Combining abilities for grain yield of the most drought tolerant maize accessions from the MRI gene bank

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Abstract
The Gene Bank of the MRI Zemun Polje is one of the largest in Europe. After two-year studies of drought tolerance at three locations, a total of 51 genotypes, originating from the gene bank, former and current working collections of the Institute, were selected. The genotypes were crossed to three different testers in order to determine combining abilities and to classify them into heterotic groups. The field trials were carried out in Zemun Polje in 2009. Out of all genotypes, 34 with good combining abilities (CA) will be used to form synthetic populations for short- and long-term breeding programmes. In this way, a genetic base of the breeding material existing in Serbia will broaden.

Key words: drought, gene bank, heterotic group, maize (Zea mays L.), tolerance

Introduction
Drought is an abiotic factor causing a significant yield reduction in the majority of maize growing areas throughout the world. Global warming and predictions of climatic changes will result in a long-term trend of increased temperatures, higher evapotranspiration and more frequent drought occurrence in certain regions (Hillel and Rosenzweig, 2002). Today, the development of maize hybrids tolerant to drought is one of the priorities in world’s leading breeding companies (Butzen and Schussler, 2006).

In temperate region, the aim is development of drought tolerant maize hybrids, with stable yields under conditions of the optimum water supply as well as under drought (Frova et al., 1999). Usually, studies of drought tolerance are performed in the managed stress environments (MSE). These locations have little or no precipitation at all during the growing season and maize is supplied by water only through irrigation.

Breeders are almost exclusively using their working collections, and recently they have started to use F1 hybrids to develop new populations and inbred lines (Parks, 1993). In that way, a genetic base is narrowed and all disadvantages of a uniform material are increasing. Moreover, breeders are using already adapted or improved material, while wild relatives, varieties and exotic germplasm available in gene banks, remain unused. The identification of potentially beneficial genes within large collections of gene banks is one of the main limiting factors of their minor exploitation in the breeding programmes (Marshall, 1989).

Pre-breeding is the best link between genetic resources and breeding programmes and encompasses the identification of desirable traits and/or genes from the non-adapted, as well as, from the adapted material, that will be under certain selection pressure. As a result of this programme, new populations are developed for the needs of breeding.

Heterotic groups are a decisive factor for the utilisation of germplasm by different crosses for developing hybrids with better performances (Eberhart et al., 1995). The advantage of pre-breeding programmes is the establishment of core collections that present genetic diversity of a certain plant species with the minimum repetitiveness. The core usually encompasses approximately 10% of the collection what makes almost 70% of its genetic variability (Brown, 1989).
In Serbia, July was the hottest month during the last four decades and with the greatest precipitation deficit, as well. Then, flowering stage in maize occurs, critical for the grain yield formation. It means that is necessary to develop drought tolerant maize hybrids. Such a complex trait requires studies of a great number of genotypes and their characterisation under conditions of adequate environments.

The gene bank of the Maize Research Institute Zemun Polje is the largest maize germplasm collection in Europe and one of the largest in the world. New sources of drought tolerance were searched among the gene bank accessions. The entire collection is consisted of the local and the introduced collection. The local collection comprises of local landraces collected from all agroecological regions of former Yugoslavia. The accessions are classified according to their morphological traits, origin and evolution into 18 agroecological groups. The collection of the introduced maize germplasm is made of accessions received from approximately 40 different countries.

The objective of our study was to select genotypes from this gene pool, observed in the adequate location for precisely defined traits and their classification into heterotic groups. This is the most important in the formation of the initial material for breeding purposes.

Material and methods

The entire material of the MRI gene bank, as well as, some previous and current commercial inbred lines and hybrids of the Maize Research Institute Zemun Polje, was subjected to water stress in Egypt, at the Setz station of the Agricultural Research Centre in 2007. A total of 6371 accessions were included into the experiment, consisting of 2217 OP varieties from the territory of former Yugoslavia, 2254 introduced inbred lines, 1335 introduced heterozygous accessions (populations, synthetics, landraces, composites), 549 inbred lines from the breeding programmes and 16 elite hybrids.

Development of genetic stock in 2007: The genotypes were sown on August 19, 2007. This material was divided into five groups, according to the duration of the growing season: extra early, early, medium, medium late and late. There is no precipitation in the vicinity of the Setz station during the growing season and, as far as the water supply is concerned, the only uncontrolled factor is the level of the underground water. Five groups of the experimental material were sown separately and were irrigated until the appearance of the first tassels (within each group), which was approximately two weeks before flowering of the earliest accessions within groups. After that, no irrigation was applied. Three weeks before harvesting, the material was scored visually, and the best accessions in that stage were recorded. This was done by recording both stay-green (on the 1-5 scale, where 5 was the highest rate), and the total appearance of the accession (on the 1-8 scale, where 8 was the highest rate). Data for pollination and silking of each accession were recorded, and their difference (ASI) was calculated.

Harvest was performed on November 8 and 9, 2007. The material was selected on the basis of ASI (3 or less for heterozygous accessions, and 4 or less for homozygous ones), % of plants with seed set (60% for heterozygous, and 50% for homozygous accessions), % of seed set (85% for heterozygous, and 80% for homozygous accessions) and % of grain filling (85% for heterozygous, and 80% for homozygous accessions).

About 10.5% of the material (a total of 672 accessions) was selected according to reported criteria for the further testing in 2008 in three locations (Egypt, Macedonia and Serbia/Zemun Polje). Within this material, there were 167 OP varieties from former Yugoslavia, 201 introduced inbreds, 204 introduced heterozygous accessions and 100 inbreds from the breeding programme. This represents a source material for selection the most drought tolerant sources, which will serve for the formation of a core-collection for drought tolerance in the MRI gene bank and also for pre-breeding for this trait.
Development of genetic stock in 2008: In 2008, these 672 accessions were tested in Egypt in already described mode, as well as, in Macedonia (Skopje) and Serbia (Zemun Polje) under rainfed conditions. The same traits were observed as the year before, and according to the average of these traits for the three studied locations, 51 most drought tolerant accessions were selected. Out of this number of accessions, there were 20 OP populations from the collection, 14 introduced populations and 17 introduced inbreds.

Beside drought tolerance, the information on CA of selected material in order to classify it into heterotic groups is necessary to form the core. The drought tolerant material but without good CA is unacceptable for selection. Therefore, these 51 accessions were crossed in Chile in 2008/09 (winter nursery) to three elite inbred testers from three heterotic groups that mutually combined well (Lancaster, BSSS and independent source). Accessions were used as female components, and at least 50 plants from each population were crossed to encompass the genetic variability.

Field trials in 2009: Testcrosses were studied in trials in Zemun Polje in 2009. The three-replicate trials were set up according to the randomised block design with 20 plants within a row while hills, i.e. rows were 0.4 m, i.e. 0.7 m apart, respectively (2 plants per hill). The trials were sown and harvested manually, while the yield t ha⁻¹ was calculated at 14% moisture. The hybrid ZP 341, as one of the most yielding and most drought tolerant ZP hybrids, was included into the trials as a check.

Criterion for the genotype selection: The criterion for the selection of good test-crosses was the yield not statistically significantly different from the check, or the performance index (based on grain yield and grain moisture at harvest) that was over 100% in comparison to the check.

Results and discussion
Combining abilities and the supposed genetic relatedness with observed heterotic sources are presented in Table 1.

Table 1. Combining abilities and the supposed genetic relatedness with observed heterotic sources of the most drought tolerant maize accessions from the MRI gene-bank

<table>
<thead>
<tr>
<th>Supposed genetic relatedness with</th>
<th>No. of investigated acc.</th>
<th>Good CA with</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSSS</td>
<td>1</td>
<td>Lancaster, Independent source</td>
</tr>
<tr>
<td>Lancaster</td>
<td>4</td>
<td>BSSS, Independent source</td>
</tr>
<tr>
<td>Lancaster, BSSS</td>
<td>3</td>
<td>Independent source</td>
</tr>
<tr>
<td>Unknown</td>
<td>7</td>
<td>BSSS, Lancaster, Independent source</td>
</tr>
<tr>
<td>Independent source</td>
<td>3</td>
<td>BSSS, Lancaster</td>
</tr>
<tr>
<td>Independent source, BSSS</td>
<td>7</td>
<td>Lancaster</td>
</tr>
<tr>
<td>Independent source, Lancaster</td>
<td>9</td>
<td>BSSS</td>
</tr>
<tr>
<td>Useless</td>
<td>17</td>
<td>None</td>
</tr>
</tbody>
</table>

Out of 51 investigated accessions, 17 did not combine well with any of heterotic sources. It is very important that 7 accessions had good CA with all three observed heterotic sources. They enable broadening of genetic variability and these accessions can make a completely different source of favourable germplasm, as well.

The further work with the chosen material (34 accessions) could be performed in the two directions: 1. the development of synthetics from accessions per se (in the first case in which only 1 accession is related to BSSS, it will be the improvement of this accession per
for the long-term breeding programme, considering a relatively low frequency of favourable alleles for more important agronomic traits (ear height, resistance to lodging, diseases and pests, etc.), except drought tolerance that had already been determined in them; 2. the approach for short-term breeding programmes is the development of synthetics from the test-crosses of the selected accessions per heterotic groups with related testers. Developed synthetics will already have 50% of favourable alleles for important agronomic traits, originating from testers. A parallel S1-HS recurrent selection, with the use of inbred testers, is recommended for the improvement of developed synthetics. In this way, synthetic performances per se can be improved, with maintenance and probably significant enhancement of their CA. The programme will broaden the genetic base of the elite breeding material and most probably new elite inbred lines with increased drought tolerance will develop. They could be used for new generations of maize ZP hybrids of higher yielding potential and adaptability.

Conclusion
New sources for drought tolerance were searched among 6371 accessions of the gene bank of the Maize Research Institute Zemun Polje. Fifty one most drought tolerant accessions were selected, and 34 out of these accessions had good CA. It is planned not only to develop synthetic populations from this material, according to the classification into heterotic pairs, but also to improve them. Such a programme will broaden the genetic base of the elite breeding material.

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References