 26.88%. Mandić *et al.* (2024), during three consecutive growing seasons (2016–2018) in Serbia, Vojvodina Province, Srem region, found that the thousand-kernel weight ranged from 197.0 g (NS 5010 in 2017) to 402.9 g (ZP 500 in 2016) with an average of 288.8 g. The genotype ZP 500 had a higher thousand-kernel weight (306.0 g), compared to NS 5010 (260.3 g).

The yield of the tested maize genotypes from different FAO ripening groups in 2014 was highest in genotype NS 6030 (11.068 t ha⁻¹), sown in mid-April (II sowing period), while the lowest yield was found in genotype NS 4023 (8.991 t ha⁻¹), sown in early April. The highest average yield in 2015 was achieved by genotype NS 5051 (8.413 t ha⁻¹), sown in mid-April, while the lowest yield was achieved by hybrids NS 6030 (4.980 t ha⁻¹) and ZP 666 (5.306 t ha⁻¹), sown in late April. Over the two years of research, we observed that the average grain yield of the tested genotypes from different FAO ripening groups was highest when sown in mid-April, which is in agreement with the results obtained by Starčević and Latković (2006). Biberdžić *et al.* (2018b) found that the highest average maize yield of genotype ZP 555 (13.10 t ha⁻¹) was achieved when sown at the end of April, although it was not statistically significantly higher than the yield achieved when sown in mid-April. The same authors found that the highest average maize yield in 2016 was achieved by genotype ZP 666

(13.10 t ha⁻¹), sown in late April, and the lowest yield was recorded for hybrid NS 4023 (10.49 t ha⁻¹), sown in early April. In 2017, the hybrid ZP 555 (9.10 t ha⁻¹), sown in mid-April, achieved the highest average yield, while hybrid ZP 666 achieved the lowest yield as it was sown at the end of April (7.10 t ha⁻¹). Djalovic *et al.* (2022), examining different maize genotypes over a two-year study, reported that yields during 2011 ranged from 11.231 t ha⁻¹ (NS 4023) to 12.738 t ha⁻¹ (NS 6030), while yields during 2012 ranged from 7.620 t ha⁻¹ (NS 4023) to 8.317 t ha⁻¹ (NS 6030). The results of Mandić *et al.* (2024) showed that grain yield ranged from 5.4 t ha⁻¹ for genotype NS 5010 in 2017, to 15.9 t ha⁻¹ for genotype ZP 500 in 2016, with an average of 10.7 t ha⁻¹. The genotype ZP 500 had a higher grain yield (11.12 t ha⁻¹), compared to NS 5010 (10.36 t ha⁻¹). Grain yields differed between the genotypes ZP 500 and AS 534. The hybrids NS 5010 and AS 534 were not statistically different in the grain yield. Based on the results of numerous research and analyses of maize yield stability in the Republic of Serbia, genotypes from mid-early ripening groups demonstrated better adaptability to unfavorable conditions during the growing season, while genotypes from later ripening groups achieved higher yields and showed positive characteristics in more favorable production conditions (Stojaković *et al.*, 2015; Branković Radojičić *et al.*, 2017; Mitrović *et al.*, 2016; Biberdžić *et al.*, 2018a; Božović *et al.*, 2018), which is consistent with the results of our research.

Jagla *et al.* (2019) and Maitah *et al.* (2021) claim that the importance of production conditions, especially temperature and precipitation, play a significant role, stating that yield is negatively correlated with temperatures during July and August. Furthermore, Zhao *et al.* (2023) point out that the yield of early maize genotypes is lower than the yield of genotypes with a longer growing season, which represents a problem that needs to be solved to improve the yield of early genotypes. Barutçular *et al.* (2016) found that water stress in the grain-filling phase reduces grain yield. The negative impact of high temperatures and lack of precipitation on maize grain yield during the grain-filling phase in hybrids with a longer vegetation period was determined in the research of Buhiniček *et al.* (2021). Meteorological conditions affected the lower average yields of all genotypes, while high average yields were achieved in the years with more favorable climatic conditions, and this was determined in the research results of Shrestha *et al.* (2022) and Ljubičić *et al.* (2023), which is consistent with the results of our research.

The sowing period is one of the factors that significantly impacts maize yield. The optimal sowing period can be defined as the sowing time that ensures the emergence of maize at the most favorable moment, allowing the crop to make use of most of the growing season conditions and achieve the highest possible yield (Zhang *et al.*, 2019). The highest yield was achieved when maize was sown on April 15, taken as a reference value, while the yield was lower on other sowing dates in April. These facts unequivocally indicate that sowing maize in April, especially in the middle of the month, is the most favorable sowing period in Serbia. The results of a two-year study by Glamočlija and Ugrenović (2016) showed that the sowing periods have a very significant influence on the studied maize characteristics, which interact with weather conditions, especially the water regime, where the examined maize hybrids showed large variations. Babel *et al.* (2014) found that the impact of climate change on maize yield per unit area can be mitigated by supplemental irrigation and adjusting the sowing period, with expectations that sowing 16 days earlier would increase the yield by 17.9%. Our research results are consistent with the results of Starčević and Latković (2006), who found that in years with favorable weather conditions, differences in yields among April sowing periods, as well as those until May 5, are usually not significant. However, Starčević and Latković (2006) also point out that in dry years, the highest yields were achieved with earlier sowing periods, and yield reduction in May sowing was significant. The same authors point out that the highest grain yield in the first sowing period (early April) was achieved by the genotype NS 6010 from FAO group 600 (13.89 t ha⁻¹). In the second period (mid-April), hybrids NS 6010 (13.46 t ha⁻¹), NS 507 (13.62 t ha⁻¹) and NS 7016 (13.73 t ha⁻¹) achieved the highest grain yield. In the third (at the beginning of May), a significantly higher yield compared to the examined genotypes was achieved by hybrids NS 6010 (13.23 t ha⁻¹) and NS 507 (13.33 t ha⁻¹), while in the fourth (mid-May), genotype NS 507 achieved a

significantly higher yield (13.14 t ha⁻¹). The results of Walle *et al.* (2023) indicate that the reduction of maize yield in late sowing can be from 23.7 to 53.7%.

Yields of cultivated plants vary to some extent from year to year, depending on agro-meteorological conditions and soil type. By applying the mixed model in maize sowing and all investigated characteristics, a high significance of the effect of genotype, environment, and the interaction between genotype and the environment was determined. Genotype × year interaction is often the most significant factor affecting maize yield (Ona *et al.*, 2018). Mandić *et al.* (2024), revealed the interaction effects of year × genotype on thousand-grain weight and grain yield of maize. AMMI analysis showed a highly significant interaction effect of genotype and environmental factors (GEI) on grain yield that varied among different environments. The results of research by Ona *et al.* (2018), Yue *et al.* (2022), and Ljubičić *et al.* (2023) are consistent with our findings, where the influence of the interaction between genotype and environmental factors on grain yield was determined. A two-year study of four maize genotypes, done by Ljubičić *et al.* (2023), showed that the grain yield of the examined maize genotypes is greatly influenced by GEI. AMMI analysis showed significant effects of genotypes, years, and GEI on maize grain yield, plant height, and number of grains per row. All four genotypes reacted differently to climatic conditions during the two-year research. More favorable weather conditions during the first year of the research resulted in significantly higher mean values for the investigated characteristics. In contrast, a long dry period in combination with extremely high daily temperatures, especially in the generative phase, had an impact on yield reduction in the second year of research. By analyzing 18 maize hybrids at 74 locations during 2018 and 2019, Yue *et al.* (2022) determined that maize grain yield is influenced by genetic factors (G), environmental factors (E), and their interactions (GEI). During production, some maize genotypes can achieve stable yields, while others show variations in yield depending on agro-ecological conditions. Hybrids with a longer vegetation period achieved higher yields in years with more favorable climatic conditions than in years with higher temperatures and worse distribution of precipitation. In 2018, Božović *et al.* (2018) conducted a two-year study with seven maize genotypes at two different locations and four treatments, and they concluded that maize genotypes have different reactions in different locations, years, and treatments. The results of the AMMI analysis showed that there was a significant difference between the genotypes' responses to different environmental conditions for grain yield. Ona *et al.* (2018), pointed out that to increase the role of the non-additive effects, the next selection cycles should focus on the plant pairs with a more pronounced heterosis for yield potential.

Water content in physiological and technological maturity

The water content at physiological and technological maturity is an indicator of the complete accumulation of dry matter in the grain and marks the beginning of the maize harvest period. These indicators are conditioned by external factors, agricultural practices, and genetic predisposition of hybrids and significantly impact the final maize yield (Biberdžić *et al.*, 2018b). The highest grain water content at physiological maturity was found in the genotype NS 6030 ranging from 31.18% in 2015 to 35.32% in 2014. The lowest grain water content at physiological maturity was found in genotype ZP 434, which varied from 23.97% in 2015 to 31.48% in 2014. Svečnjak *et al.* (2012) point out that the water content at physiological maturity is not always a reliable indicator of the duration of the vegetation of certain hybrids, as there can be significant variations until harvest. Current knowledge and research results indicate that maize hybrids at the same maturity stage can vary significantly in terms of grain water content (Jukić, 2004), which was also noticed in the results of our research. Maize genotypes with lower grain moisture at harvest are becoming increasingly popular due to earlier harvest dates and lower drying costs. In research, Melut and Rosca (2016) state that hybrids that lose water from their grains more rapidly allow for earlier harvesting, while the faster water loss enables timely preparation of the soil for cereal sowing.

The average rate of grain water release during 2014 and 2015 varied depending on the genotype, sowing period, and year of research. In 2014, the highest average water loss from grains was achieved in hybrids ZP 434

and NS 4023 (0.37% per day), which were sown in early and mid-April. The lowest average water loss was recorded in hybrids ZP 666 and NS 6030 (0.27% per day), sown at the end of April. In 2015, the highest average water loss from grains was achieved with hybrid ZP 555 (0.49% per day), sown at the beginning of April, while the lowest was found in hybrid NS 6030, sown at both the beginning and end of April (0.35% per day), and in hybrid NS 4023 (0.35% per day), sown at the end of April. Biberdžić *et al.* (2018b) found that the highest percentage of water release from grains in 2016 was recorded in hybrid ZP 434 (0.53% per day), sown in early April, while in 2017, the highest percentage of water release from grains was recorded in hybrid NS 5051 (0.66% per day), sown at the beginning of April. Bearing in mind, that the years differed in climatic conditions, especially in precipitation and temperature, the rate of water release from the grain varied accordingly. Thus, the rate of grain water release in 2014 was 0.32% per day, when temperatures were 1.54°C lower and 208.2 mm less rain fell than in 2015, when the average rate of grain water release amounted to 0.40% per day. Our research shows that hybrids from the FAO ripening group 400 had a higher rate of grain water released per day (0.36%) in 2014, while the hybrids from the FAO ripening group 500 had a higher rate in 2015 (0.43%), compared to genotypes from the FAO group 600 (0.28% per day in 2014; 0.37% per day in 2015). The average rate of grain water release over the two-year study (2014 and 2015) depended on genotype, sowing period, and year of the study. Our research results are consistent with the results of other researchers (Biberdžić *et al.*, 2018b; Jagła *et al.*, 2019), who determined that water content in maize depends on both genotype and sowing period. Hellevang (2004) notes that the daily water loss in some seasons is less than 0.3% per day, while in more favorable thermal conditions, this loss can be as high as 1% per day. It can be noticed that the rate of grain water release is significantly influenced by the climatic conditions, sowing period, as well as the hybrid itself. Thus, hybrids with a rapid water release rate can remain green until the end of the growing season and have lower moisture content at the time of harvest (Arriola *et al.*, 2012). By examining the influence of different sowing periods and genotypes on maize grain yield, Videnović *et al.* (2011) observed that the highest average yield was achieved when sowing on April 15, and that the water content at harvest was higher in hybrids from later ripening groups. During their two-year research, Biberdžić *et al.* (2018b) found that maize genotypes from the same ripening group differed in terms of water content, both at physiological and technological maturity. In both research years, hybrids from earlier FAO ripening groups lost water faster than hybrids from later FAO ripening groups. Jagła *et al.* (2019) concluded that the total sums of atmospheric precipitation and average daily air temperature significantly influenced both maize yield and grain water content during harvest.

Correlations between the analyzed traits

Different climatic conditions during the two growing seasons influenced the established correlations between certain characteristics, which varied significantly throughout the research. The 2014 growing season was favorable for maize production, with consistent precipitation during key stages of maize development. In contrast, 2015 was dry, with limited and poorly distributed precipitation, particularly during the dry matter accumulation and ripening periods. Lana *et al.* (2014) demonstrated that the rate of grain water release, along with other factors, is largely influenced by air temperature, that is, the sum of thermal units, and our results are consistent with this as well. Based on the results of the correlation analysis shown in Table 15, it can be concluded that, for each year, there is a strong positive correlation between the number of grains, the absolute mass of grains, and grain yield. A positive correlation indicates that an increase in the number of grains, leads to an increase in both thousand-kernel weight and grain yield. Positive correlations between yield and yield components were observed by Wajid *et al.* (2007) and Nastasic *et al.* (2010). A strong genetic relationship between yield and thousand-kernel weight was determined by Rafiq *et al.* (2010), while Ahmad and Saleem (2003) noted a low genetic connection between yield and thousand-kernel weight. In contrast, negative correlations between yield and thousand-kernel weight were observed by Yosuf and Saleem (2001). Mandić *et al.* (2024), revealed that grain yield was statistically associated with grain weight per ear ($r=0.28^{**}$) and thousand-kernel weight ($r=0.48^{**}$), and that the number of grains per ear was correlated with grain weight per

ear ($r=0.63^{**}$), and thousand-kernel weight ($r=0.53^{**}$). In this study, a significant correlation between thousand-kernel weight and daily grain water loss was observed in the first and third sowing periods, while in the second sowing period, no significant correlation between grain yield and grain water release was noticed. The results of Zhang *et al.* (2019), showed that yield was correlated with the sowing date based on the thermal time before sowing ($r=0.62^{**}$), and that the yield was consistently maintained at a high level ($>10,500 \text{ t ha}^{-1}$) when the pre-thermal time exceeded $479 \text{ }^{\circ}\text{C}$. The percentage of grain water release is positively correlated with yield and it also depends on the FAO ripening group (Melut and Rosca, 2016).

Conclusions

According to the results of the two-year study, it can be concluded that the influence of agro-climatic conditions, temperatures, and amounts of precipitation during the investigated research period, as well as different sowing periods, had a significant impact on the phenotypic expression of the grain yield in the tested maize hybrids from different FAO ripening groups. Over the two-year research period, significant differences were observed, not only in terms of the total amount of precipitation during the growing season but also in the distribution of precipitation by month. The 2015 growing season was less favorable due to high temperatures and low rainfall throughout important stages of maize growth (vegetative growth, grain filling, and grain water release), resulting in a lower yield.

The highest number of grains per maize cob in 2014 was observed in the genotype NS 6030 (604.62) in 2014, and in the genotypes ZP555 (427.47) and NS 5051 (423.07) in 2015. The highest overall number of grains in 2014 was recorded in the second sowing period (578.72), while in 2015 it was achieved in both the first (416.90) and second sowing periods (414.25).

The average value of thousand-kernel weight was significantly higher in 2014 (380.00 g) compared to 2015 (312.78 g) for all tested maize genotypes. The genotype NS 6030 (407.82 g) in 2014, and genotype NS 5051 (385.72 g) in 2015, exhibited a significantly higher thousand-kernel weight compared to the other genotypes. The highest thousand-kernel weight was observed during the second sowing period in 2014 (398.17 g) and 2015 (343.63 g).

During the research, the average value of grain yield for all tested maize genotypes varied by year and was significantly higher in 2014 (10.010 t ha^{-1}) compared to 2015 (7.004 t ha^{-1}). The yield of maize grains differed significantly among all sowing dates, where the highest yield achieved was in the second sowing period in 2014 (10.570 t ha^{-1}) and 2015 (7.629 t ha^{-1}).

The highest average water loss from grains was observed in genotypes ZP 434 and NS 4023 (0.37% per day) when sown in early and mid-April 2014, while the highest average water loss in 2015 occurred in hybrid ZP 555 (0.49% per day) when sown in early April 2015. The rate of grain water release during the study was significantly higher in the first sowing period compared to the third sowing period.

The highest stability in the number of grains per maize cob and grain yield was observed in the genotypes ZP 555 and NS 5051, indicating greater tolerance of these genotypes from the FAO 500 ripening group to drought and high temperatures, which often occur during the critical stages of maize growth in our conditions. In terms of environmental conditions, the highest grain yield stability was recorded in 2014 across all three sowing periods, while the highest grain yield stability in 2015 was recorded in the first and second sowing period. These findings clearly indicate that sowing maize in April, particularly in the middle of the month, is the most favorable sowing period in the Jablanica district of the Republic of Serbia.

Considering that maize in the Jablanica district is primarily grown under dry farming conditions, ensuring stable production requires the sowing of drought-tolerant genotypes. These include ZP 555 and NS 5051 from FAO group 500, which are more resistant to drought and high temperatures, conditions that often occur during the critical stages of maize growth in this area.

Authors' Contributions

All authors have participated in this research. VR, VP and JS has designed and written the paper; Conceptualization, VR, JS, VP, MB and NĐ; methodology, VR, JS, VP, NĐ and MB; software, DT, VP and MMS; validation, VR, JS, VP and MMS; formal analysis, VR, JS, DT, KL and VP; writing-review and editing, KL, DT, MB, VP and MMS; visualization, NĐ, DT, MB, KL and VP; supervision, VR, DT, MB, VP and MMS; project administration, VP and NĐ. All authors have read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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