Effects of the herbicide application on physiological and productive parameters of maize inbred lines

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Abstract
Susceptibility of maize inbred lines causes a need to study their response to the existing and new active ingredients of herbicides. The present study observes the effects of the application of five sulfonylurea herbicides at the content of dry weight and soluble proteins in seedlings, as well as at the grain yield of nine ZP maize inbred lines. The differences in susceptibility to applied herbicides were observed among genotypes. Dry weight values of the plant shoots of the studied maize inbreds varied and were significantly lower in 2007 than in 2006. The highest yield reduction, on the average for all genotypes, was determined in the treatment with foramsulphuron in 2006 and thifensulphuron-methyl in 2007 (7.06 and 4.10 t ha⁻¹, respectively).

Key words: maize, inbreed lines, herbicides, dry weight, yield

Introduction
Maize inbred lines, parental components of hybrids, are characterised by low vigour, slower growth and smaller habitus, what makes them susceptible to various stress conditions. The weed presence and the inadequate herbicide application are factors that compromise the seed production. As weed infestation very often complicates many activities that should be performed on the optimum dates, and also affects the maize grain yield reduction, the post-emergence herbicide application has been increasingly becoming a protection measure. The same herbicide combinations are applied in the maize seed crop, as well as in the hybrid crop. The suppression of perennial and annual grass weeds became successful when sulfonylurea herbicides were introduced into practice (Foy and Witt, 1990). These herbicides have been widely applied in seed maize crops, due to their good efficiency, broad spectrum activity and the application in a very small rates. The efficient and safe application of sulfonylurea herbicides is reduced in maize inbred lines due to their different responses (Green and Urlich, 1994; Malidža et al., 1996; Stefanović et al., 2000). Climatic conditions that greatly affect a faster or slower emergence, growth and the development of maize and weed plants, contribute to better or poorer effects of herbicides. In addition, it is well known that the application of greater herbicides rates per area unit is not recommended because of maize inbred susceptibility (Stefanović et al., 2001; Stefanović et al., 2007; Stefanović and Simić, 2008).

The precise information on inbred susceptibility is of a great significance in yield planning in the hybrid maize seed production. The reaction of maize inbred lines depends on the genotype, herbicides, environment, as well as, on the interaction of all these factors (Landi et al., 1989; Malidža, 1996; Stefanović and Simić, 2008). It was observed that the introduction of sulfonylurea herbicides increased susceptibility of maize inbred lines under the conditions of our country (Stefanović et al., 1996, 2007; Malidža et al., 1996). Plant injuries in susceptible inbreds are expressed in the form of various deformities, colour alternations that are mostly manifested as the red or yellow leaf colour, twisting of the plant shoots. These
changes are observable in the beginning of the growing season (Stefanović et al., 2001). The more susceptible plants have the greater intensity of changes, and in some cases the plant dries and dies (Stefanović et al., 2000). The herbicide treatments result in changes of the dry weight content of the plant shoots, and in the disturbance of the grain moisture at harvest. Due to the field intensive infestation by grass weeds, the application of herbicides of the sulfonylurea group has become a necessity in the seed maize production. As the application of these herbicides are not allowed in seed crops, it is necessary to know and monitor a response of individual inbreds and to make solutions for each hybrid combination.

**Material and methods**

Field experiments were conducted during 2006-07 at the Maize Research Institute, on a slightly calcareous chernozem soil type. During the both experimental years, winter wheat was used as a preceding crop. Effects of the sulfonylurea herbicides application on the content of dry weight and proteins in seedlings, as well as, on the grain yield of nine ZP maize inbred lines were observed in the trial. The main plots encompassed one row of each inbred line, while subplots included a five post-emergence herbicides and a control, without the herbicide application.

Inbred lines were sown manually on April 18 and 29, while herbicides were applied in the 4-6-leaf stage of maize. The following herbicides were applied: nicosulphur (Motivell) in the amount of 50.0 g a.i. ha\(^{-1}\), foramsulphuron (Equip) in the amount of 50.0 g a.i. ha\(^{-1}\), rimsulphuron + dicamba (Tarot plus-WG) in the amount of 9.78 + 182.4 g a.i. ha\(^{-1}\), foramsulphuron + iodosulohuron - methyl - sodium (Maister-OD) in the amount of 45.0+1.5 g a.i. ha\(^{-1}\) and rimsulphuron + thifensulphuron - methyl (Grid 75-WG) in the amount of 10.0 + 5.0 g a.i. ha\(^{-1}\). The trial also encompassed the control, in which herbicides were not applied.

The dry weight (after drying at 105 °C) and the soluble protein content (Lowrey et al., 1951) were determined 48 hours after the herbicide application. The grain yield was measured at the end of a growing cycle and recalculated at 14% of moisture.

Obtained data have been statistically processed by the analysis of variance (ANOVA), while differences of means were determined by the LSD test at the 0.05 probability level.

The average monthly air temperatures during the maize growing season were different in the two experimental years: in 2007 was higher a\(\overline{v}\)erage monthly temperature (20.7 °C) than in 2006 (18.1°C). The sum of the precipitation was optimal in 2007 (364.5 mm), while it was sufficient in 2006 (229.4 mm).

**Results and discussion**

Gained results point out to a great variation in values for the dry weight of the plant shoots in observed maize inbreds lines depending on meteorological conditions and applied herbicides (figure 1). The dry weight of the shoots was significantly lower in 2007 than in 2006. It is well known that environmental factors, such as high temperatures and air humidity directly or indirectly affected the absorption of herbicides (Janjić, 2002). Therefore, higher average monthly temperatures and the greater precipitation sum in 2007 contributed to a better absorption of herbicides what affected the growth of inbred plants. The soluble protein content in the shoots of treated inbreds significantly varied from the control (figure 2). Depending on a genotype and an herbicide, the protein content in the shoots was generally higher in variants treated with herbicides than in the control in both years of investigation. Results obtained in previous studies show that the protein content increased in susceptible genotypes as a results of the herbicides' application such as...
Atrazine and metolachlor (Hiranpradit et al., 1972; Pillai et al., 1979). On the other hand, sulfonylurea herbicides have a very specific mode of actions; initially and applied in small rates they do not affect photosynthesis, respiration, synthesis of proteins, lipids and RNA, but if applied in certain concentrations they strongly block the cell division (Ray, 1982). This can be explained by the increased content of soluble proteins in susceptible maize plants 48 hours after the application of herbicides.

Regardless of the fact that the meteorological conditions significantly affected the dry matter content of the shoots, the dependence of the protein content was less pronounced. The protein content was higher in the majority of genotypes than in the control, particularly in treatments with foramsulphuron and nicosulphuron in 2006.

The grain yield of maize inbreds also varied over genotypes, years and applied herbicides (table 1). Due to the differences in meteorological conditions of the season, the grain yield was significantly higher in 2006 (7.83 t ha\(^{-1}\)) than in 2007 (4.30 t ha\(^{-1}\)). It is observable that
the reduction in grain yields was not significant concerning the control, meaning that inbreds had successfully recovered during the growing season. However, the average yield in 2006 was a somewhat lower than in the control. The yield obtained in certain inbreds was even higher in variants with herbicides than in the control (foramsulphuron + iodosulphuron -methyl - sodium in 2006 and nicosulphuron in 2007). On the other hand, the highest yield reduction, on the average for all genotypes, was recorded in the treatment with foramsulphuron in 2006 (7.06 t ha\(^{-1}\)) and thifensulphuron-methyl in 2007 (4.10 t ha\(^{-1}\)). Genotypes are differently susceptible to applied herbicides. Hence, the inbred L2 had the lowest yield in both years in treated variants compared to the control, so as it can be referred to as a susceptible inbred. The grain yield of this inbred was particularly low in treatments with rimsulphuron+dicamba and thifensulphuron-methyl. The grain yield of the inbred L6 was not recorded in the variant treated with foramsulphuron in 2007.

<table>
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<th>Genotype</th>
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<th>Tarot pl.</th>
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Gained results are in accordance with results obtained in previous studies in which grain yields of maize inbreds were significantly affected by meteorological conditions, applied herbicides and genotypes (Malidža, 2007; Stefanović et al., 2007; Stefanović and Simić, 2008).

**Conclusion**

Obtained results on effects of the application of herbicides of the sulfonylurea group on the content of dry weight and soluble proteins in seedlings, as well as, on the grain yield of ZP maize inbred lines, indicate a great variation in values of observed parameters. The dry weight values of the plant shoots were significantly lower in 2007 than in 2006, while the content of soluble proteins diverged in a greater degree from the control in both years.
The grain yield was significantly higher in 2006 (7.83 t ha\(^{-1}\)) than in 2007 (4.30 t ha\(^{-1}\)). The highest yield reduction, on the average for all genotypes, was determined in the treatment with foramsulphuron in 2006 (7.06 t ha\(^{-1}\)) and thifensulphuron-methyl in 2007 (4.10 t ha\(^{-1}\)).

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**References**


