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GRAIN YIELD AND YIELD STABILITY OF ZP MAIZE HYBRIDS IN DROUGHT CONDITIONS IN SERBIA

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Abstract

Selection of maize hybrids in Maize Research Institute “Zemun Polje”(ZP) exists for over 60 years. In this study 12 ZP hybrids from different maturity groups from FAO 300-600 and two foreign hybrids as checks were tested. Macro experiments were set up at 18 locations throughout Serbia during 2012. The past 2012th year was extremely unfavorable for corn production. Besides significant lack of rainfall, grain yield was reduced and affected by the extreme heat during pollination and grain filling period of maize. The average yield on the 18 selected sites was 5.87 t/ha. The highest yield was obtained by ZP 505 (6.39 t/ha). Mid-early and mid-late maturing hybrids have achieved better results on average compared to a long growing season hybrids. The most stable is the new hybrid ZP 427, which showed equally well to both favorable and unfavorable growing conditions. Besides mentioned hybrid, high stability was obtained by hybrid ZP 505. ZP 434 was the most unstable hybrid, which showed significantly better adaptation to poorer growing conditions, as well as hybrids ZP 548 and ZP 555, which also showed unstable, but better adapted to favorable growing conditions. ZP 341 obtained the best perfomance in poor growing conditions. Based on the results of the tests, it is concluded that ZP hybrids had good performance in agroecologicaly unfavorable 2012th year. Mid-early and mid-late maturing hybrids (FAO 300-500) are recomendation for dry areas and years in Serbia, which was concluded by their both, grain yield and stability.

Key words: maize, grain yield, stability preformance, drought

Introduction

Maize is one of the leading crops in world’s agriculture. When it comes to area sown, maize finds itself on third place after wheat and rice (Glamočlija, 2004), while in Serbia it occupies the first place on an average of 1.2 million hectares sown annually. Serbia has two production areas, Vojvodina (northern province of Serbia) and Central Serbia. The main difference is that the climate is drier and harsher in Central Serbia, ie. primarily reflected in lower rainfall during the vegetation period and higher altitude compared to Vojvodina.

Maize breeding program in Zemun Polje exists for over 60 years and all created hybrids can be divided into hybrids of the six cycles of selection (http://www.mrizp.rs/en/research-l/breeding). Each next cycle produced hybrids for more intensive production conditions than the previous one. They were more modern than previous, had bigger yield potential and were capable of handling the needs of producers on one side and the problems of abiotic and biotic stresses on the other. Besides selection for high and stable yield, maize growing technology of also changed. It is believed that about 60% increase in grain yield is resulting from new hybrid creation, while the remaining 40% represents a result of new technological solutions and education of maize producers (Jocković et al. 2010).

Climate change puts a difficult task before the maize breeders. The production of hybrids adapted to the conditions of temperature increase in Serbia and a decrease in precipitation represents new task of breeders. Increase in temperatures throughout Vojvodina and the reduction of rainfall in the same area is expected for future times (Lalic et al. 2011).

When testing new hybrid, it is necessary to do statistical analysis, with which conclusions can be given about the quality of newly developed hybrids. For each hybrid is essential that high yield is accompanied by a maximum yield stability. The stability of hybrids is best to be checked in adverse and favorable environmental conditions. The past 2012th years in Serbia was very dry with high temperatures and lack of rainfall through maize vegetation period. One way to check hybrids is to test them at greater number of locations. While testing the stability of hybrids, it is possible to happen that the highest yielding hybrids show a below-average stability (Babic, 2006). The high stability of genotypes is one of the most desirable features as one of the main preconditions for the expansion of the same hybrids for cultivation in large areas (Singh and Choudhary, 1977).

Maize Research Institute "Zemun Polje" has in its offer hybrids of all FAO maturity groups (FAO 100-800). Earlier, as the most cultivated hybrids were those of later latter maturity grooups (FAO 600-700). Today, there is an increasing demand for hybrids FAO 300-500, because they are hybrids that spend their growing period in terms of somewhat better supply of soil moisture and lower air temperatures. The aim of this study was to examine the productivity of commercial maize hybrids yield variability, and to determine the stability of grain yield of hybrids in the dry 2012th year.

Materials and methods

In this study 12 ZP maize hybrids were investigated from different maturity groups of FAO 300-600 and two foreign hybrid checks. All hybrids are grown and commercial, and are widespread in the whole of Serbia. Besides our hybrids, two foreign checks were also used in order to get a better picture and clearer validation of our hybrids. Checks were representatives from maturty groups FAO 500 (ch 500) and FAO 600 (ch 600).

Macro trials were set up at 18 locations through out Serbia during the year 2012: Zemun Polje (ZP), Divoš (DI), Sremska Mitrovica (SM), Kuzmin (KU), Bečej (BE), Zmajevo (ZM), Deronje (DE), Botoš (BO), Izbište (IZ) representing Vojvodina province and Loznica (LO), Mačvanski Prnjavor (MP), Šalinac (ŠA), Aleksandrovac (AL), Crnoklište (CR), Kurjače (KU), Smederevo (SD), Svilajnac (SV) and Leskovac (LE) representing Central Serbia. Selected locations cover the major production areas in the country.

Plot size was 0.1 ha. Sowing and harvesting operations are carried out mechanically. Plant density per area depended on the maturity group, and was performed at three different densities: FAO 300-400: 70.000 plants per hectare, FAO 500-600: 65.000 plants per hectare and 600 FAO: 60.000 plants per hectare. The yield was calculated in tonnes per hectar (t/ha) at grain moisture of 14%.

For the purposes of this paper average yields were calculated separately for Central Serbia and Vojvodina, for the sake of determination of difference in yield production areas, on the other hand, stability parameters were performed using Eberhart and Russell (1966) for all 18 locations together.

Eberhart and Russell method is represented by the following equation:

$Y_{ij} = m + b_i I_j + d_{ij}$

Y_{ij} - the average yield of the ith genotype in the jth location

m - the average yield of the ith genotype at all locations

b_i – standardised regression coefficient of the environment and genotype, genotype relationship to the environment
I_j - index of the environment as the average of all genotypes in the j^{th} location, reduced from the total average
d_{ij}-deviation from regression of the i^{th} genotype in the j^{th} site

Standardized regression coefficient (b_i) shows the response of genotypes to environment. When b_i=1, then the average adaptability and stability of the tested genotypes was considered uniform under the influence of favorable and poor environment conditions; when $b_i > 1$, genotype was considered stable and good only in favorable environment conditions, and when the $b_i < 1$, genotype was considered to perform better than the average in less favorable groing conditions and enviroments. All calculations were don in Excel programme.

Results and discussion

The results of grain yield trials on all 18 locations and stability parameters are shown in Table 3, and grain yields of hybrids tested on locations of production areas of Vojvodina and central Serbia are shown in Tables 1 and 2.

Achieved grain yield in Vojvodina province and Central Serbia show difference between yields of hybrids on different locations of the same area of production, and between two areas themselfes (Tables 1 and 2). When it comes production areas average grain yield of all hybrids was 6.11 t/ha and 5.63 in Vojvodina and Central Serbia respectively, with a difference in grain yield between Vojvodina and Central Serbia nearly 0.5 t/ha (0.49 t/ha).

Grain yields of hybrids ranged form 5.36 t/ha (ZP 648) to 6.82 t/ha (ZP 505) in Vojvodina and 4.75 t/ha (ZP 684) to 5.96 t/ha (ZP 505) in Central Serbia. ZP 505 showed the best result in both production areas. Vojvodina province, on all locations has eight hybrids reaching yield above 6 t/ha, where none of tested hybrids menaged to cross the line of 6 t/ha in Central Serbia.

Table 1. Grain yield of ZP hybrids on locations in Vojvodina province (t/ha)

Hybrid	ZP	DI	SM	KU	BE	ZM	DE	BO	IZ	Average
ZP 341	9.05	4.84	5.05	4.33	7.92	5.72	5.88	7.09	7.53	6.38
ZP 427	9.41	3.60	4.50	2.77	8.47	5.69	6.32	6.69	8.10	6.17
ZP 434	8.39	4.71	5.07	4.37	7.05	6.03	6.74	7.22	8.19	6.42
ZP 505	9.00	4.02	4.75	5.11	8.91	6.44	6.60	7.62	8.90	6.82
ZP 548	8.74	3.67	3.95	4.42	7.56	5.04	6.65	6.87	8.77	6.19
ZP 555	9.64	4.24	5.43	4.42	8.79	5.77	5.42	7.56	8.21	6.61
ZP 560	7.75	3.10	5.31	4.30	8.33	6.00	3.74	7.53	8.43	6.05
ZP 600	7.57	3.28	5.13	4.27	7.34	5.66	3.59	7.43	8.79	5.89
ZP 606	8.17	3.66	5.37	3.77	7.58	5.31	4.23	7.03	8.51	5.96
ZP 648	8.06	2.52	5.00	2.94	7.52	3.83	4.09	5.91	8.32	5.36
ZP 666	8.45	4.56	5.86	3.97	8.58	5.27	4.48	6.77	8.69	6.29
ZP 684	6.84	3.81	5.21	3.32	7.19	4.43	4.95	6.60	8.28	5.63
ch 500	6.41	3.76	6.74	4.30	7.70	5.37	2.65	7.19	7.72	5.76
ch 600	6.14	4.02	6.16	2.87	9.01	5.16	4.08	7.58	8.29	5.92
Average	8.12	3.84	5.25	3.94	8.00	5.41	4.96	7.08	8.33	6.11

When it comes to locations alone, average grain yield ranged from 3.84 t/ha (location Divoš) to 8.33 t/ha (location Izbište) with interval of yield variation of 4.49 t/ha in Vojvodina, and 3.07 t/ha (location Crnoklište) to 8.60 t/ha with interval of yield variation of 5.53 t/ha in Central Serbia.

Table 2. Grain yield of ZP hybrids on locations in Central Serbia (t/ha)

Hybrid	LO	MP	ŠA	AL	CR	KU	SD	SV	LE	Average
ZP 341	4.85	7.57	9.12	5.89	3.48	6.11	4.42	6.87	4.35	5.85
ZP 427	4.87	7.17	7.88	6.00	2.96	4.65	4.75	5.55	5.67	5.51
ZP 434	4.81	7.23	8.03	6.73	3.11	5.70	4.13	6.77	4.60	5.68
ZP 505	4.77	7.93	8.89	7.27	3.59	4.71	5.02	6.32	5.17	5.96
ZP 548	5.32	7.43	9.82	7.18	2.47	3.74	3.37	7.26	5.71	5.81
ZP 555	4.52	8.01	9.53	7.65	3.83	3.66	3.89	7.70	4.53	5.92
ZP 560	4.06	7.59	9.01	7.72	2.72	3.05	5.24	6.34	5.78	5.72
ZP 600	3.72	7.77	8.42	7.32	3.34	5.47	5.52	6.22	5.74	5.95
ZP 606	3.56	7.41	8.32	5.09	3.61	4.87	5.30	6.10	6.06	5.59
ZP 648	3.09	7.54	8.36	5.14	2.52	5.16	3.63	5.48	4.72	5.07
ZP 666	3.71	6.75	8.42	5.27	3.95	5.12	5.98	7.42	6.34	5.88
ZP 684	3.12	6.82	6.88	5.33	2.10	3.71	3.82	6.30	4.63	4.75
ch 500	3.99	8.07	8.45	5.42	3.10	4.03	5.53	6.57	5.30	5.61
ch 600	4.22	7.80	9.28	5.75	2.23	4.70	4.87	6.19	4.63	5.52
Average	4.19	7.51	8.60	6.27	3.07	4.62	4.68	6.51	5.23	5.63

Looking at the summing results of grain yields in the Table 3, hybrids of early medium maturity group FAO 300-400 fully menaged to cope with hybrids of latter maturity hybrids in 2012 th year, who usually achielve better yields. Hybrids ZP 341 and ZP 434 reaching 3th and 6 th place in rank according to obtained grain yields of 14 hybrids. This could be understanded by their earlier polination and start of grain filling period, while soil humidity and air temperatures are still good. A situation where the higest yielding hybrid does not need to be necessary the most stable one is repeated here with the hibrid ZP 505. ZP 427 with 5.83 t/ha on all 18 locations, ranking 9th was the most stable one with b_i=1.00. ZP 505 on the other hand achieved the highest grain yield, but ranked at 2nd place in a rank according to b_i with b_i=1.01, showing exellent result in dry 2012. year. The lowest yielding hybrid in Serbia in 2012th year was ZP 684, but showed good stability with a 3rd place in rank accordiong to b_i.

Table 3. Grain yield of commercial ZP hybrids on all 18 locations in production trials in 2012. year

Hybrid	Grain Yield (t/ha)	Rank according to grain yield	Moisture content at the time of harvest (%)	b_i	Rank according to b_i
ZP 341	6.12	3	13.0	0.89	6
ZP 427	5.83	9	12.9	1.00	1
ZP 434	6.05	6	13.6	0.82	9
ZP 505	6.39	1	15.2	1.01	2
ZP 548	6.06	5	15.5	1.15	8
ZP 555	6.27	2	15.2	1.15	8
ZP 560	5.88	8	15.5	1.12	7
ZP 600	5.92	7	15.7	1.09	4
ZP 606	5.78	10	15.8	0.94	3
ZP 648	5.21	13	16.2	1.12	7
ZP 666	6.09	4	15.6	0.90	5
ZP 684	5.19	14	16.7	0.94	3
ch 500	5.68	12	14.2	0.90	5
ch 600	5.72	11	14.7	1.09	4
Average	5.78	/	15.0	1	/

Hybrid with the lowest stability was ZP 434 with b_i far lower from 1, ie. 0.82, prooving his superiority in poorer production conditions but reaching only number 6 in rank according to grain yield. ZP 666 is latter maturuty hybrid but menaged to gain high yield, ranking 4th place, but also had b_i=0.90 showing his better adaptibility for poorer growing conditions in comparing to other FAO 500-600 maturing hybrids. The hybrids with the highest b_i=1.15 were ZP 548 and ZP 555, where ZP 555 was 2nd highest yielding hybrid and ZP 560 with b_i=1.12, leading to conclusion that these hybrids are more adaptibile for better growing conditions, where they obtain very high results.

Two foreign checks ch 500 and ch 600 they showed 12th and 11th in ranks according to achieved grain yield and 4th and 5th place in rank according to b_i. One advantage that foreign checks showed was lover moisture content at the time of harvest with 14.2 % and 14.7 % respectevily, putting them in category of hybrids for harvesting by grain shelling.

Conclusion

ZP hybrids showed very good performane in 2012th year considering agroecological conditions in the same year. Yields in Vojvodina and Central Serbia showed that Vojvodina has little bit more favorable conditions, with a difference of 0.49 t/ha. Furthermore, Vojvodina also showed smaller variation in grain yield, concluding more equable growing conditions than Central Serbia who had highest yield obtained in Šalinac, but also lowest yield obtained in Crnoklište of both production areas. Also, looking at the grain yields of hybrids it self, eight of them menaged to score yield over 6 t/ha in Vojvodina compared to none reaching such result in Central Serbia.

Hybrids of latter maturity groups (FAO 500-600) mostly obtained b_i higher than 1, showing better adaptibility for more favorable growing conditions. Such representatives are primarily ZP 548, ZP 555 and ZP 560. ZP 505 showed the best results considering both grain yield and stability, and is recomended for production in dry areas in Serbia. Hybrids of FAO 300-400 maturity group never crossed b_i of 1, showing better adaptiblity to poorer growing conditions. Hybrid ZP 434 and ZP 341 with their achieved results are definetly recommended for dry and unfavorable locations in Serbia. This statement is in accordance with Pavlov et all. (2011), who also mentioned redistribution of maize hybrids of early and early medium maturity group for poorer and latter maturity maize hybrids for better agroecological growing conditions. The exeption is hybrid ZP 666, being a latter maturity hybrid, but showed very good result in grain yield. Being the only hybrid with b_i=0.90 and belonging to FAO 600 maturity gruop, and still ranking 4th in grain yield shows his great drought and high temperature tolerance, and is recomendation for dry areas with poorer growing conditions.

When it comes to comparasion of ZP hybrids and two foreign checks, it can be concluded that maize breeding programme in Maize research Institute „Zemun Polje“ completely follows foreign maize breeding programme in grain yield and stability, but lacks grain dry down rate, where two FAO 500-600 foreign checks had lower moisture content in harvesting period than ZP maize hybrids of the same maturity group, allowing them harvesting directly in grain by shelling, rather than harvesting in cobs.

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