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Influence of year and soil type on the yield of different maize hybrids

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ABSTRACT

During the three-year field trials (2017, 2018 and 2019), 9 maize hybrids of different FAO maturity groups (400–600) were tested. The experiment was set up in three locations – three types of soil, in the Jablanica district, to recommend hybrids for the studied area based on the yield obtained, depending on soil type and the year of cultivation. During the three-year research, the hybrids achieved the highest average yields in 2018, when the amount and distribution of precipitation were most favourable, while the lowest average yield was obtained in 2017, when the amount of rainfall was insufficient during critical development stages. The highest average yields were produced on an alluvium soil, in the area of Leskovac (12.418 t ha^{-1}), and the lowest on parapodzol, in the village of Orašje (8.672 t ha^{-1}). The highest average grain yields in 2017, 2018 and 2019 were achieved by the hybrids ZP 560 (12.820 t ha^{-1}), ZP 606 (15.569 t ha^{-1}) and ZP 560 (14.863 t ha^{-1}), respectively. The higher yields in 2018 can be attributed to higher amounts and a more favourable distribution of precipitation during the growing season than under the agro-climatic conditions in 2017 and 2019.

Keywords: maize, FAO groups, climatic conditions, soil type, yield

ИЗВОД

Током трогодишњих пољских испитивања (2017, 2018. и 2019) тестирано је 9 хибрида кукуруза различитих ФАО група зрења (400–600). Огледи су постављени на три локалитета – три типа земљишта, на подручју Јабланичког округа, са циљем да се, на основу висине приноса, зависно од типа земљишта и године производње, препоруче хибриди за испитивано подручје. Током трогодишњег истраживања, хибриди су имали највеће просечне приносе у 2018. години, када су количине и распоред падавина биле најповољније, док је најмањи просечни принос остварен у 2017. години, када је количина падавина била недовољна у критичним фазама развоја кукуруза. Највећи просечни приноси остварени су на земљишту типа алувијум, на подручју Лесковца (12,418 t ha^{-1}), а најмањи на параподзолу, у атару села Орашје (8,672 t ha^{-1}). Највећи просечан принос зрна у 2017. години остварио је хибрид ЗП 560 (12,820 t ha^{-1}), у 2018. години хибрид ЗП 606 (15,569 t ha^{-1}), а у 2019. години хибрид ЗП 560 (14,863 t ha^{-1}). Већи приноси у 2018. години могу се приписати већим количинама и повољнијим распоредом падавина током вегетационог периода у поређењу са агроклиматским приликама током 2017. и 2019. године.

Кључне речи: кукуруз, ФАО групе, климатски улови, тип земљишта, принос

1. Introduction

Maize (*Zea mais* L.) is a versatile crop that thrives in a variety of agro-climatic environments (Singh et al., 2023; Kumar et al., 2023). Together with wheat and rice, it occupies the largest area of total agricultural production in the world. Since its domestication around 9,000 years ago, maize has played an increasingly important role in global agro-cultural and food systems (Erenstein et al., 2022). As the largest food crop in the world, high and stable maize yields are closely related to the security of sufficient food supply (Kang et al., 2017).

In 2023, maize was sown on 922,980 ha in the Republic of Serbia (SORS, 2023). Maize has undergone various phenotypic changes during the breeding process, resulting in the creation of hybrids with good agronomic traits (Popović et al., 2022). Despite maize yields, the good genetic potential for yield in different weather conditions varies significantly, and this is one of the reasons for the low utilization of maize fertility. In Serbia, increasing the yield of maize per unit area requires an increase in the genetic potential of the fertility of new hybrids, as well as an improvement in cultivation technology. In addition to higher genetic fertility potential, modern hybrids should also be characterized by greater tolerance to stressful production conditions (Živanović et al., 2019). Maize, unlike other crops, shows great diversity in terms of vegetation length; of all external factors, temperature has the greatest influence on vegetation length. The grain yield of maize hybrids largely depends on weather conditions during the growing season (Starčević and Latković, 2006). Precipitation and temperature are of great importance for maize cultivation. Maize is most sensitive to the lack of water in the soil during vegetative growth, flowering, fertilization and grain filling (Pejić et al., 2009). In areas with less rainfall, it is recommended to sow hybrids of FAO 300–500 maturity groups, i.e. hybrids with a longer vegetation period (Glamočlija, 2004). Hybrids with a shorter vegetation period flower earlier, and they can avoid the dry periods in June and August, which often occur under Serbian conditions. The rise in temperature and the lack of precipitation during July and August are the result of global warming, which can result in a decrease in maize yields. One of the central issues facing the world is the risk of significant climate change, which is an environmental problem in all sectors of the economy (Hong et al., 2019). Yu et al. (2013) announced that maize yields are projected to decrease by 0.4–11.9% by 2050. Studying the effects of climate factors and soil fertility on crop yields is important for assessing the impact of climate change on crop production (Wei et al., 2021). Soil water availability, temperature and soil composition can affect plant growth along with other factors that can affect crop development, such as soil pH and nutrient status (McMichael and Quisenberry, 1993).

Large fluctuations in yield are mainly the result of production in dry farming conditions; therefore, unfavourable weather conditions during the growing season very often cause a reduction in maize grain yield. Soil as an extremely dynamic environment is one of the most important elements of crop production and is the basic prerequisite for high and stable yields (Biberdžić et al., 2018). In addition to climate change, agronomic practices can also cause major changes in soil fertility (soil organic carbon, nutrient content, and pH value), which significantly affect land use productivity and land use responses to climate change (Wei et al., 2021). The large variations in yield are due to the amount and distribution of rainfall and other factors, such as soil fertility, reduced availability of nutrients, the water-air regime on the land, smaller plots and less commercially oriented and dominantly oriented production that depends on rainfall (Dugalić et al., 2024). Soil type (chernozem and cambisol) had a very significant effect on maize yield, which was greater than the effects of hybrids and fertilization (Živanović, 2012).

This study aimed at determining the yield of various maize hybrids (*Zea mays* L.) depending on the locality – soil type and climatic conditions.

2. Materials and methods

2.1. Experimental site, planting material and experimental design

For research purposes, the experiment involved 9 maize hybrids of different FAO ripening groups: FAO 400 (NS 4051, BC Pajdaš), FAO 500 (NS 5051, ZP 560) and FAO 600 (Blast, Delija, AS 6E02, ZP 606 and NS 6030). The research was conducted over three years: 2017, 2018 and 2019 at three locations, on three types of soil: location 1 – Leskovac (43°02'89.46" N, 21°95'63.10" E, 228 m a.s.l.), alluvial soil; location 2 – the village of Orašje (42°98'14.98" N, 22°11'73.65" E, 314 m a.s.l.), Vlasotince municipality, parapodzolic soil; and location 3 – the village of Kacabać (43°04'66.69" N, 21°76'71.29" E, 218 m a.s.l.), Bojnik municipality, vertisol.

Before starting the experiment, an agrochemical analysis of the soil was performed. Wheat was used as a pre-crop. After fertilization (300 kg ha^{-1} NPK (16:16:16)) and basic tillage during the autumn and winter periods, the seed-bed preparation of the soil was continued on the day of sowing, with a disc in two passes. The experiment was set up according to a randomized block design in 3 replications. Sowing was conducted in all three years, in the period 19–23 April, depending on weather conditions, with 4 rows of each hybrid sown at an inter-row distance of 70 cm x 21 cm (FAO 400 group), 70 cm x 25 cm (FAO 500) and 70 cm x 30 cm (FAO 600), to ensure optimal density for the hybrids. Top dressing was carried out at the 3–5 leaf stage with 300 kg ha^{-1} KAN (calcium ammonium nitrate). The herbicides Basar and Rezon were applied for the control of seed weeds immediately after maize sowing, whereas the herbicides Talisman and Scout were used to control broad-leaved and narrow-leaved weeds. The liquid complex fertilizer containing trace elements Foligal Super 3.0 l ha^{-1} was used for foliar feeding.

2.2. Climatic and soil characteristics

The Leskovac basin is one of the largest basins in Serbia, which differs from the climate of neighbouring regions. Good indicators of open-field crop production possibilities are the sum of active and effective temperatures and the length of the vegetation period. The municipality of Bojnik is located in the Pusta River basin and below Radan Mountain. The largest part of the relief of Bojnik municipality is mountainous, with 2/3 of the territory at an altitude of 400 to 1200 m (66% of the area), while 1/3 is flatland, highly suitable for agricultural production. The municipality of Vlasotince covers the area of the lower and middle basin of the Vlasina River, in southeastern Serbia. The upper part of the environment of the municipality of Vlasotince is predominantly hilly and mountainous, with peaks (10 peaks from 476 m to 1638 m). In the lower part of this area, the Vlasotina vineyard stretches. All three localities are located in the south of Serbia, in the Jablanički district, and are characterized by a temperate continental climate and an uneven distribution of precipitation by month (Figure 1).

The meteorological station in Leskovac was used to obtain data on average daily temperatures and precipitation (Figures 1 and 2). During the three-year research period, differences were observed in terms of the total amount of precipitation during the growing season, and in terms of the distribution of precipitation by month. The amount of precipitation during the growing season is very important for the successful production of maize. Figure 1 shows that 2018 was the most favourable year (April–September 363.3 mm), i.e. with a more even distribution of precipitation by month during the most significant period for the formation of maize yield June-August 244 mm, which led to the highest yield of all of the hybrids in 2018. The production year 2017 was characterized by the lowest rainfall (April–September 244 mm), but also had a very poor distribution during June, July and August, with only 73 mm of rainfall in these three months, which was 171 mm less than in 2018. In the last 25 years, grain yield has become increasingly dependent on weather conditions during the maize growing season, which have often involved "extreme climate events"

(Bekavac et al., 2010). Drought has become the main limiting factor of plant production in the world, which reduces yields in the developed world's agriculture as well (Đekić et al., 2019; Wang et al., 2024). In 2019, 323 mm fell in the period April–September and 157 mm in the period June–August, which ranks 2019 as a moderately favourable year for maize production.

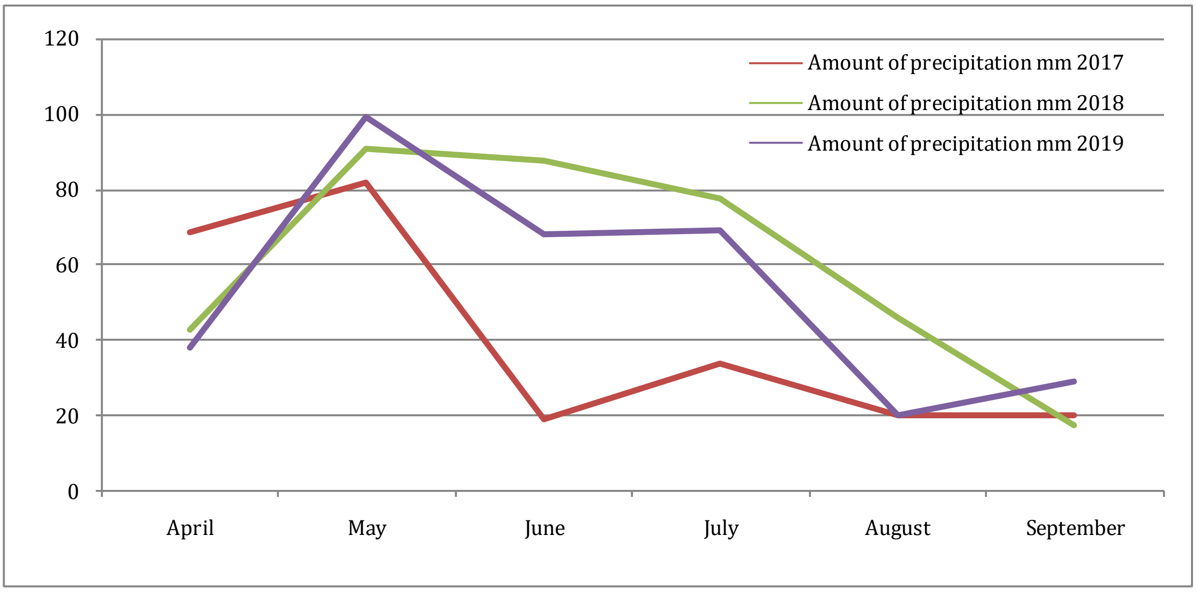

Figure 1. Precipitation distribution in the Jablanica district, Serbia (2017–2019)

During the three-year research, the highest average temperature in the growing season was recorded in 2018 (20.12°C), but the sufficient amount and good distribution of precipitation mitigated the negative effects of high temperatures (Figure 2). The year 2019 had the lowest measured temperatures during the three years (19.25°C), but during this year there was also less precipitation, especially during the period of June, July and August (87 mm less than in 2018 during these three months); therefore, 2019 was moderately favourable for maize production. The average measured temperature in the period April–September was 19.92°C, but this year was unfavourable for maize production due to the low amount and poor distribution of precipitation. Markulj et al. (2010), Paunović et al. (2011) and Wei et al. (2021) stated that the lack of precipitation combined with high air temperatures is considered a limiting factor for maize production. A constant decrease in precipitation in summer and a more frequent rise in temperature lead to more intense summer droughts. Drought is one of the most serious environmental stresses that cause significant damage to plants (Sheoran et al., 2022). Drought stress during silking and grain-filling phases can lead to yield losses of 50 and 21% (Liang et al., 2020).

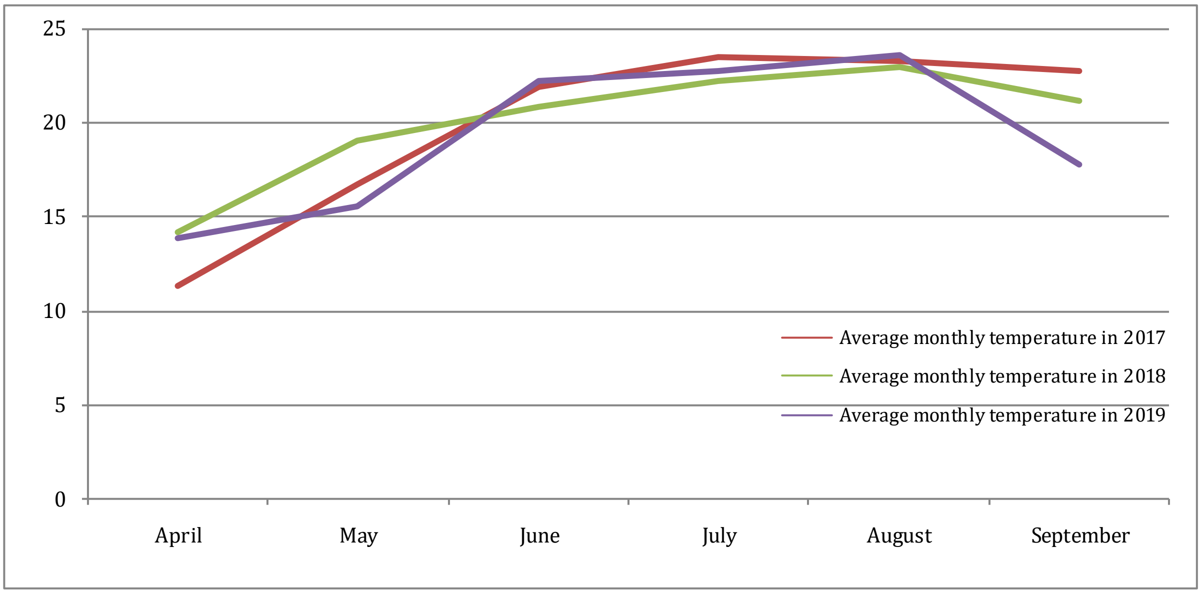

Figure 2. Average monthly temperatures in the Jablanica district, Serbia (2017–2019)

2.3. Soil analysis

The analysis of the soil from the sample plots (Table 1) was performed at the Agricultural Extension Service in Leskovac, in the Soil Fertility Testing Laboratory.

The soil acidity was determined by the Kapen method, the humus content by the Kotzman method and the total nitrogen content by the Kjeldahl method. Readily available phosphorus and potassium levels were determined by the Engner-Riehm Al method.

The measured values of pH in KCl in Table 1 show that alluvium (5.92) belongs to the group of moderately acidic soils, whereas parapodzol (4.95) and vertisol (4.74) are classified in the acidic soil group (Belić et al., 2014). According to the humus content of the sampled soil, all three soil types are poorly supplied with humus, while the content of total nitrogen from all plots is approximately the same value, which places them in the group of soils moderately supplied with nitrogen. The alluvial soil is optimally supplied with phosphorus (23.00 mg P_2O_5 per 100 g^{-1}), while parapodzol (10.80 mg P_2O_5 per 100 g^{-1}) and vertisol (9.78 mg P_2O_5 per 100 g^{-1}) have a low phosphorus content. Based on the soil analysis results, alluvium (34.50 mg K_2O per 100 g-1) and vertisol (30.00 mg K_2O per 100 g^{-1}) are classified as soils with a high potassium supply, while parapodzol (15.50 mg K_2O per 100 g^{-1}) is optimally supplied with this element.

Table 1.
Chemical properties of soil from experimental plots

Soil/Location	pH in KCl	Humus (%)	Nitrogen (%)	Phosphorus (mg 100 g^{-1})	Potassium (mg 100 g^{-1})
Alluvium/Leskovac	5.92	2.90	0.14	23.00	34.50
Parapodzol/Orašje	4.95	2.70	0.13	10.80	15.50
Vertisol/Kacabać	4.74	2.12	0.12	9.78	30.00

To preserve soil fertility, in the coming period, it is necessary to apply amelioration measures to all three types of land, because intensive exploitation of the land impoverishes it. During intensive use, soil fertility changes and mainly decreases due to the depletion of crop yield, plant nutrient losses, acidification, but also alkalization and reduction in organic matter content (Stevanović, 2012). Inappropriate application of mineral fertilizers, such as N-only fertilization and unbalanced fertilization can significantly affect soil structure and nutrient availability (Wang et al., 2019). The combination of organic and inorganic fertilizers has a significant effect on the physico-chemical properties of the soil and the yield parameters of maize (Singh et al., 2023).

2.4. Statistical analysis

Statistical data processing and analysis was performed using the GenStat (2013) programme for PC/Windows 7. In the paper, a three-factor analysis of variance (ANOVA) was used to test differences between groups.

3. Results and discussion

Insufficient yield stability across years and localities is one of the main factors that lead to a pronounced difference between the genetic yield potential and the realized grain yield of maize hybrids (Branković-Radojčić, 2016). The identification of high-yielding and stable genotypes is one of the main tasks in the breeding programme (Drašković et al., 2021). This is particularly pronounced in areas with less favourable agro-ecological conditions. In addition to the choice of hybrids, climate and applied agricultural techniques, the type and availability of readily available nutrients are the main factors for achieving high and stable maize yields.

The average values of maize yield during the three-year research (2017–2019) on three different types of soil (alluvium, parapodzol and vertisol) in the areas of Leskovac, Orašje and Kacabać are shown in Tables 2, 3 and 4.

During the three-year research, in the area of Leskovac (Table 2), depending on the hybrid, the maize grain yield ranged from 10.566 t ha^{-1} in 2017 to 14.067 t ha^{-1} in 2018. All examined hybrids achieved the highest average yields in 2018. The hybrids ZP 560 and ZP 606 had the highest average yield during the three-year research. The hybrid Delia in 2017, Blast in 2018 and the medium-late hybrid AS 6E02 in 2019 had the lowest average yields during the research.

As shown by the data in Table 3 on the average yield during the three-year research, the yields ranged from 6.185 t ha^{-1} in 2017 to 10.931 t ha^{-1} in 2018. In 2017, the hybrids NS 4051 of the FAO 400 maturity group and ZP 560 of the FAO 500 group achieved the highest yield of maize grain, while the FAO 600 hybrids (AS 6E02, ZP 606 and NS 6030) gave the lowest yields. In 2018, the hybrids ZP 606 and NS 6030 of the FAO 600 ripening group achieved the highest yield (12.227 t ha^{-1}; 12.125 t ha^{-1}, respectively), and the lowest yield was obtained by BC Pajdaš of the FAO 400 ripening group (9.120 t ha^{-1}). In 2018, all hybrids achieved higher yields than in 2017 and 2019. In 2019, ZP 560 of the FAO 500 group achieved the highest grain yield, followed by the FAO 600 hybrids (ZP 606 and NS 6030), while the lowest yields were recorded for the medium-sized hybrids AS 6E02, Blast and Delia of the same maturity group.

Table 2.
Average values of maize yield in the area of Leskovac

Genotypes	2017			2018			2019		
	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$
NS 4051	9.850	0.250	0.144	13.832	0.166	0.096	11.680	0.085	0.049
BC Pajdaš	9.205	0.314	0.181	14.509	0.193	0.111	13.147	0.411	0.237
NS 5051	11.270	0.352	0.203	14.002	0.135	0.078	12.410	0.090	0.052
ZP 560	12.820	0.291	0.168	15.164	0.165	0.095	14.863	0.330	0.191
Blast	11.320	0.275	0.159	12.430	0.134	0.077	11.920	0.205	0.118
Delija	7.670	0.230	0.133	12.515	0.184	0.106	11.232	0.173	0.100
AS 6E02	11.121	0.347	0.200	14.409	0.169	0.098	10.350	0.132	0.076
ZP 606	11.390	0.280	0.162	15.569	0.226	0.130	14.027	0.155	0.090
NS 6030	10.450	0.156	0.090	14.174	0.311	0.180	13.950	0.108	0.062
Average	10.566	1.456	0.280	14.067	1.028	0.198	12.620	1.434	0.276

Table 3.
Average values of maize yield in the area of Orašje

Genotypes	2017			2018			2019		
	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$
NS 4051	7.230	0.325	0.188	10.060	0.230	0.133	8.985	0.316	0.183
BC Pajdaš	6.725	0.367	0.212	9.120	0.267	0.154	8.422	0.210	0.121
NS 5051	6.589	0.121	0.070	11.047	0.227	0.131	9.619	0.256	0.148
ZP 560	7.050	0.248	0.143	11.518	0.185	0.107	10.150	0.243	0.140
Blast	6.250	0.277	0.160	10.180	0.120	0.069	7.824	0.691	0.399
Delija	5.950	0.252	0.145	11.250	0.244	0.141	7.950	0.569	0.328
AS 6E02	5.210	0.406	0.234	10.850	0.170	0.098	7.537	0.404	0.233
ZP 606	5.105	0.506	0.292	12.227	0.330	0.190	9.763	0.243	0.140
NS 6030	5.556	0.369	0.213	12.125	0.391	0.226	9.850	0.129	0.075
Average	6.185	0.780	0.154	10.931	0.994	0.191	8.900	1.005	0.193

During the three-year study, at the Kacabać location, depending on the hybrid, the yield ranged from 5.556 t ha^{-1} in 2017 to 12.023 t ha^{-1} in 2018 (Table 4). All maize hybrids achieved the highest average yields in the production year 2018. The hybrids NS 5051 and ZP 560 of the FAO 500 maturity group had the highest average yield in 2017, and ZP 606 and NS 6030 of the FAO 600 group had the lowest yield in the same year. Among the FAO 600 hybrids, ZP 606 and NS 6030 had the highest average yield in 2018; the lowest yield in this year was obtained by NS 4051 and BC Pajdaš of the FAO 400 group. In 2019, the highest yield of maize grains was achieved by Delia of the FAO 600 maturity group, and the lowest by NS 4051 and BC Pajdaš of the FAO 400 maturity group.

Table 4.
Average values of maize yield in the area of Kacabać

Genotypes	2017			2018			2019		
	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$
NS 4051	5.850	0.266	0.154	10.950	0.255	0.147	8.435	0.097	0.056
BC Pajdaš	5.460	0.380	0.219	10.471	0.241	0.139	7.750	0.243	0.140
NS 5051	6.231	0.354	0.204	11.780	0.276	0.159	10.280	0.110	0.064
ZP 560	6.783	0.502	0.290	12.350	0.305	0.176	10.590	0.148	0.086
Blast	5.273	0.289	0.167	11.490	0.243	0.140	8.910	0.196	0.113
Delija	5.100	0.244	0.141	12.990	0.386	0.223	11.050	0.161	0.093
AS 6E02	5.396	0.346	0.200	12.305	0.363	0.210	8.863	0.346	0.200
ZP 606	5.010	0.345	0.199	13.050	0.292	0.169	10.520	0.126	0.073
NS 6030	4.904	0.392	0.226	12.820	0.242	0.140	10.350	0.188	0.109
Average	5.556	0.666	0.128	12.023	0.913	0.176	9.639	1.125	0.216

During the three-year research, the highest average yields were achieved by the hybrids in 2018, when the amount and timing of precipitation were the most favourable, while the lowest average yield was obtained in 2017, when the amount of rainfall was insufficient during the critical stages of development. Similar results were reported by Madić et al. (2021) in their analysis of the grain yields of maize hybrids in 2018, which was characterized by more favourable agrometeorological conditions than the previous year, especially in terms of precipitation and temperature during the summer (June, July and August). The same authors noted that almost all hybrids had two to three times higher yields than in 2017. Also, Petrović et al. (2020) analysed certain climatic conditions and maize yield in three different locations in the period 1991–2011. The low amount of precipitation and high maximum temperature values in the growing season resulted in yield reductions. The influence of climatic conditions, especially temperature and precipitation, is also evidenced by the data of Živić et al. (2016), Maitaha et al. (2021) and Stojiljković et al. (2023), who found that yield was negatively correlated with temperatures in July and August, and positively correlated with precipitation in the same period.

The average yields per FAO ripening group differed depending on the study year. The more favourable the production conditions, the higher the yields of the later ripening groups; while in years with worse climatic conditions, the yields of the later FAO ripening groups were lower. There are significant differences in yield between the hybrids of different FAO ripening groups; the hybrids of longer maturing FAO groups have significantly higher yields than those with a shorter growing season. This is supported by the results of Videnović et al. (2013), who reported higher yields in hybrids from higher FAO ripening groups in favourable years.

Table 5 shows the yield of maize hybrids during the three-year research depending on the type of soil – the location of the experimental plot. The highest yields during the three-year research were achieved on the alluvium, in the area of Leskovac (12.418 t ha^{-1}), and the lowest on parapodzol, in the village of Orašje (8.672 t ha^{-1}). The hybrid ZP 560 achieved the highest average yield in all localities. Bekavac (2012) emphasized the high requirements of maize for land, given that maize is a highly productive plant species. One of the most important factors for the normal physiological processes of the plant in all its stages of growth and development is the provision of mineral nutrients (Kozhukhov et al., 2020). Differences in the yield of maize grains can be the result of the chemical properties of the soil and the different availability of certain elements. Based on laboratory research, it was determined that loamy and parapodzol soils have acidic reactions and low phosphorus contents, in contrast to alluvium, which is well supplied with phosphorus. Differences in yield can be caused by other agroclimatic factors important for yield formation. In addition, the locations where the tested soil types were located are at different altitudes (Biberdžić et al., 2018), which is consistent with the results of our research.

Table 5.
Average yield values of different maize genotypes by locality during the three-year research

Genotypes	Leskovac			Orašje			Kacabać		
	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$	$\bar{x}$	Sd	$S_{\bar{x}}$
NS 4051	11.787	1.733	0.578	8.758	1.263	0.421	8.412	2.217	0.739
BC Pajdaš	12.287	2.401	0.800	8.089	1.096	0.365	7.894	2.187	0.729
NS 5051	12.561	1.204	0.401	9.085	1.980	0.660	9.430	2.497	0.832
ZP 560	14.282	1.129	0.376	9.573	1.992	0.664	9.908	2.483	0.828
Blast	11.890	0.515	0.172	8.085	1.754	0.585	8.558	2.713	0.904
Delija	10.472	2.181	0.727	8.383	2.342	0.781	9.713	3.569	1.190
AS 6E02	11.960	1.878	0.626	7.866	2.473	0.824	8.855	3.007	1.002
ZP 606	13.662	1.841	0.614	9.032	3.149	1.050	9.527	3.568	1.189
NS 6030	12.858	1.818	0.606	9.177	2.902	0.967	9.358	3.516	1.172
Average	12.418	1.947	0.216	8.672	2.164	0.240	9.073	2.836	0.315

At all three locations during the three-year study (Table 6), the highest average maize yields per hybrid were achieved by NS 5051 and ZP 560 of the FAO 500 maturity group (10.359 t ha-1 and 11.254 t ha-1, respectively) and ZP 606 and NS 6030 of the FAO 600 group (10.740 t ha-1 and 10.464 t ha-1, respectively). The lowest yields were produced by NS 4051 and BC Pajdaš of the FAO 400 group (9.652 t ha-1 and 9.423 t ha-1, respectively) and the FAO 600 hybrids (Blast, Delija and AS 6E02).

During the three-year research, the hybrid ZP 560 of the FAO 500 maturity group achieved the highest average yield (11.254 t ha^{-1}), and this was the case on all three soil types, whereas the lowest yield was achieved by BC Pajdaš of the FAO 400 maturity group (9.423 t ha^{-1}). These results are consistent with those of a two-year study by Biberdžić et al. (2018), who found that the highest average yields for all soil types were achieved by growing FAO 500 hybrids and the lowest by FAO 400 hybrids.

Based on the results of the field research and the analysis of maize yield stability in the Republic of Serbia, medium early hybrids show better adaptability to unfavourable conditions during the growing season, while hybrids of later ripening groups achieve higher yields and show positive characteristics in more favourable production conditions (Branković-Radojičić, 2016; Ikanović et al., 2018; Božović et al., 2020; Grčak et al., 2020; Nikolić et al., 2022).

Table 6.
Average values of grain yield by maize hybrids at all three locations during the three-year research

Genotypes	$\overline{X}$	Sd	$S_{\overline{x}}$
NS 4051	9.652	2.305	0.444
BC Pajdaš	9.423	2.807	0.540
NS 5051	10.359	2.471	0.476
ZP 560	11.254	2.879	0.554
Blast	9.511	2.504	0.482
Delija	9.523	2.801	0.539
AS 6E02	9.560	2.985	0.574
ZP 606	10.740	3.534	0.680
NS 6030	10.464	3.224	0.620
Average	10.054	2.880	0.185

Among the examined maize genotypes, during the three-year research, a high statistical significance of the effect of year on grain yield was found (Table 7). The evaluation of the significance of the tested maize hybrids during the three-year research showed a high statistical significance of the influence of the location, year x location interaction, and year x genotype x location interaction on maize grain yield. Among the tested maize genotypes during the three-year study, no statistical significance of the influence of the genotype was established. Based on the analysis of variance, it can be observed that the interactions year x genotype and genotype x locality did not show a statistically significant effect on the maize grain yield.

The influence of climatic conditions on maize yield has been confirmed by many studies that show that meteorological conditions have a great effect on yield stability, especially the amount and distribution of precipitation during the vegetation period of plants (Kresović, 2003; Branković-Radojičić, 2016; Ikanović et al., 2018; Božović et al., 2020, Biberdzic et al., 2018; Madić et al., 2021; Stojiljković et al., 2023). Our results are in agreement with the results of Heijden et al. (1998), Drašković et al. (2021) and Ljubičić et al. (2023), which indicated that crop yield can be significantly influenced not only by the choice of hybrids and climatic factors, but also by soil fertility and agronomic practices, as well as by the interaction of the examined factors.

Stojaković et al. (2010) tested the yield of maize grains from 15 hybrids at 10 locations in Serbia and found a deviation in the yield of hybrids depending on the location and year. Newer maize hybrids have a genetic potential of 15 to 20 t ha^{-1}. In the production conditions, the achieved yields are on average 6.5 t ha^{-1} of maize grains in average years. Under the most favourable conditions, yields range up to 8.0 t ha^{-1}, which indicates that only 25–30% of the genetic fertility potential is used (Filipović et al., 2015). Crop yield can be significantly affected not only by climatic factors but also by other factors, such as soil fertility and agronomic practices, as well as by the interactions of factors (Heijden et al., 1998).

Table 7.
Analysis of variance of the grain yield (ANOVA)

Effect of	df	Mean sqr Effect	Mean sqr Error	F	*p*-level
Year, Y	2. 240	493.775	4.2470	116.264**	0.000
Genotype, G	8. 234	11.991	8.166	1.468	0.170
Locations, L	2. 240	342.639	5.506	62.225**	0.000
Year x Genotype, YxG	16. 216	3.931	3.984	0.987	0.472
Year x Locations, YxL	4. 234	15.802	1.157	13.654**	0.000
Genotype x Locations, GxL	16. 216	3.219	5.436	0.592	0.888
Year x Genotype x Locations, YxGxL	32. 162	1.476	0.082	18.064**	0.000

*Statistically significant (P<0.05); **Statistically highly significant (P<0.01)

4. Conclusions

The yields of maize hybrids of different FAO maturity groups were found to be highly influenced by climatic conditions and soil type during the three-year research. The highest average yields of all tested hybrids were achieved in 2018, and they can be attributed to higher amounts and more favourable distribution of precipitation during the 2018 growing season than under the agroclimatic conditions in 2017 and 2019. The lowest average yields of all tested maize hybrids were obtained in 2017, which was the year with the lowest amount of precipitation, especially during the June–August period.

The best yields during the three-year research were achieved on alluvial soil in the area of Leskovac, and the lowest on parapodzol in the location of the village of Orašje, Vlasotince municipality. The resulting differences in yield are the result of the chemical properties of the soil and the different availability of certain elements, as well as of other agroclimatic factors important for yield formation.

The highest yield during the three-year research was achieved by the hybrid ZP 560 of the FAO 500 maturity group. This hybrid showed the best adaptability, and this was the case in all locations – soil types. In FAO 400 and 500 hybrids, smaller variations in yield were observed in the years with less favourable climatic conditions than in FAO 600 hybrids.

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Declaration of competing interests

The authors declare that they have no conflict of interest.

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