Grain yield of ZP maize hybrids in the maize growing areas in Serbia

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Abstract
Five commercial ZP-maize hybrids were tested at 10 locations in Serbia over a three-year period to assess their yield potential and stability. Average grain yield of hybrids in three-year trail ranged from 7.439 t ha⁻¹ (ZP-5) to 8.332 t ha⁻¹ (ZP-3). Values of regression coefficient \( b_i \) indicate better adaption of early to medium maturity hybrids to poor environments and good adaption of medium to late maturity hybrids to better environments. Hybrid ZP-3, which was highest yielding was not most stable, according to values of regression coefficient. According to the results gathered applying Lin & Binns model, hybrid ZP-3 is considered as a most stable genotype. By obtaining results of Spearman rank correlation coefficient we found positive correlation between values of \( \text{Pi} \) and grain yield and didn’t find correlation between grain yield and regression coefficient \( b_i \).

Key words: maize hybrids, grain yield, yield stability

Introduction
The development of maize hybrids with high grain yielding potential is one of the most important tasks of breeding. Grain yield depends on the genetic constitution of hybrids, i.e. on the frequency of favourable alleles controlling the yield that are not accumulated in hybrids and even more on the capacity of hybrids to resist limiting environmental factors (Stojaković et al (2002).

It is very important to create hybrids with high yielding potential, but new created hybrids should have some other desirable morphological and physiological characteristics.

In recent times in Serbia maize has been grown on the area of approximately 1,250,000 ha. Maize is one of the most important field crops and since it is sown on almost 60% of arable areas it has various purposes in nutrition of humans and animals and is a very important factor in the export of agricultural products. Due to favourable and very favourable conditions (Vojvodina) of the majority of macroecological regions maize is successfully grown in our country (Jovanović, 2007). Early maturity hybrids have a shorter growing season and significantly lower grain moisture content at harvest (16-18%), which is a great advantage in maize storing. On the other side, late maturity hybrids have higher grain yield potential, but they need better agroecological conditions to release their high potential. Currently, hybrids from FAO 600 maturity group are most distributed in Serbia. The selection of locations, different soil and climatic conditions and long-term studies completely provide the adequate regional distribution of hybrids for different agroecological areas in Serbia.

The biological basis of the regional distribution of hybrids is established on the specific genotype × environment interaction, which is complex and has been an object of interest of science and practice for many decades (Ivanović et al., 2007).

In order to make maize production more stable and to improve it, it is necessary to adequately select maize hybrids of certain locations (Jovin et al., 2002).
Materials and method

Five maize hybrids from different FAO maturity groups were used in this study (ZP-1: FAO 350, ZP-2: FAO 400, ZP-3: FAO 500, ZP-4: FAO 550, ZP-5: FAO 650). All of these hybrids are commercial and widely grown in Serbia.

Macro trails were set up on 10 locations, over a three-year period. Selected locations represent main maize production areas in Serbia. Plot size was 0.1 ha. Planting and harvesting were mechanized. During the harvesting samples for moisture content were taken. Hybrids were sown at different densities: FAO 300-400: 70000 plants per hectare, FAO 500: 65000 plants per hectare and FAO 600: 60000 plants per hectare. Grain yield data converted to t ha⁻¹ at 14% moisture level are shown in this work.

Stability parameters were estimated by models of Eberhart and Russel (1966) and Lin and Binns (1988). Correlation coefficients between both investigated stability parameters and grain yield were computed.

As described by Eberhart and Russell (1966), the behavior of the cultivars was assessed by the model

\[ Y_{ij} = m + b_i I_j + d_{ij} + e_{ij} \]

where \( Y_{ij} \) = observation of the \( i \)-th (\( i = 1, 2, ..., g \)) cultivar in the \( j \)-th (\( j = 1, 2, ..., n \)) environment, \( m \) = general mean, \( b_i \) = regression coefficient, \( I_j \) = environmental index obtained by the difference among the mean of each environment and the general mean \( d_{ij} \) the regression deviation of the \( i \)-th cultivar in the \( j \)-th environment and \( e_{ij} \) = effect of the mean experimental error (Scapim et al., 2000).

Regression coefficient (\( b_i \)) measures the response of genotypes to environments. When \( b_i = 1 \) there is average stability and adaptability to both poor and good environments, when \( b_i > 1 \) genotypes give above average stability only in good environment. Whereas, when \( b_i < 1 \), it indicates genotypes adaptation to poor environment (Aremu et al, 2009).

The Lin and Binns' (1988) model uses the \( P_i \) parameters obtained by the expression

\[ P_i = \frac{\sum_{j=1}^{n} (X_{ij} - M_j)^2}{2n} \]

to assess the superiority of the cultivar, where \( P_i \) = superiority index of the \( i \)-th cultivar in the \( j \)-th environment, \( M_j \) = maximum response obtained among all the cultivars in the \( j \)-th environment, and \( n \) = number of environments. This expression was further partitioned into

\[ P_i = \left( \frac{n}{n-1} \right) \left( M_i - \bar{M} \right)^2 + \frac{\sum_{j=1}^{n} (X_{ij} - M_j)^2}{2n} \]

where \( M_i = \frac{\sum_{j=1}^{n} M_j}{n} \) and \( \bar{M} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \) = yield mean of the \( i \)-th cultivar in the \( n \) environments and \( \bar{M} \) = mean of the maximum response in the \( n \) environments.

According to Lin and Binns (1988), the first part of the \( P_i \) expression quantifies the genetic deviation and the second quantifies the G x E interaction. It characterizes the genotypes with a single parameter \( (P_i) \) by associating stability and productivity, and defines a superior cultivar as one with a performance near the maximum in various environments.

Estimation of the relationship between stability parameters, and between investigated stability parameters and grain yield was calculated using Spearman rank correlation coefficient.

\[ r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \]

where \( d_i \) is the difference in the ranks given to the two variable values for each item of data, and \( n \) is the number of subjects.

Results and discussion

According to the results of three-year period, we can conclude that 2007 had unfavourable conditions for maize production because of extremely high temperatures during the july. Other two years characterized better conditions for maize production and grain yield was higher.

Average grain yield per year ranged from 6.920 t ha⁻¹ in 2007. to 8.717 t ha⁻¹ in 2009. It is interesting that all hybrids obtained yields close to average in 2008.
Table 1. Grain yield (t ha\(^{-1}\)) of investigated hybrids during the three-year period

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>2007</th>
<th>Rank</th>
<th>2008</th>
<th>Rank</th>
<th>2009</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZP-1</td>
<td>7.285</td>
<td>2</td>
<td>8.020</td>
<td>2</td>
<td>8.706</td>
<td>3</td>
</tr>
<tr>
<td>ZP-2</td>
<td>6.829</td>
<td>3</td>
<td>8.187</td>
<td>1</td>
<td>8.944</td>
<td>2</td>
</tr>
<tr>
<td>ZP-3</td>
<td>7.758</td>
<td>1</td>
<td>8.016</td>
<td>3</td>
<td>9.223</td>
<td>1</td>
</tr>
<tr>
<td>ZP-4</td>
<td>6.667</td>
<td>4</td>
<td>7.882</td>
<td>4</td>
<td>8.439</td>
<td>4</td>
</tr>
<tr>
<td>ZP-5</td>
<td>6.063</td>
<td>5</td>
<td>7.979</td>
<td>5</td>
<td>8.275</td>
<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>6.920</td>
<td></td>
<td>8.016</td>
<td></td>
<td>8.717</td>
<td></td>
</tr>
</tbody>
</table>

The main grain yield of hybrids in three-year period ranged from 7.439 t ha\(^{-1}\) (ZP-5) to 8.332 t ha\(^{-1}\) (ZP-3). Early to medium maturity hybrids ZP-1 and ZP-2 had very good grain yields, better than late maturity hybrids ZP-4 and ZP-5 (Tab. 2).

Table 2. Average grain yield for period 2007-2009. and stability parameters for investigated hybrids

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Grain yield</th>
<th>Rank</th>
<th>bi</th>
<th>Rank</th>
<th>Pi</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZP-1</td>
<td>8.004</td>
<td>2</td>
<td>0.959</td>
<td>2</td>
<td>2.101</td>
<td>4</td>
</tr>
<tr>
<td>ZP-2</td>
<td>7.986</td>
<td>3</td>
<td>0.879</td>
<td>5</td>
<td>1.912</td>
<td>3</td>
</tr>
<tr>
<td>ZP-3</td>
<td>8.332</td>
<td>1</td>
<td>1.062</td>
<td>3</td>
<td>1.111</td>
<td>1</td>
</tr>
<tr>
<td>ZP-4</td>
<td>7.663</td>
<td>4</td>
<td>1.069</td>
<td>4</td>
<td>1.604</td>
<td>2</td>
</tr>
<tr>
<td>ZP-5</td>
<td>7.439</td>
<td>5</td>
<td>1.031</td>
<td>1</td>
<td>2.117</td>
<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>7.884</td>
<td></td>
<td>1.000</td>
<td></td>
<td>1.769</td>
<td></td>
</tr>
</tbody>
</table>

The values of regression coefficient bi indicate better adaption of early to medium maturity hybrids to poor environments and good adaption of medium to late maturity hybrids to better environments (Tab. 2). These results are in concordance with results obtained by Madić et al., (2010).

Furthermore, maize hybrids ZP-1 and ZP-5 showed the best stability among investigated hybrids, but at the same hybrid ZP-5 had lowest grain yield in the trial. Delić et al. (2009) also found that hybrid with low grain yield showed good stability.

Regarding the method proposed by Lin and Binns’ (1988) it was observed that hybrid ZP-3 showed lowest value of Pi measure and is considered as a most desirable genotype. Similar results were obtained by Alberts, 2004 who concluded that the highest yielding genotype had lowest Pi value.

By obtaining results of Spearman rank correlation coefficient we found positive correlation between values of Pi and grain yield and didn’t find correlation between grain yield and regression coefficient bi (Tab. 3).

Table 3. Spearman’s coefficients of rank correlation for grain yield and stability parameters

<table>
<thead>
<tr>
<th></th>
<th>Grain yield</th>
<th>bi</th>
<th>Pi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>0.000</td>
<td>0.667</td>
</tr>
<tr>
<td>bi</td>
<td>x</td>
<td>-0.333</td>
<td></td>
</tr>
<tr>
<td>Pi</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion

Based on results obtained in this study, we can conclude that early to medium maturity hybrids produced higher yielding than medium to late maturity.

Maize hybrid ZP-3 had highest average yield during the three-year period.

Early to medium maturity hybrids are recommendable for growing in poor environments and medium to late maturity hybrids are recommendable for better environments.

Regarding the values of regression coefficients, hybrid ZP-5 showed the best stability between investigated genotypes, but at the same time lowest grain yield.

According to the results gathered applying Lin and Binns model, hybrid ZP-3 is considered as a most stable genotype.

There is no correlation between grain yield and regression coefficients, so some hybrids can have good stability but low grain yield and some hybrids with high grain yield is not always considered as a stable...
References


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