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# IMPORTANCE OF TWO-CROP ROTATION IN MAIZE WEED CONTROL

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## Abstract

Importance of two-crop rotation on decreasing a number of weed plants and fresh weed biomass and increasing maize grain yield, were studied on two cropping system: maize monoculture (MM) and maize-wheat rotation (MW) in period 2009-2013. Experiment was conducted at the experimental field of Maize Research Institute Zemun Polje, Belgrade. During five years of study, on MM plot maize was sown every year and on MW plot maize and wheat were rotated (maize was sown in 2009, 2011, 2013 and wheat was sown 2010 and 2012). Studies were conducted on maize hybrids ZP 677 (H1) and ZP 606 (H2).
After every rotation of maize and wheat, number of weed plants and their fresh biomass in maize decreased in MW. In 2013, after closing of two rotation, weed infestation decreased for 20 plants/$m^2$ and 412,0 g/$m^2$ in H1 and 12 plants/$m^2$ and 449,9 g/$m^2$ in H2. After two rotation of maize and wheat, in maize monoculture weediness increased for 4 plants/$m^2$ and 133,0 g/$m^2$ in H2. Number of weed plants and their fresh biomass was the same as in the first year of study in H1. Compared to monoculture, maize grain yield was higher in MW for 1,14 t/ha (H1) and 2,03 t/ha (H2) in 2011 and for 1,06 t/ha (H1) and 2,35 t/ha (H2) in 2013. All differences in maize grain yield were significant, based on statistical analysis. Wheat can directly influence decrease of weediness in maize and indirectly increase its grain yield.

**Key words**: *maize, wheat, monoculture, crop rotation, weeds.*

## Introduction

Weed infestation of cereals is a problem for growers despite numerous options and methods of weed suppression, both chemical and non-chemical ones (Stasinskis, 2009). Continuous cropping, as a system of plant production, can be a significant infection source by many diseases and pests, and also a factor of intensive weed development on soils (Kovačević, 2003). Polycrop rotations adversely affect both, the disease development cycle and the growth and development of weeds and, in such a way, they contribute to the yield increase of crops (Karlen et al., 1994). Crop sequencing and due to it the application of different herbicides, significantly contributes to control of annual, and especially of perennial weeds (Simic et al., 2014). Crop rotation sometimes is not the most important measure, but only one that can properly help in suppression of weeds, diseases and pests (Kovačević et al., 2008).
The composition of weed associations depends more on preceding crops and herbicide application timing than on tillage methods (Streit et al., 2003). Wheat as a preceding crop, alongside with herbicides applied during the growing season as well as glyphosate-based herbicides applied to stubble fields after wheat harvest, greatly contribute to the reduction of weed infestation of maize as the following crop.
The objective of the study was to demonstrate the significance and the advantages of wheat as a preceding crop of maize for the reduction of weed infestation and therefore for the increase of maize gain yield compared to maize continuous cropping.

## Materials and Methods

The split-plot trial was carried out in the experimental field of the Maize Research Institute, Zemun Polje (44º52’ N 20º20’ E) in the 2009-2013 period. Two types of crop rotation were applied: maize continuous cropping and maize-wheat rotation. Comply with the alteration of crops, maize was continuously cropped in all five years of investigation, while in the two crop rotation maize was grown in 2009, 2011 and 2013, while wheat was grown in 2010 and 2012.
The trials were performed with the following two maize hybrids of FAO maturity group 600 developed at the Maize Research Institute: ZP 677 (hybrid of the older generation) and ZP 606 (hybrid of a more recent generation).
Herbicides Trophy (acetochlor 1536 g a.i./ha) and Merlin (isoxaflutole 105 g a.i./ha) were applied in the recommended rates after sowing but prior to emergence of maize. Weeds were estimated by a one square meter survey 45-50 days after the application of herbicides. The number of weed plants and then weed fresh biomass per square meter, were determined. The grain yield was established at the full maturity of maize and calculated at 14% moisture. As results obtained on maize weed infestation and grain yields were compared between maize continuous cropping and maize-wheat rotation, this paper presents results gained in 2009, 2011 and 2013. The differences in weed infestation and grain yields were not compared between hybrids, because maize hybrids do not affect weediness and also hybrids used in the study were of the older and the more recent generation, and as it is known newly developed hybrids are more yielding.
In tables we presented only six species of weeds: CHEAL (*Chenopodium album* L.), CHEHY (*Chenopodium hybridum* L.), DATST (*Datura stramonium* L.), SORHA (*Sorghum halepense* Pers.), CONAR (*Convolvulus arvensis* L.) and CIRAR (*Cirsium arvense* L. Scop.) and in last row of table we gave total weediness.
Meteorological conditions were similar for maize production in 2009, 2011 and 2013 (Table 1). Maybe, last year of experiment was the most unfavourable for maize production. One of reasons can be less precipitation in summer (Jun and July) of 2013 year than in same period in 2009 and 2011 year.

Table 1. Precipitation sums (mm) and average monthly temperatures (°C) on experimental field in 2009, 2011 and 2013.

| Month | Precipitations | | | Temperatures | | |
|---|---|---|---|---|---|---|
| | 2009 | 2011 | 2013 | 2009 | 2011 | 2013 |
| April | 5,6 | 11,1 | 14,9 | 16,2 | 14,6 | 14,9 |
| May | 35,0 | 62,6 | 93,9 | 19,8 | 17,3 | 19,7 |
| Jun | 153,0 | 40,4 | 37,8 | 21,2 | 22,4 | 21,9 |
| July | 79,6 | 107,4 | 16,0 | 24,0 | 24,2 | 23,8 |
| August | 44,8 | 8,9 | 12,7 | 24,1 | 24,8 | 23,7 |
| September | 4,6 | 48,5 | 70,1 | 21,1 | 23,2 | 16,9 |

## Results and Discussion

The number of weed plants differed in both hybrids in dependence on the type of crop rotation (Tables 2 and 3). This number in the hybrid ZP 677 generally remained unchanged in maize continuous cropping (12-14 plants/$m^2$), while it ranged in maize-wheat rotation from 20 plants/$m^2$ in the first year of investigation (2009) over 3 plants/$m^2$ at the end of the first rotation (2011) to 0 plants/$m^2$ after the second rotation (Table 2). It is important to emphasise that the two-crop rotation significantly lowered number of perennial weeds in comparison to maize continuous cropping, taking in account that applied herbicides are not created for perennial weeds control.
According to the LSD test, the difference in the number of weed plants between observed crop rotations was statistically very significant (Table 2).

Table 2. Number of weed plants in maize continuous cropping and maize-wheat rotation in hybrid ZP 677 (plants/$m^2$)

| | MM | | | MW | | |
|---|---|---|---|---|---|---|
| | 2009 | 2011 | 2013 | 2009 | 2011 | 2013 |
| Annual weeds (A) | | | | | | |
| CHEAL | | 2 | | | | |
| CHEHY | 3 | 2 | 3 | 6 | | |
| DATST | | | | 4 | | |
| **Total** | **4** | **6** | **4** | **10** | **0** | **0** |
| Perennial weeds (B) | | | | | | |
| SORHA | | 1 | 4 | 1 | 1 | |
| CONAR | 8 | 4 | 6 | 8 | 2 | |
| CIRAR | 2 | 1 | | | | |
| **Total** | **10** | **6** | **10** | **10** | **3** | **0** |
| **Sum A+B** | **14** | **12** | **14** | **20** | **3** | **0** |
| $LSD_{0,05}$ | | 6,47 | | $LSD_{0,01}$ | 8,50 | |

Table 3. Number of weed plants in maize continuous cropping and maize-wheat rotation in hybrid ZP 606 (plants/$m^2$)

| | MM | | | MW | | |
|---|---|---|---|---|---|---|
| | 2009 | 2011 | 2013 | 2009 | 2011 | 2013 |
| Annual weeds (A) | | | | | | |
| CHEAL | | 2 | | | | |
| CHEHY | 6 | 2 | 2 | 1 | | |
| DATST | 1 | | | | | |
| **Total** | **10** | **5** | **5** | **1** | **1** | **0** |
| Perennial weeds (B) | | | | | | |
| SORHA | | 3 | 7 | 3 | | |
| CONAR | 5 | 4 | 6 | 8 | 5 | 1 |
| CIRAR | 1 | | | 1 | | |
| **Total** | **6** | **7** | **15** | **12** | **5** | **1** |
| **Sum A+B** | **16** | **12** | **20** | **13** | **6** | **1** |
| $LSD_{0.05}$ | | 9.70 | | $LSD_{0.01}$ | 13.41 | |

In regard to the hybrid ZP 606, the number of weed plants in maize continuous cropping increased from 16 plants/$m^2$ in 2009 to 20 plants/$m^2$ in 2013 (Table 3.). On the other hand, weed infestation decreased in the maize-wheat crop rotation from 13 plants/$m^2$ in 2009 to 1 plant/$m^2$ in 2013 (Table 3). It should be noted that the number of perennial weed plants in

maize continuous cropping increased from 6 plants/$m^2$ (2009) to 15 plants/$m^2$ (2013), while this number in the two crop rotation decreased from 12 plants/$m^2$ (2009) to 1 plant/$m^2$ (2013). According to the LSD test, the differences in the number of weed plants between maize continuous cropping and the maize-wheat rotation were statistically significant (Table 3).
One of the reasons that could decrease the number of weed plants in the two-crop rotation is wheat, a crop alternating with maize. Wheat seedlings and straw have allelopathic effects on the increase of weed plants (Wu *et al*.,1998). A preceding crop has a great effect on a weed population (Streitetal, 2003). Small grains due to a higher growing density can suppress many weeds, particularly some perennial species, resistant to other control measures (Stefanović et al., 2011).
Weed fresh biomass in the hybrid ZP 677 in maize continuous cropping in the first year of investigation and after two crop rotations was completely equal, while it was reduced in the two crop rotation from 412.0 g/$m^2$ (2009) to 57.2 g/$m^2$ after the first rotation, while there were no weeds after the second crop rotation (Table 4). In addition to unchanged weed fresh biomass in maize continuous cropping, fresh biomass of perennial weeds increased by 54.5 g/$m^2$ in maize continuous cropping and it decreased by 291.9 g/$m^2$ in the crop rotation (Table 4).

Table 4. Weed fresh biomass in maize continuous cropping and two-crop rotation in hybrid ZP 677 (g/$m^2$)

| | MM | | | MW | | |
|---|---|---|---|---|---|---|
| | 2009 | 2011 | 2013 | 2009 | 2011 | 2013 |
| Annual weeds (A) | | | | | | |
| CHEAL | | 25.6 | | | | |
| CHEHY | 130.1 | 37.8 | 85.1 | 50.9 | | |
| DATST | | | | 69.2 | | |
| **Total** | **144.3** | **89.5** | **89.3** | **120.1** | **0.0** | **0.0** |
| Perennial weeds (B) | | | | | | |
| SORHA | | 30.3 | 266.3 | 3.0 | 30.8 | |
| CONAR | 174.9 | 80.1 | 164.2 | 264.4 | 26.4 | |
| CIRAR | 201.1 | 33.6 | | | | |
| **Total** | **376.0** | **144.0** | **430.5** | **291.9** | **57.2** | **0.0** |
| **Sum A+B** | **520.3** | **233.5** | **519.8** | **412.0** | **57.2** | **0.0** |
| $LSD_{0.05}$ | 230.7 | | $LSD_{0.01}$ | 318.9 | | |

A similar trend was noticed in the hybrid ZP 606 (Table 5). Total weed fresh biomass and fresh biomass of perennial weeds in maize continuous cropping increased from 440.1 g/$m^2$, i.e. 219.5 g/$m^2$ (2009) to 573.1 g/$m^2$, i.e. 499.0 g/$m^2$ (2013), respectively (Table 5). However, total weed fresh biomass and fresh biomass of perennial weeds in the maize-wheat rotation reduced from 535.3 g/$m^2$ and 498.8 g/$m^2$ (2009), respectively, to 85.4 g/$m^2$, which was total weed fresh biomass and fresh biomass of perennial weeds, because only perennial weeds were distributed after herbicide application.
According to the LSD test, the differences in weed fresh biomass between maize continuous cropping and maize-wheat rotation were very statistically significant in hybrid ZP 677 and on the level of statistical significance in hybrid ZP 606.

Table 5. Weed fresh biomass in maize continuous cropping and two-crop rotation in hybrid ZP 606 (g/m$^2$)

| | MM | | | MW | | |
|---|---|---|---|---|---|---|
| | 2009 | 2011 | 2013 | 2009 | 2011 | 2013 |
| | | | Annual weeds (A) | | | |
| CHEAL | | 50.9 | | | | |
| CHEHY | 137.6 | 43.6 | 22.4 | 36.5 | | |
| DATST | 47.9 | | 15.8 | | | |
| **Total** | **220.6** | **103.9** | **74.1** | **36.5** | **17.3** | **0.0** |
| | | | Perennial weeds (B) | | | |
| SORHA | | 262.7 | 310.2 | 69.0 | | |
| CONAR | 188.7 | 51.3 | 136.7 | 419.0 | 103.4 | 85.4 |
| CIRAR | 30.8 | | | 10.8 | | |
| **Total** | **219.5** | **314.0** | **499.0** | **498.8** | **103.4** | **85.4** |
| **Sum A+B** | **440.1** | **417.9** | **573.1** | **535.3** | **120.7** | **85.4** |
| $LSD_{0.05}$ | | 489.1 | | $LSD_{0.01}$ | 676.2 | |

Gained results are in accordance with results obtained by Kovačević et al. (2008). These authors showed that weed fresh biomass in two crop rotations was significantly lower than in maize continuous cropping and other polycrop (3, 4 and 6) rotations. Crop sequencing unlike continuous cropping reduces the number of weed species as well as total coverage of weed communities (Milošev et al., 2008). Positive effects of crop rotations on weed suppression, therefore, consist of prevention of over-distribution and spreading of certain weed species and accumulation of their seeds and vegetative organs in the soil, which is normally achieved by growing crops in continuous cropping.

Due to observed weed infestation, grain yields were higher in two-crop rotations than in maize continuous cropping (Table 6). Grain yields of the hybrid ZP 677 were higher by 1.04 t/ha, 1.18 t/ha and 1.16 t/ha in 2009, 2011 and 2013, respectively. The corresponding values of the hybrid ZP 606 were 0.2 t/ha, 2.05 t/ha and 2.35 t/ha.

According to the LSD test, the differences in grain yields between maize continuous cropping and the two-crop rotation in hybrids ZP 677 and ZP 606 were statistically significant and very statistically significant, respectively (Table 6).

Table 6. Grain yields of hybrids ZP 677 and ZP 606 obtained in maize continuous cropping and maize-wheat rotation (t/ha)

| Year | H1 | | H2 | |
|---|---|---|---|---|
| | MM | MW | MM | MW |
| 2009 | 11.60 | 12.64 | 15,06 | 15,26 |
| 2011 | 7.92 | 9.10 | 8,55 | 10,60 |
| 2013 | 7.45 | 8.51 | 9,11 | 11,46 |
| | **H1** | | **H2** | |
| $LSD_{0.05}$ | 1.04 | | 1.27 | |
| $LSD_{0.01}$ | 1.44 | | 1.75 | |

Effects of continuous cropping on grain yields mainly depend on the duration of continuous cropping, climate, varieties (hybrids) and the level of applied cropping practices, first of all applied rates of fertilisers and herbicides (Dolijanović et al., 2005). Crop rotations improve grain quality and reduce maize yield variability (Kaye et al., 2007). Grain yield is on the average higher by 10-17% when maize is grown in crop rotations in comparison with continuous cropping (Higgs et al., 1990).

## Conclusion

Weed infestation of maize, in respect to the number of weed plants and weed fresh biomass is much weaker in two-crop rotations than in continuous cropping. The effects of crop rotations are particularly more expressed on reducing weed infestation in perennial weeds that are very troublesome for suppression. Wheat, grown in maize-wheat rotation, had allelopathic and mechanical effects on the reduction of weed infestation. The lower weed infestation level gives more favourable growing conditions for maize production, causing weaker competition for water, nutrients and light between maize and weeds.

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