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GRAIN YIELD OF MAIZE HYBRIDS IN DIFFERENT LOCATIONS IN CENTRAL SERBIA

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Abstract: Field trials with 11 maize hybrids (9 newly released and two standards) of the FAO maturity groups 300-600 were sown in four locations. The aim of the work was to recommend hybrids for individual location based on their reaction to different agroecological conditions, as well as to evaluate the possibility of replacing later hybrids with hybrids of earlier maturity groups, with certain changes in agrotechnics. ZP hybrids of the latest generation showed high grain yield potential and stability, as well as wide adaptability to different ecological conditions, degree of soil fertility and application of agrotechnical measures. A significantly higher grain yield of all hybrids compared to other locations was at the Valjevo location, that is, the location with the highest amount and favorable distribution of precipitation during the growing season. In these trials, maize hybrids of different FAO maturity groups were grown with the same number of plants per unit area. For maize hybrids with shorter vegetation, which are characterized by a lower plant height, a greater number of plants per unit area is recommended, compared to hybrids with a longer growing season. With changes in agrotechnics in this direction, along with the advantages of earlier hybrids, which are seen in avoiding critical periods for water, the grain yield of earliy hybrids could reach the yield level of later hybrids.

Keywords: maize, hybrid, grain yield, location

Introduction

World crop production increased by 52% between 2000 and 2020 (FAOSTAT 2021). Cereals were the main group of crops, where corn production grew three times faster than wheat, so in terms of total production, corn became the second crop in the world (Grčak et al. 2020). The increase in production can mainly be attributed to the cultivation of high-yielding varieties, i.e. hybrids, as well as the increase in the use of fertilizers, pesticides, irrigation and, to a lesser

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extent, the increase in arable land. In 2022, the average grain yield of maize in the Republic of Serbia was about 4.8 t ha^{-1}, which led to a decrease in total maize production by 3.3 million tons compared to 2020. In the last 25 years, the grain yield of maize depends more on meteorological conditions during the growing season, which is often characterized by the occurrence of "extreme climatic events" (Bekavac et al., 2010, Pavlov et al., 2011). The most important factors recently leading to the reduction and variability of yields in most regions are the increase in temperature and uneven distribution of precipitation, especially in critical periods of maize growth (Kovačević et al., 2010; Stojaković et al., 2010; Arunkumar et al., 2020; Madić et al., 2021). The high potential for grain yield of maize hybrid is best manifested in conditions when the plants are supplied with 550-700 mm of water precipitation during the growing season (Filipović et al., 2015). One of the ways to achieve a compromise, and satisfy the interests of both producers and breeders, is to divide the cultivation area of a crop in the region based on the geographical, climatic and soil conditions that characterize them, and recommend hybrids for each region (Babić et al., 2013). In the Republic of Serbia, a large number of maize hybrids have been created and relaised so far, and it is necessary to set up trials every year in a large number of locations, with the aim of informing the producers to the newly selected hybrids, and to check the new hybrids in different agroecological conditions.

Taking into account the frequent reaction of hybrids to changing agroecological conditions, four locations were selected for these experiments. The aim of this research was to select the most suitable hybrids for a specific location, based on their reaction to the agroecological conditions of the location. In addition, the grain yield of hybrids of different maturity groups would indicate the possibility of replacing hybrids with longer vegetation with earlier hybrids, with an increase in the number of plants per unit area. By choosing such hybrids, the consequences of climate change would be mitigated, that is, the influence of high temperatures and drought in critical periods of maize growth would be avoided.

Materials and methods

Nine perspective SC hybrids of maize FAO maturity groups 300-600 (ZP 341, ZP 427, ZP 443, ZP 548, ZP 555, ZP 560, ZP 600, ZP 606, ZP 666) and two standards (ZP 434 and ZP 677) were selected for this experiment.The experiment was set up in 2018 at four locations, on soil of different production characteristic: Divci (Valjevo, 44017'58'' N, 20001'02''N, 148 m a.s.l., alluvium soil), Lađevci (Kraljevo 43091'05'' N, 20035'12'' N, 209 m a.s.l., smonica soil), Topola (44015'27'' N, 20048'28'' S, 140 m a.s.l., alluvial soil), Aleksandrovac (Smederevska Palanka 44027'06'' N, 21011'51'' S, 85 m a.s.l., valley-meadow land). In the first part of April, 8 rows of each hybrid on a 200 m length were sown in all locations. Sowing was done at a between-row distance of 0.7 m, and a within-row distance of 0.25 m, so that all hybrids were grown at a density of 51,143 plants per hectare. During the growing season, the usual production technology was applied along with basic cultivation: 20 t ha^{-1} of manure was added to the soil; in pre-sowing preparation 400 kg NPK ha^{-1} (16 : 16 : 16) and in phase 5-6 leaves 250 kg ha^{-1} KAN. As part of the protection measures, herbicides were used to control weeds: Mont 0.75 5 l ha^{-1} + Terbis 0.5 l ha^{-1}. In all locations crops were not irrigated. At maturity, the yield of cobs from 100 plants from 4 inner rows was measured from each plot, on the parts where sprouting was uniform and converted to grain yield t ha^{-1} with 14% moisture. The obtained data were processed by the two-factor analysis of variance (hybrid, location) without repetition, with a preliminary check of additivity (absence of interaction between factors) by Tukey's test (Tukey, 1949). For factors for which the F test was statistically significant, a comparison of individual values were performed using the LSD test.

Weather conditions

Average annual air temperatures in 2018 did not differ much by location (Table 1). However, if comparing individual months, some differences can be noticed. Thus, the locations of Valjevo and Kraljevo had slightly warmer February and March, compared to the locations of Topola and S. Palanka, which had a warmer May compared to the other locations. In June, July and September, similar mean monthly temperatures were measured in all locations, but the Topola location had a slightly lower temperature compared to the other locations. The highest mean monthly temperatures in all locations were recorded in August when the precipitation deficit was also pronounced. There was a similar trend in the amount of precipitation in all locations, except in the area of Topola, where a slight increase in the amount of precipitation was recorded in July compared to June (Table 1), while in other locations a decrease in the monthly amount of precipitation in June compared to July was observed.

Observing the sums of precipitation in the period of intensive maize growth (May, June and July), it can be seen that it was higher in the locations of Valjevo and Kraljevo compared to the locations of Topola and S. Palanka (Table 1). In all locations, the most rainfall during the growing season was in May, and the least in August. The amount of precipitation in May was 140.4 mm in the Valjevo, which is 18 mm more compared to the Kraljevo, i.e. 38.1 mm more compared to the S. Palanka, while the Topola location recorded two times less rainfall (70.9 mm).

Table 1. Mean monthly temperatures (T°C) and precipitation (mm) in 2018

Monthly	Valjevo		Kraljevo		Topola		S. Palanka	
	T°C	mm	T°C	mm	T°C	mm	T°C	mm
IV	13.7	25	13.7	69.9	13.3	41.2	13.3	36.7
V	17.6	144	17.8	122.4	18.	70.9	18.0	102.3
VI	20.5	63.9	19.0	90.1	19.9	56.5	20.0	78.3
VII	22.6	42.7	22.2	23.2	21.6	60.6	22.2	7.4
VIII	23.7	28	23.8	23.0	23.1	50.1	24.0	31
IX	16.4	54.7	16.2	48.6	16.1	49.6	15.9	52.1
Average/ Sum	19.1	343	18.9	377.2	18.7	328.9	18.9	307.8

Results and discussion

The latest generation of maize hybrids have the potential for grain yield of 15 to 20 t ha^{-1}. However, the realized grain yields in our conditions are around 6.5 t ha^{-1} in average years, i.e. in the most productive years up to 8.0 t ha^{-1}, which indicates that only 25-30% of the grain yield potential is realized (Filipović et al. 2015). Starčević et al. (1991) stated that in years with favorable weather conditions, the difference in grain yield is greater in favor of hybrids with a longer vegetation period (from 18 to 26%), in less favorable years, the yields are even, while in unfavorable years, early hybrids had a higher grain yield (up to 7%) compared to mid-early and mid-late hybrids. The yield and water content in the grain were significantly dependent on weather conditions in the growing season (Jagła et al. 2019). Considering the amount and distribution of rainfall in 2018, it can be seen that it was relatively favorable for corn production. Observed as a whole, the grain yield ranged from 5.91 t ha^{-1} for hybrid ZP 443 at the S. Palanka location to 10.37 t ha^{-1} for hybrid ZP 600 at the Valjevo location (Table 2). At the Valjevo location, all hybrids had a significantly higher grain yield and a higher grain water content compared to the other locations. The lowest grain yield, on average for all hybrids, was at the Kraljevo location, while the lowest water content in the grain was at the S. Palanlka. The hybrids ZP 600, ZP 548 and ZP 560 had a grain yield of over 10 t ha^{-1}, while the hybrid ZP 443 had the lowest yield, unexpectedly low at the S. Palanka location, which is the most likely the result of some uncontrollable factor. The ZP 666 achieved the highest grain yield at the S. Palanka which, compared to other locations, was characterized by the lowest amount of precipitation during the growing season.

Table 2. Grain yield (t ha^{-1}) and grain moisture (%) of maize hybrids in four locations

	Locations							
Hybrids	Valjevo		Kraljevo		Topola		S. Palanka	
	Grain yield	Grain moisture	Grain yield	Grain moisture	Grain yield	Grain moisture	Grain yield	Grain moisture
ZP 341	9.25	17.60	6.85	16.00	7.82	15.10	6.47	12.30
ZP 427	8.34	17.60	6.32	17.40	7.49	13.50	6.96	12.60
ZP 443	9.06	18.30	7.29	17.00	8.54	13.60	5.91	13.10
ZP 548	10.03	18.10	7.39	17.00	8.52	13.40	7.07	13.70
ZP 555	8.71	19.70	6.57	17.60	8.09	16.80	7.28	14.10
ZP 560	10.01	19.70	6.87	18.60	7.49	17.50	7.55	13.90
ZP 600	10.37	19.50	7.04	18.00	7.79	16.40	8.02	14.70
ZP 606	9.60	19.30	7.19	17.00	7.75	15.90	8.81	15.60
ZP 666	8.53	19.70	6.94	17.80	6.88	15.20	9.23	15.30
St 1	10.29	16.40	8.02	16.00	6.84	14.30	7.46	13.20
St 2	9.51	18.40	7.03	15.80	5.94	13.60	6.88	14.20
Average	9.43	18.57	7.05	17.11	7.56	15.03	7.42	13.88

Two standard hybrids for grain production (ZP 434 and ZP 677) were also included in the experiment. Both standards had a higher yield at the Valjevo location, while the lowest yield was recorded at the S. Palanka. In years with a small amount of precipitation, hybrids with a shorter growing season had a higher average grain yield, while in years with average and above-average rainfall, higher yields were achieved with hybrids with a longer growing season (Branković - Radojčić et al. 2017). Changes in the environment affect the growth and yield grain due to significant genotype × environment interactions (GEI) (Changizi et al., 2014; Djurović et al., 2014; Stojaković et al., 2015; Madić et al., 2022). The obtained results indicate that the amount and distribution of precipitation, as well as average daily temperatures, greatly influenced grain yield and grain water content, which is in agreement with the results of Petrovic et al. (2023). Analysis of the variance of grain yield indicates the existence of significant differences between locations, while differences between hybrids within locations were not significant (Table 2). On the other hand, in their research, Faria et al. (2017), Arunkumar et al. (2020) and Madić et al. (2022)

pointed out significant differences among environments, hybrids, and their interactions. Hybrid ZP 606 achieved the highest grain yield, on average for all locations(8.34 t ha^{-1}), while hybrid ZP 427 had the lowest yield (7.28 t ha^{-1}). Observing the results of ZP hybrids by FAO maturity groups, it can be seen that the highest average yields were achieved by mid-late hybrids (FAO 600), where ZP 606 (8.34 t ha^{-1}) and ZP 600 (8.31 t ha^{-1}) hybrids stand out. In the group of mid-late hybrids (FAO 500), the highest yield was recorded in hybrid ZP 548 (8.25 t ha^{-1}). It should be also pointed out that the mid-early hybrids (FAO 300-400), especially ZP 443 (7.70 t ha^{-1}) and ZP 341 (7.60 t ha^{-1}), which are not behind the previous ones in terms of grain yield. This indicates their good adaptability to different agroecological conditions.

Table 3. Mean grain yield and grain moisture in maize hybrids

		Grain yield (t ha^{-1})	Grain moisture (%)
Hybrids	ZP 341	7.60	15.25 b
	ZP 427	7.28	15.27 b
	ZP 443	7.70	15.50 b
	ZP 548	8.25	15.55 b
	ZP 555	7.66	17.05 a
	ZP 560	7.98	17.42 a
	ZP 600	8.31	17.15 a
	ZP 606	8.34	16.95 a
	ZP 666	7.90	17.00 a
	Standrad 1	8.15	14.97 b
	Standard 2	7.34	15.50 b
Location	Valjevo	9.43 a	18.57 a
	Kraljevo	7.05 b	17.10 b
	Topola	7.56 b	15.02 c
	S. Palanka	7.42 b	13.88 d

Column values marked with different lowercase letters are significantly different ($P<0.05$) according to the LSD test.

Based on the analysis of the results of a macro-trials with 15 maize hybrids at 30 different locations on the territory of Serbia, Stojaković et al. (2010) state that the hybrids from the FAO maturity groups 500 and 600 had a higher yield and lower water content in the grain compared to the hybrids FAO 700, which leads to the conclusion that in Central Serbia the sum the temperatures is a determining factor in the choice of hybrids. The consequences of stress caused by unfavorable weather conditions could be mitigated by growing hybrids more resistant to drought and introducing minor changes in agrotechnics

(Kovačević et al. 2010). The results of these studies indicate a significant impact of climate change on the grain yield of maize, which points to the necessity of changes in agrotechnical, as well as the creation of maize hybrids with greater adaptability, especially to the stress caused by high temperatures and water deficit. Filipović et al. (2015) state that trends in modern maize breeding in the world lead to the creation of hybrids of modern architecture, i.e. plants with a lower habitus, upright position of the upper leaves, cobs with a larger number of grain rows, a smaller number of grains in a row, as well as the ability to quickly release water from the grain during the period of maturity.

Conclusion

ZP hybrids of the latest generation showed high grain yield potential and yield stability, i.e. wide adaptability to different environmental conditions, soil fertility level and applied agrotechnical measures. The significantly higher grain yield at the Valjevo location compared to the other locations, can be explained by the greater amount and more favorable distribution of precipitation during the growing season. In these trials, maize hybrids of different FAO maturity groups were grown with the same number of plants per unit area. For maize hybrids with a shorter growing season, which are characterized by a smaller habitus, a greater number of plants per unit area is recommended compared to later hybrids. By changing agrotechnics in this direction, with the advantages reflected in avoiding critical periods for water, the grain yield of hybrids with a shorter growing season could reach the yield level of later hybrids.

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