NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 30, 2013
Print ISSN 1222-4227; Online ISSN 2067-5720

POTENTIAL OF EARLY MATURITY FLINT AND DENT MAIZE HYBRIDS AT HIGHER ALTITUDES

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ABSTRACT

There is a growing trend in production of early maturity maize hybrids as far north and on higher altitudes as possible, even in regions where they were not previously cultivated. Thus, an increased demand at the global market for early maturity maize hybrids of FAO 100 and 200 is present. These hybrids are able to mature under not so favourable temperature conditions. The experiments were performed in Planinica - central part of Serbia at 650 m above sea level, during four years (2001-2004). Nine Zemun Polje (ZP) dent and nine flint hybrids of the FAO 100 and 200 were observed. The highest average grain yield (7.19 t ha^{-1}) was recorded in 2002 and it was also high in 2004 was (7.18 t ha^{-1}), while in the remaining two years, yields were significantly lower (6.50 t ha^{-1} - 2001 and 4.32 t ha^{-1} - 2003). In more productive years two dent hybrids: ZP 290 (9.90 t ha^{-1} in 2002) and ZP 251 (10.22 t ha^{-1} in 2004) gave highest yields, while under less favourable weather conditions two flints ZP 114 (7.45 t ha^{-1} in 2001) and ZP 125 (5.40 t ha^{-1} in 2003) were most productive. Flint hybrid ZP 115 (7.22 t ha^{-1}) was the highest yielding, on average. Also, high average yields were observed in two dent hybrids ZP 290 (7.10 t ha^{-1}) and ZP 248 (6.88 t ha^{-1}), and one flint ZP 246 (7.09 t ha^{-1}). Thus, these four early maize hybrids were characterized as genotypes of high yielding potential.

Key words: early maturity maize hybrids, flints, dents, yield.

INTRODUCTION

Although maize is known to be thermophilic crop its production is being spread even in regions in which maize was not previously cultivated, due to the fact that maize, as either grain or silage, is a base for livestock feeding. The bulk of the corn is produced between latitudes 30 and 55^{o}, with relatively little grown at latitudes higher than 47^{o} (Shaw, 1988). In Russian Federation, there is a need to cultivate maize even up to latitude of 56^{o}. Some predictions of climate changes indicate that according to the global warming forage maize could be introduced into southern Finland without risks of too short vegetation season, night frosts and cool periods, even by the mid-century (Peltonen-Sainio et al., 2009).

The wide diversity of maize germplasm opens the possibility of its cultivation over a wide range of climatic conditions, and problems such as cold springs and short vegetative season could be overcome. One of the ways in solving these issues is in pre-breeding programs that are determining genotypes expressing early vigour under cold stress (Peter et al., 2009; Schneider et al., 2011), which will provide plants with fast developing canopy that will maximize the capture of solar radiation, and rapid ground cover and soil protection. This would allow maize to compete better with weeds and minimize the risk of unfavourable environmental effects such as soil erosion and nitrate leaching. Since early maturity hybrids are cultivated at high densities and since emergence conditions are frequently unfavourable, it is necessary that seed have good vigour and germination.

On the other hand, many breeding programs are focused on early and ultra early maturity maize hybrids of FAO maturity groups 100 and 200, which reach maturity in 100-110-days period. These hybrids, due to their short growing season, can mature under

Received 18 May 2012; accepted 22 January 2013. First online: 4 February 2013. DII 2067-5720 RAR-197

unfavourable temperature conditions. Moreover, the advantage of these hybrids is in the fact that they are harvested earlier under more favourable conditions and with grain moisture at harvest of about 14%, hence there is no need for grain drying. This significantly decreases production costs, for the grain drying requires energy and time, and some losses always occur during this process (Pavlov et al., 2010). Kolčar and Videnović (1988) concluded that hybrids of the FAO maturity group 200 could be successfully grown even if sown at the end of May in the regions of Serbia that belong to the mid continental climate zone. Thus, early maturity hybrids can be grown as stubble crops for grain or silage in maize growing regions. The leaf area index (LAI) of early maturity hybrids is smaller than the LAI of late maturity hybrids, so they can be grown in higher sowing densities up to 100,000 plants per hectare due to their smaller habit. New generations of maize hybrids are characterized with a better ability of plants to be grown in a denser stand, as they were selected under such conditions (60-100,000 plants per ha) (Simić et al., 2009). The higher density results in the modified appearance of the plant and newer generations of maize hybrids have less robust plants, ears that are placed lower, while the angle of top leaves in relation to the stalk is smaller.

Flint genotypes dominate among ultra early maturity maize genotypes, especially those originating from Canada and France. Under wet and cold growing conditions, flint maize genotypes express higher yielding potential and have a faster dry down rate in relation to dents. Under lowland conditions, as well as, under conditions of stubble crop sowing, dent genotypes have an advantage among early maturity hybrids (Frei, 2000). This is very important in the seed production that needs to be cost-effective; hence there is an advantage in semi-flint hybrids. The advantage of such hybrids lies in the fact that semi-flints as female components have higher yields in the seed production and under lowland conditions of the continental climate. Due to this, when the seed production is performed in regions with more arid continental climate, it is desirable that at least one inbred line in the female component is dent (Frei, 2000). Flint and dent maize genotypes differ in their endosperm structure and composition (Darrah and McMullen, 2003), and this could be the reason for the difference in dry down rate between dents and flints. Maiorano et al. (2010), highlighted that maize grain composition can influence water availability during maturation and found different moisture content trends during maturation among flint hybrid and dent hybrids involved in their research.

Breeding programme of early maturity maize hybrids at the Maize Research Institute, Zemun Polje was established in the 1970s and 83 early maturity hybrids of the FAO maturity groups 100 and 200 have been released so far. Twenty five maize hybrids of FAO maturity groups 100 and 200 were released in following countries: Russian Federation (6); Ukraine (6); Belarus (2); Kazakhstan (1); Italy (3); Poland (1) and Germany (6). Testing of early maize hybrids were performed in Russia - the Moscow region, Kazakhstan - Zarkent, Belarus - Zodino, Ukraine - the Kiev region, Bosnia and Herzegovina - Banja Luka, Slovenia - Kranj, etc. Due to such a comprehensive programme, globally known results in selection of early maturity ZP maize hybrids have been achieved. The present study is just a contribution to these results.

The aim of the present study was (i) to observe yields of early maturity ZP maize hybrids obtained at 650 m above sea in Serbia, (ii) to establish which genotype had the highest yield and (iii) to select three to four higher yielding genotypes to be used in practice.

MATERIAL AND METHODS

Site description

Experiments were performed on reddish brown soil in Planinica during four years (2001-2004). Planinica is located at 650 m above sea level, 125 km south-east of Belgrade. According to its weather conditions, it is a typical location with a shorter growing season and therefore suitable for selection of early maturity maize hybrids. Selection of early maturity maize ZP hybrids was initiated in Planinica station in 1974. This soil is extremely acid in the 0-20 cm layer - pH in H_20 is 5.42 and in KCl is 4.46; humus content amounts 2.19%, P_20_5 - 8.0 (poor in available phosphorus) and K_2O - 13.8 (moderately supplied with potassium) (Biberdžić et al., 2004). Soil is susceptible to erosion. The importance of testing maize on this acid soil is high, because maize is often grown on such soils, and hybrids selected on this soil are more adaptable. Besides, this experimental breeding station for ZP maize hybrids has similar weather conditions as targeted regions for these hybrids.

Experimental design and cultural practices

A three-replication trial was set up according to the randomised complete block design. The sowing density was 71,425 plants ha^{-1} (70 x 20 cm). The experimental plot size was 7.0 m^2. Nine ZP dent hybrids (ZP 118; ZP 205; ZP 207; ZP 228; ZP 245; ZP 248; ZP 251; ZP 274 and ZP 290) and nine ZP flint hybrids (ZP 105; ZP 114; ZP 115; ZP 125; ZP 138; ZP 196; ZP 219; ZP 225 and ZP 2460) were studied.

All hybrids were three way crosses, where in the dent constitution at least two inbreds were dents and one in the female component could be semiflint or semident. Likewise in flint hybrids at least two inbreds were flint type and one in the female component could be semiflint or semident. Among dent hybrids one belonged to FAO maturity group 100 (ZP 118) and eight hybrids to FAO maturity group 200. Six flint hybrids were FAO maturity group 100 (ZP 105; ZP 114; ZP 115; ZP 125; ZP 138; ZP 196) and three hybrids FAO maturity group 200.

Tillage was performed in a conventional way. Winter wheat was used as preceding crop. When wheat was harvested, shallow stubble ploughing down was done to the depth of 15 cm. In autumn, ploughing was done to the depth of 25 cm.

A seedbed preparation was done by a seedbed conditioner 7-10 days prior to sowing. All amounts of fertilisers: 150 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} were applied in autumn by spreading over the soil surface. Pre-emergence herbicides Atrazine 500SC in amount 1 l ha^{-1} (atrazine 500 g a.i.) and Harnes 2 l ha^{-1} (acetochlor 900g a.i.) were applied. One inter-row cultivation was performed during the growing season.

Maize grain yield was measured at the end of the growing cycle from the two inner rows and calculated with 14% of moisture. All observed data were analysed by two-factorial analysis of variance (ANOVA), where the year was factor A (4), while hybrid was factor B (18). Treatment means were compared using Fisher's least significant difference (LSD) test (P=0.05) and coefficients of variation (CV).

Meteorological conditions

Weather conditions varied in the April-October period during the four-year study. The precipitation sum amounted: 686.1, 623.8, 438.5 and 544.3 mm in 2001, 2002, 2003 and 2004, respectively (Figure 1).

Based on this and on data presented in Figure 1 it is noticeable that the lowest precipitation sum was recorded in 2003, when there were two periods with lack of precipitation, the first in June and the second, more pronounced, in August. Although in 2002 precipitation was sufficient, there was one short period in June with a low precipitation sum.

This period did not significantly affect yield. Furthermore, a higher precipitation sum during October of 2002, when the growing season was over, did not significantly affect yields. According to the sums and distributions of precipitation, 2004 was the most favourable year. On the other hand, although the highest sum of precipitation was recorded in 2001, the highest oscillations in precipitation during growing season were recorded in this year and that affected maize production.

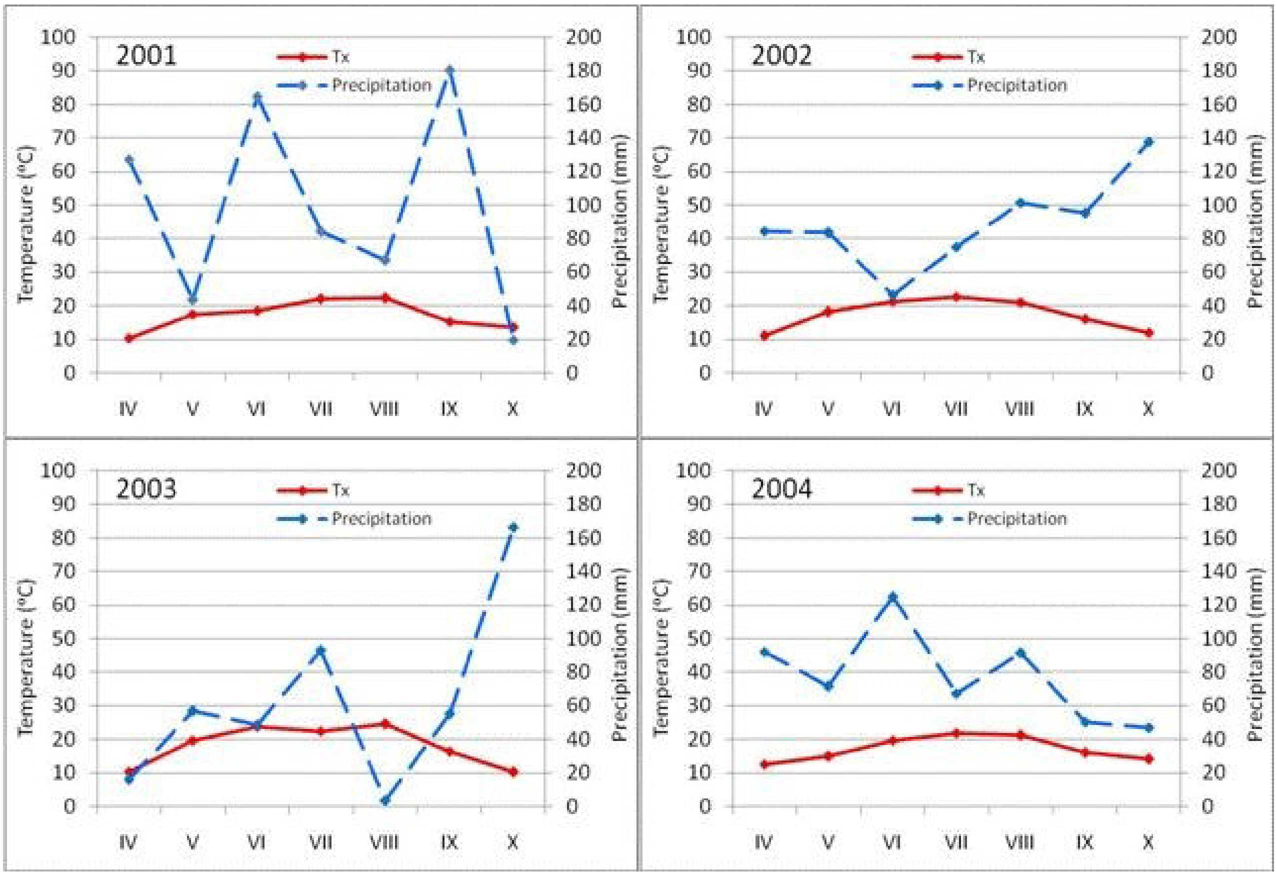

Figure 1. Walter's diagram of precipitation and average air temperatures from April till October in Planinica in the four year period (2001-2004)
(Note: Data presented on clima diagram were recorded in the nearest weather station in Valjevo, 27 km from the Planinica station.)

RESULTS

This study showed that yields of the early ZP maize hybrids significantly varied according to both examined factors, i.e. year and genotype, and their interaction (Table 1).

Table 1. ANOVA of maize grain yield for the year, genotype, and their interaction

Sources of variation	D.F.	Mean square
Replication	2	0.33
Year	3	99.78**
Genotype	17	3.51**
Year x Genotype	51	2.90**
Error	142	0.21

**significant at the 0.01 probability level.

Results obtained during the 2001-2004 period (Table 2) indicate that there were significant differences in yields over years. The highest average yield of 7.19 t/ha (100.00%) was recorded in 2002. In 2004, yield was almost the same as the yield obtained in 2002 (7.18 t/ha - 99.86%). Significantly lower yields were recorded in 2001 - 6.50 t/ha (90.40%), and especially in 2003 - 4.32 t/ha (60.08%), which was the lowest average yield. It was noticed that in years with less favourable weather conditions 2001 and 2003, flint hybrids achieved higher average yields (6.52 t/ha and 4.44 t/ha, respectively), than dent hybrids (6.48 t/ha and 4.19 t/ha, respectively) (Figure 2).

In those two years, highest yields were registered in two flint hybrids of the FAO maturity group 100: ZP 114 - 7.45 t/ha (2001) and ZP 125 - 5.40 t/ha (2003).

On the other hand in more favourable years, average yields of dent hybrids were higher than average yields of flint hybrids (dents 7.34 t/ha, flints 7.05 t/ha in 2002; dents 7.54 t/ha, flints 6.81 t/ha in 2004) (Figure 2). In 2002 and 2004 the highest yields were detected in two dent hybrids: ZP 290 - 9.90 t/ha and ZP 251 - 10.22 t/ha, respectively (Table 1).

Table 2. Yields (t ha^{-1}) of early maturity ZP maize hybrids obtained in Planinica during 2001-2004

	Hybrids	2001	2002	2003	2004	*Average*	CV
Dents	1. ZP 118	6.65	7.46	3.78	7.78	*6.42*	34.9
	2. ZP 205	6.72	5.74	4.35	7.35	*6.04*	29.7
	3. ZP 207	6.97	5.55	4.80	5.74	*5.77*	14.9
	4. ZP 228	6.47	5.89	4.99	6.14	*5.87*	11.0
	5. ZP 245	7.02	7.94	4.67	6.36	*6.50*	20.0
	6. ZP 248	7.19	8.42	4.13	7.79	*6.88*	25.4
	7. ZP 251	6.65	6.69	▽3.55	▲10.22	*6.78*	37.4
	8. ZP 274	▽4.61	8.46	3.76	7.77	*6.15*	35.2
	9. ZP 290	6.09	▲9.90	3.68	8.74	*7.10*	36.2
	Average dents	*6.48 ± 12.8*	*7.34 ± 26.0*	*4.19 ± 16.2*	*7.54 ± 19.6*	*6.39*	18.6
Flints	10. ZP 105	5.74	6.81	4.37	6.46	*5.85*	22.1
	11. ZP 114	▲7.45	6.97	4.90	6.28	*6.40*	17.5
	12. ZP 115	7.16	8.98	5.04	7.71	*7.22*	24.9
	13. ZP 125	5.12	5.59	▲5.40	▽5.48	*5.40*	4.8
	14. ZP 138	6.71	7.01	4.10	7.27	*6.27*	22.3
	15. ZP 196	6.27	▽5.37	3.55	7.37	*5.64*	28.3
	16. ZP 219	6.73	6.75	4.20	5.77	*5.86*	19.3
	17. ZP 225	6.36	7.22	4.38	6.52	*6.12*	19.6
	18. ZP 246	7.14	8.74	4.04	8.42	*7.09*	27.7
	Average flints	*6.52 ± 12.2*	*7.05 ± 22.4*	*4.44 ± 15.7*	*6.81 ± 15.3*	*6.20*	16.4
	Average	*6.50b ± 12.4*	*7.19a ± 24.1*	*4.32c ± 16.2*	*7.18a ± 18.7*	*6.30*	17.8

$LSD_{0.05}$ for the year (A) = 0.34; hybrid (B) = 0.39; interaction (AxB) = 0.75
▲= hybrids with the highest yields during the year; ▽= hybrids with the lowest yields during the year.

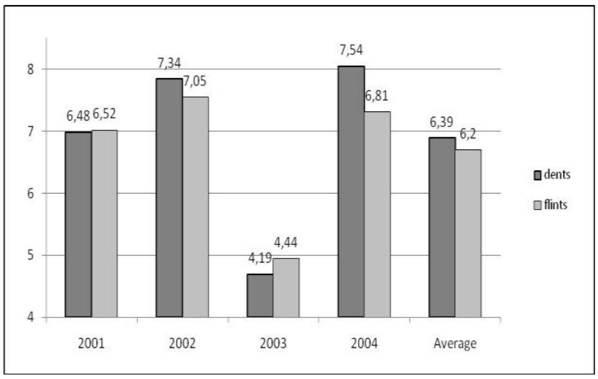

Figure 2. Average yields (t ha^{-1}) of dent and flint ZP hybrids in Planinica (2001-2004)

Coefficients of variation also showed that years induced much more variation of grain yield than genotype. In favourable 2002, coefficients of variation had the highest value for dents (26.0%), flints (22.4%), and, as well as, for all hybrids in average (24.1%). Flint hybrid ZP 125 and dent hybrid ZP 228 expressed the highest yield stability (CV - 4.8 and 11.0%) during period of investigation.

Significant differences in average yields were observed among studied genotypes. The analysis showed that the highest yielding genotype on average for all four years was flint hybrid ZP 115 with 7.22 t ha^{-1}. There were no significant differences between this and the following three top yielding hybrids: ZP 290 - 7.10 t ha^{-1} (dent); ZP 246 - 7.09 t ha^{-1} (flint) and ZP 248 - 6.88 t ha^{-1} (dent) (Figure 3).

DISCUSSION

Meteorological conditions in our four year study significantly affected yields of examined hybrids. Yields variations were in agreement with analysed weather conditions. In two years that were characterized as favourable for maize production, as they had sufficient sums and favourable distribution of precipitation (2002 and 2004), average yields were significantly higher than in 2001 and 2003. Extreme oscillations in precipitations in 2001 significantly lowered maize yields, although the actual sum of precipitation was the highest of all observed years.

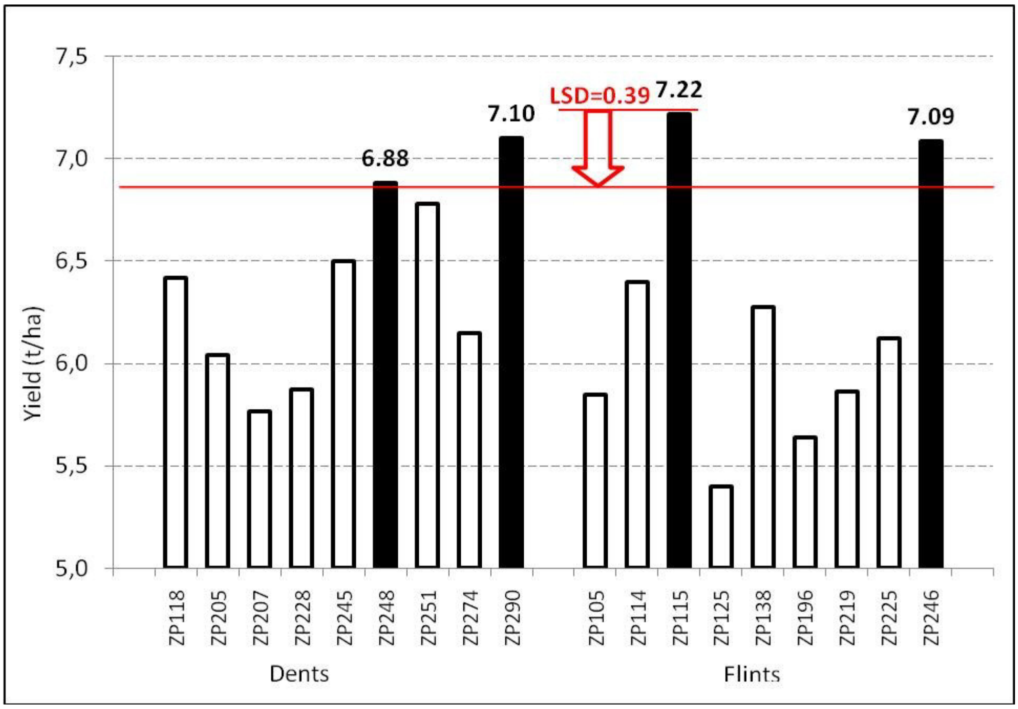

Figure 3. Average yields (t ha^{-1}) of early maturity ZP maize hybrids in Planinica (2001-2004)

In 2003 yields of all hybrids included in this research were significantly lower compared to the other years, and the average yield was significantly lower than average yields in other years. This was due to the two periods with lack of precipitation, one in June in the silking and tasseling phase and other, more pronounced in August in the grain filling stage. Drought stress has the greatest impact on maize yield when it occurs close to flowering, as it inhibits floral development, and provokes failure in fertilization and zygote abortion (Saini and Westgate, 2000). This is the critical developmental phase in determination of the number of kernels per ear, which is the main yield component. Accordingly, the reduction in number of kernels per ear causes significant yield reductions (Grant et al., 1989; Çakir, 2004; Zarco-Perello et al., 2005). It is important that studies were carried out in two years with less favourable weather conditions and two years with more favourable weather conditions, as it is very significant for the selection of best genotypes.

Weather conditions, and especially sums and distributions of precipitation, in different years had different impact on the yields of dent and flint maize hybrids. In less productive years, flint maize hybrids expressed higher average yields and two flint hybrids of FAO 100 achieved highest yields. When weather conditions were more favourable, dent hybrids were higher yielding on average and among genotypes, i.e. two dent hybrids of FAO 200 were most productive (ZP 290 and ZP 251 in 2002 and 2004, respectively).

The highest average yielding hybrid in the four year study was ZP 115 (7.22 t ha^{-1}), which is flint type hybrid and belongs to the FAO maturity group 100. The least variation in yields over years was detected in this hybrid, meaning that this hybrid was more adaptable than the remaining hybrids, which is one of the desirable traits. One more flint type hybrid (ZP 246), and two dent hybrids (ZP 209 and ZP 248), were characterized as highly productive, as they did not significantly differ from the highest yielding hybrid ZP 115. These four top yielding hybrids have erect leaves, tassels with two to three branches and very good other phenotypic and genetic traits, hence they were selected as hybrids with great potential. It is also observed that there is correlation between the erect position of the top leaves and a faster dry down rate in the grain maturation period (Radenović et al., 2010), which is a very desirable trait in modern hybrids.

Hybrids characterised with high yields and fast dry down rates under certain weather conditions, might not express the same traits under conditions of different environments. Therefore, it is the most desirable to perform selection under conditions under which hybrids will be grown.

On the other hand, the degree of utilization of maize genetic yielding potential mostly depends on weather conditions and the level of maize cropping practices (Kresović et al., 2004; Videnović et al., 2005; Videnović et al., 2007).

CONCLUSIONS

The four year study of yields of early maturity ZP maize hybrids showed the following:

The lowest precipitation sum, including two periods with rainfall deficit, was recorded in 2003. Although in 2001 the highest sum of precipitation was recorded, the highest oscillations in precipitation during the growing season were also noticed, which significantly affected maize yields. In 2002 precipitation sum was sufficient, and also in 2004 precipitation sum and distribution was favourable.

Average yields in the period 2001-2004 significantly varied over years. The most productive years were 2002 with highest average yield of 7.19 t ha^{-1}, and 2004 with average yield of 7.18 t ha^{-1}.

Significant differences were observed in average yields among investigated genotypes. Hybrid ZP 115 with 7.22 t ha^{-1} was the highest yielding hybrid. The yield of this genotype expressed least variation over years. Next three genotypes- ZP 290, ZP 246 and ZP 248 were also selected as genotypes of high yielding potentials.

Besides, it was observed that the highest yields under unfavourable conditions were registered in two flint hybrids: ZP 114 (2001) and ZP 125 (2003) and two dent hybrids: ZP 290 (2002) and ZP 251 (2004). The year x genotype interaction was significant; hence these results should be considered in the future selection process.

Acknowledgements

A part of this study was financially supported by the Ministry of Science and Education of the Republic of Serbia through the project "Integrated field crop production: conservation of biodiversity and soil fertility" (Reg. No. TR 31037).

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