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# WEEDS SEED BANK RICHNESS IN MAIZE FIELD: EFFECTS OF CROP ROTATION AND HERBICIDES

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## Abstract

Crop rotation is important measure within Integrated Weed Management System. Sequences with row and grain crops, legumes and cereals influence weed community composition and seed bank richness. Cropping system diversification through extended rotation sequences contribute to reductions in weed sandbanks which determination in arable fields can facilitate to prediction of the future weed problems. This study assessed the effects of cropping system – continuous cropping, two and three crop rotations, and different weed management practices (application of full recommended herbicide dose and half that dose, weed removal by hoeing and weedy check) on weed seed bank richness in maize field.

Soil sampling for seed bank counting was carried out on the sowing and harvest time in 2012 and 2013. Soil samples were collected from the upper soil layer, with shovel 10x10 cm in a base and 4 cm deep. The average 200 g soil sample was washed inside special designed cylinders made from sieves mesh (0.2 mm), in order to separate weed seeds which were counted and identified by species under a magnifying glass (×10).

The most abundant were broadleaf annual weed species *Chenopodium* sp., *Amaranthus* sp. and *Datura stramonium*. The highest number of total weed seeds was identified in maize continuous cropping and the lowest number in three crop rotation maize-wheat-soybean in both years. Application of different amounts of herbicides did not affect weed seed bank richness in the first 3-4 years of crop rotation. Processes which affects the weed seed bank in the fields are complex and vary according to production practices.

**Key words:** *weed seed bank, crop rotation, herbicides, maize*

## Introduction

Weed seeds placed in and on the soil, are the primary cause of weed infestation in maize fields. Seed bank richness is changeable and many processes influence seed additions and losses in the soil through time and system of production (Mohler, 2001). Herbicide application is a usual practice in maize weed control, but occurrence of resistant biotypes and invasive weeds, prevalence of troublesome weed species and increasing of weed seed bank richness, are the most important consequences of limitation in cropping systems, a lack of rotation of herbicide chemistry or sites of action and a limitation in weed control techniques (Menne and Köcher, 2012). Weed seed bank determination in arable fields can contribute to prediction of the future weed problems. Crop rotation is important measure within Integrated Weed Management System (IWMS), (Swanton and Weise, 1991). Requirements in maize growing are nowadays still high and there are many reasons for very intensive and profitable maize production. That forces maize continuous growing with positive effects on economy and many negative effects on environment and agro-phytocenoses, especially weed community. Cropping system diversification through the use of longer rotations of dissimilar crops can increase the mortality factors that regulate weed population dynamics and can facilitate effective weed control with reduced rates of applied herbicides (Liebman et al., 2014). Sequences with row and grain crops, legumes and cereals influence weed community composition, abundance of individuals and soil seed bank richness (Teasdale et al., 2004; Bohan et al., 2011). Rotations facilitate the rotation of herbicides with the ability to control different weed species. Previous studies have documented reductions in weed seed banks due to cropping system diversification through extended rotation sequences (Schreiber, 1992; Teasdale et al., 2004).The alternation of crops breaks the life cycle and prevents a high distribution of any single weed species (Bastiaans, 2010). This study assessed the effects of cropping system – continuous cropping, two and three crop rotation, and different weed management methods including herbicide application, on weed seed bank richness in maize field.

## Material and methods

A long-lasting field experiment have started in 2009, as a split-plot trial in the Maize Research Institute Zemun Polje, at the vicinity of Belgrade (44°52'N 20°20'E), Serbia. The main plots encompassed the following plant production systems: maize continuous cropping (MC), maize–wheat rotation (MW), maize-wheat-soybean (MWS) and maize–soybean–wheat rotation (MSW). The hybrid ZP606, wheat variety Takovčanka and soybean variety Lana were conventionally sown within optimal periods in all the production systems. Conventional tillage was applied in the trial. A total of 30 t $ha^{-1}$ of manure was incorporated in the autumn of 2008 in MW, MWS and MSW systems and then every third year. In the autumn of 2008 and 2010, 20 t $ha^{-1}$ of manure was incorporated in the two-crop rotation and every second year thereafter. Immediately, prior to ploughing, 150 kg $ha^{-1}$ of MAP fertilizer (N:P = 11:52) was added. Crop side dressing was performed according to the results obtained by the analysis of the available nitrogen in soil in the 5–6 leaf stage of maize.

The sub-plot treatments were represented by different weed management methods applied in maize: (RD) herbicide application of isoxaflutole + acetochlorat recommended dose (105 g a.i. + 1536 g a.i.) and half that dose (1/2 RD)(52.5 g a.i. + 768 g a.i.), hand hoeing treatment (weed free) and weedy check (weeds stayed throughout vegetation). Each sub-treatment had four replications. In wheat and soybean, the usual combination of herbicides for broadleaf and grass weed control was applied. At the beginning of the experiment, samples were taken only from different cropping systems, excluding herbicide treatments.

The elementary plot size was 28 $m^2$ and soil sampling (three soil sample cores from each elementary plot) for seed bank counting was carried out on the sowing (middle of May) and harvest time (middle of September) in 2012 and 2013. Soil samples were collected from the upper soil layer, with shovel 10x10 cm in a base and 4 cm deep. The average 200 g soil sample was washed inside special designed cylinders made from sieves mesh (0.2 mm), in order to separate weed seeds which were identified and counted by species under a magnifying glass (×10).

## Results and discussion

Total number of weed seeds was different between cropping systems in 2009, and, in average, lower in autumn (2958.5 seeds/$m^2$) than in spring (3850.0 seeds/$m^2$), Table 1. Maize crop was grown in all four fields and differences in weed seed richness between cropping systems, at the beginning of the experiment, are probably occurred as a results of previous agricultural practice. Number of seeds in 2009 was higher for all cropping systems than in 2012 and 2013.

Table 1. Number of weed seeds (No of seeds/m$^2$) in different cropping systems in 2009

| Weed species | Cropping system | | | | |
|---|---|---|---|---|---|
| | MC | MW | MWS | MSW | Average |
| | | Spring | | | |
| *Chenopodium* sp. | 2880 | 1530 | 1130 | 1500 | 1760.0 |
| *Amaranthus sp.* | 2780 | 1180 | 950 | 2450 | 1840.0 |
| *Daturastramonium* | | 75 | 200 | 125 | 92.5 |
| *Abuthilontheophrasti* | 25 | 50 | | | 18.8 |
| *Ambrosia artemisiifolia* | 50 | | | | 12.5 |
| *Atriplexpatula* | 150 | 180 | 75 | 50 | 113.8 |
| *Bilderdykia convolvulus* | | | 25 | 25 | 12.5 |
| Total | 5885 | 3015 | 2380 | 4150 | 3850.0 |
| | | Autumn | | | |
| *Chenopodium* sp. | 1250 | 530 | 630 | 850 | 820.0 |
| *Amaranthus sp.* | 2725 | 1630 | 600 | 1775 | 1682.5 |
| *Daturastramonium* | 75 | | 100 | 300 | 118.8 |
| *Convolvulus arvensis* | | | | 100 | 25.0 |
| *Atriplexpatula* | 800 | 100 | 250 | | 287.5 |
| *Bilderdykia convolvulus* | | 25 | 50 | 25 | 25.0 |
| Total | 4850 | 2285 | 1630 | 3050 | 2958.5 |

In spring 2012, the significantly highest average number of weed seeds was identified in maize continuous cropping (6425.0 seeds/m$^2$), Table 2. Application of herbicides affected weed seed bank richness and the highest number of seeds was identified in untreated control, in almost all production systems. Very effective in decreasing of weed seed bank richness was weed free treatment in which the lowest number of weed seeds was identified. But, differences in amounts of herbicides did not significantly affect weed seed bank richness in the first 3-4 years of crop rotation. The most distributed were broadleaf annual weed species *Chenopodium* sp., *Amaranthus* sp. and *Datura stramonium*. *Amaranthus* sp. accounted for 57.1% in total weed seeds number in MW rotation and 59.0% in MWS rotation.

Table 2. Number of weed seeds (No of seeds/m$^2$) in different cropping systems in spring 2012

| Weed species | Herbicide treatments | | | | |
|---|---|---|---|---|---|
| | Weedy check | RD | ½ RD | Hoeing | Average |
| | | Maize continuous cropping | | | |
| *Chenopodium* sp. | 3150 | 2950 | 2275 | 2550 | 2731.3 |
| *Amaranthus sp.* | 5775 | 3675 | 2125 | 2075 | 3412.5 |
| *Daturastramonium* | 300 | 175 | 125 | 200 | 200.0 |
| *Abuthilontheophrasti* | 25 | | 25 | | 12.5 |
| *Setariaviridis* | 25 | | | | 6.3 |
| *Hibiscus trionum* | 50 | | | | 12.5 |
| *Polygonumconvolvulus* | 25 | 125 | 25 | | 43.8 |
| *Sinapisarvense* | | 25 | | | 6.3 |
| Total | 9350 | 6950 | 4575 | 4825 | 6425.0 a |
| | | Maize-wheat rotation | | | |
| *Chenopodium sp.* | 1650 | 1100 | 1400 | 875 | 1256.3 |
| *Amaranthus sp.* | 3775 | 1675 | 2025 | 1175 | 2162.5 |
| *Daturastramonium* | 225 | 250 | 275 | 300 | 262.5 |
| *Polygonum convolvulus* | 50 | 50 | | 175 | 68.8 |

| | | | | | |
|---|---|---|---|---|---|
| *Convolvulus arvensis* | 25 | 25 | 50 | 25 | 31.3 |
| *Abutilon theophrasti* | | | 25 | | 6.3 |
| Total | 5725 | 3100 | 3775 | 2550 | 3787.5 b |
| Maize- Wheat-Soybean | | | | | |
| *Chenopodium sp.* | 1350 | 1350 | 1025 | 875 | 1150.0 |
| *Amaranthus sp.* | 1350 | 2000 | 1350 | 775 | 1368.8 |
| *Daturastramonium* | 175 | 325 | 75 | 100 | 168.8 |
| *Polygonum convolvulus* | 125 | 125 | 100 | 75 | 106.3 |
| Total | 3000 | 3800 | 2550 | 1825 | 2793.9 b |
| Maize-Soybean-Wheat | | | | | |
| *Chenopodium sp.* | 1100 | 1150 | 1175 | 1350 | 1193.8 |
| *Amaranthus sp.* | 2750 | 2700 | 1650 | 1650 | 2187.5 |
| *Daturastramonium* | 300 | 200 | 275 | 175 | 237.5 |
| *Polygonum convolvulus* | 75 | 50 | 75 | 75 | 68.8 |
| *Convolvulus arvensis* | 25 | | | 25 | 12.5 |
| *Sorghum halepense* | 25 | | | | 6.3 |
| Total | 4275 | 4100 | 3175 | 3275 | 3706.4 b |
| Average | 5587.5 a | 4487.5 a | 3518.8 a | 3118.8 b | 4178.2 |
| LSD 0.05 plant production system = 2236.0; LSD 0.05 weed management method = 2447.0 LSD 0.05 interaction = 2070.0 | | | | | |

After one cycle of rotation, number of weed seeds was lower in autumn 2012, than in spring, over all cropping systems, Table 3. This could be connected with life cycles of prevalent weed species. Most of them are late spring weeds and they emerge when first analyse was conducted in May, and then in September their seeds was not completely matured and disseminated yet. Average number of seeds was higher in maize continuous cropping 2.0 times than in MW rotation, 2.5 times than in MWS and 1.4 times than in MSW rotation. The most abundant were broadleaf annual weed species *Chenopodium* sp., *Amaranthus* sp. and *Daturastramonium*. *Amaranthus* sp. accounted for 40.7% in total weed seeds number in maize continuous cropping, 52.3% in MW rotation, 45.3% in MWS and 56.8% in MSW rotation.

Table 3. Number of weed seeds (No of seeds/m$^2$) in different cropping systems in autumn 2012

| Weed species | Herbicide treatments | | | | |
|---|---|---|---|---|---|
| | Weedy check | RD | ½ RD | Hoeing | Average |
| Maize continuous cropping | | | | | |
| *Chenopodium* sp. | 3525 | 2525 | 2400 | 2725 | 2793.8 |
| *Amaranthus sp.* | 3025 | 2150 | 2275 | 2300 | 2437.5 |
| *Daturastramonium* | 550 | 100 | 175 | 275 | 275.0 |
| *Polygonum convolvulus* | 25 | 975 | 650 | | 412.5 |
| *Hibiscus trionum* | 50 | | | 25 | 18.8 |
| *Convolulusarvensis* | 25 | | | | 6.3 |
| *Solanumnigrum* | 150 | | | | 37.5 |
| *Sorghum halepense* | | | 25 | | 6.3 |
| Total | 7350 | 5750 | 5525 | 5325 | 5987.5 a |
| Maize-wheat rotation | | | | | |
| *Chenopodium sp.* | 900 | 1525 | 1250 | 700 | 1093.8 |
| *Amaranthus sp.* | 2525 | 1300 | 1200 | 1175 | 1550.0 |

| | | | | | |
|---|---|---|---|---|---|
| *Daturastramonium* | 275 | 150 | 375 | 250 | 262.5 |
| *Polygonum convolvulus* | 25 | 75 | 25 | 50 | 43.8 |
| *Sorghum halepense* | | 25 | | | 6.3 |
| *Abuthilontheophrasti* | | | | 25 | 6.3 |
| Total | 3725 | 3075 | 2850 | 2200 | 2962.5 b |
| Maize- Wheat-Soybean | | | | | |
| *Chenopodium sp.* | 1000 | 1050 | 1025 | 800 | 968.8 |
| *Amaranthus sp.* | 800 | 1375 | 1200 | 925 | 1075.0 |
| *Daturastramonium* | 125 | 175 | 125 | 75 | 125.0 |
| *Polygonum convolvulus* | 225 | 300 | 100 | 150 | 193.8 |
| *Sorghum halepense* | | | 50 | | 12.5 |
| Total | 2150 | 2900 | 2500 | 1950 | 2375.0 b |
| Maize-Soybean-Wheat | | | | | |
| *Chenopodium sp.* | 1500 | 1525 | 1425 | 1225 | 1418.8 |
| *Amaranthus sp.* | 1450 | 2850 | 1775 | 3425 | 2375.0 |
| *Daturastramonium* | 200 | 225 | 150 | 600 | 293.8 |
| *Polygonum convolvulus* | 75 | 150 | 50 | 75 | 87.5 |
| *Convolvulus arvensis* | 25 | | | | 6.3 |
| Total | 3250 | 4750 | 3400 | 5325 | 4181.3a |
| Average | 4118.8ns | 4118.8ns | 3568.8ns | 3700.0ns | 3876.6 |
| LSD 0.05 plant production system =1663.0; LSD 0.05 weed management method = 2153.0 | | | | | |
| LSD 0.05 interaction = 1427.0 | | | | | |

Number of weed seeds decreased in crop rotations together with herbicide application or weed removal by hoeing in spring evaluation 2013, Table 4. Total number of weed seeds was 1.7 times lower in MW, 2.1 times in MWS and 1.4 times in MSW rotation than in continuous cropping. Especially effective were MW and MWS in which, after four years, crop rotation and herbicide application decreased the number of weed seeds even in comparison to 2012. In those two production systems, even in the untreated control, number of weed seeds in the soil upper layer was significantly lower (2700 and 1425 seeds/m$^2$) than in continuous cropping (4850 seeds/m$^2$). The most abundant were again broadleaf weed species *Chenopodium* sp., *Amaranthus* sp. and *Daturastramonium,* esspecialy *Amaranthus* sp, which participated about 50% in total weed seeds number.

Table 4. Number of weed seeds in different cropping systems in spring 2013

| Weed species | Herbicide treatments | | | | |
|---|---|---|---|---|---|
| | Weedy check | RD | ½ RD | Hoeing | Average |
| Maize continuous cropping | | | | | |
| *Chenopodium* sp. | 1800 | 2150 | 1350 | 1425 | 1681.3 |
| *Amaranthus sp.* | 2800 | 3000 | 1350 | 1250 | 2100.0 |
| *Daturastramonium* | 250 | 150 | 125 | 175 | 175.0 |
| *Hibiscus trionum* | | | | 25 | 6.3 |
| *Convolulusarvensis* | | | | 25 | 6.3 |
| *Polygonum convolvulus* | | | 25 | | 6.3 |
| Total | 4850 | 5300 | 2850 | 2900 | 3975.0 a |
| Maize-wheat rotation | | | | | |
| *Chenopodium sp.* | 875 | 1075 | 1125 | 825 | 975.0 |
| *Amaranthus sp.* | 1575 | 1350 | 950 | 975 | 1212.5 |
| *Daturastramonium* | 200 | 175 | 100 | 125 | 150.0 |

| | | | | | |
|---|---|---|---|---|---|
| *Polygonum convolvulus* | 25 | 75 | 25 | | 31.3 |
| *Sorghum halepense* | 25 | | | 25 | 12.5 |
| *Convolvulus arvensis* | | 25 | | | 6.3 |
| Total | 2700 | 2700 | 2200 | 1950 | 2387.5 b |
| Maize- Wheat-Soybean | | | | | |
| *Chenopodium sp.* | 600 | 400 | 400 | 550 | 487.5 |
| *Amaranthus sp.* | 650 | 2050 | 1050 | 775 | 1131.3 |
| *Daturastramonium* | 125 | 125 | 100 | 150 | 125.0 |
| *Polygonum convolvulus* | 50 | 100 | 175 | 75 | 100.0 |
| *Sorghum halepense* | | 75 | 25 | | 25.0 |
| Total | 1425 | 2750 | 1750 | 1550 | 1868.8 b |
| Maize-Soybean-Wheat | | | | | |
| *Chenopodium sp.* | 1725 | 950 | 1250 | 775 | 1175.0 |
| *Amaranthus sp.* | 2200 | 1150 | 1575 | 1325 | 1562.5 |
| *Daturastramonium* | 100 | 125 | 200 | 200 | 156.3 |
| *Polygonum convolvulus* | 25 | | 50 | 25 | 25.0 |
| *Sorghum halepense* | | | 25 | 25 | 12.5 |
| *Abuthilontheophrasti* | | 25 | | | 6.3 |
| Total | 4050 | 2250 | 3100 | 2350 | 2937.5 a |
| Average | 3256.3ns | 3250.0ns | 2475.0ns | 2187.5ns | 2792.2 |
| LSD 0.05 plant production system = 1391.0; LSD 0.05 weed management method = 1532.0 LSD 0.05 interaction = 1131.0 | | | | | |

Weed community is radically reduced under intensive application of high cropping technology (crop rotation, fertilization, herbicide application, etc.), which was obviously adequate (Barberi et al., 1998). Total number of weed species which were detected in maize field during two years (2012-2013) is between 4 and 8 species. Number of weed species was not affected by crop rotation, and even herbicide application, but number of their seeds was. Significant differences between maize continuous cropping and other cropping systems were found for number of weed seeds in the soil. The highest total number of weed seeds in average was identified in MC and the lowest in MWS rotation, in both years. Weed sandbank richness was the highest in spring 2012 (4187.2 seeds/m$^2$), lower in autumn 2012 (3876.6 seeds/m$^2$) and the lowest in spring 2013 (2792.2 seeds/m$^2$). Total number of weed seeds in spring 2013 was 1.7 times higher in MC than in MW, 2.2 times than in MWS and 1.4 times than in MSW cropping system. It is also noticeable that average number of weed seeds was even lower in spring 2013 than in spring 2012, which contribute to the integrated application of crop rotation with chemical weed control (Simic et al., 2014). Broadleaf species prevailed in comparison to grasses (Table 1, 2, 3 and 4), in all production systems and homogeneity of weed seed bank community analysed from upper layer of the soil, was noticeable as it was showed in previous investigations (Barberi et al., 1998). Similar results with *Amaranthus* sp. seeds prevalence was noticed in previous investigation of management system influence on seed bank composition in maize crop (Barberi et al., 1998).

Crop rotation significantly reduced weed seedbank richness and the most effective was MSW rotation in both years. Application of weed control methods also affected number of weed seeds in the upper soil layer and the most effective was weed removal by hoeing. Differences in efficiency of herbicides in weed seedbank size between recommended and half dose, were not significant. The lowest values of weed seeds were obtained in MSW cropping system, in spring 2013 (in average 1868.8 seeds/m$^2$), after four years of rotation. Wheat as a cereal crop, together with herbicides used for its production is suited better for effective weed control and maize production than soybean. According to previous results, reduced herbicide rate together with rotations that include cereals or forage crops can facilitate suppression of some troublesome weeds (Heggenstaller and Liebman, 2005).

## Conclusion

Crop rotation in combination with herbicides can reduce level of maize weed infestation in comparison to continuous cropping. The highest total number of weed seeds in average was identified in maize continuous cropping and the lowest in MWS rotation, in both years. The most abundant were broadleaf annual weed species *Chenopodium* sp., *Amaranthus* sp. and *Datura stramonium*. Results indicated that the processes affecting the weed seed bank in the fields are complex and will vary greatly based on the production practices used and the timing of their application. Because crop rotation expressed its effects after some years, the study will be continued in order to achieve more precise results.

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## References

Barberi, P., Cozzani, A., Macchia, M., Bonari, E. (1998). Size and composition of the weed seedbank under different management system for continuous maize cropping. Weed Research, Vol. 38, 319-334.

Bastiaans, L. 2010. Crop rotation and weed management. Proceedings of 15th EWRS Symposium, 12-15 July, Kaposvar, Hungary, 244-245.

Bohan, D.A., Powers, S.J., Champion, G., Haughton, A. J., Hawes, C., Squire, G., Cussans, J., Mertens, S. K. (2011). Modelling rotations: can crop sequences explain arable weed seed bank abundance? Weed Research, Vol. 51, 422-432.

Liebman, M., Miller, Z.J., Williams, C.L., Westerman, P.R., Dixon, P.M., Heggenstaller, A., Davis, A.S., Menalled, F.D., Sundberg, D.N. (2014). Fates of *Setariafaberi* and *Abutilon theophrasti* seeds in three crop rotation systems. Weed Research, Vol. 54, 293-306.

Menne, H., Köcher, H. (2012). HRAC Classification of Herbicides and Resistance Development. In: Modern Crop Protection Compounds (Eds) Krämer W., Schirmer U., Jeschke P. And Witschel M., Vol. 1: Herbicides, pp. 5-28, Wiley-VCH, VerlagGmbH&Co.KgaA.

Mohler, C.L. (2001). Weed life hystory: identifying vulnerabilities. *In*: Ecological Management of Agricultural Weeds (eds.) Liebman, M., Mohler, C. L., Steaver, C. P.), 40-98. Cambridge University Press, Cambridge, UK.

Schreiber, M.M. (2004). Influence of tillage, crop rotation, and weed management on giant foxtail (*Setariafaberi*) population dynamics and corn yield. Weed Science, 40, 645-653.

Simić, M., Spasojević, I., Brankov, M., Dragičević, V. (2014). Integrisanaprimenaplodoreda i herbicida za kontrolukorova u kukuruzu. Biljnilekar, Vol. 42, (*in press*).

Swanton, J. C., Weise,F. S. (1991). Interated Weed Management: The Rationale and Approach. Weed Technology, Vol. 5, 657-663.

Teasdale, J.R., Mangum, R.W., Radhakrishnan, J., Cavigelli, M.A. (2004). Weed seed bank dynamics in three organic farming crop rotations. Agronomy Journal, Vol. 96, 1429-1435.