Pestic. Phytomed. (Belgrade), 35 (3), 2020, 161-172
DOI: https://doi.org/10.2298/PIF2003161S

UDC 631.543.3: 632.51:633.15
Original scientific paper

Does continuous cropping of maize contribute to infestation with Johnsongrass (*Sorghum halepense* (L.) Pers.)?

Milena Simić*, Vesna Dragičević, Milan Brankov and Milena Šenk

Maize Research Institute Zemun Polje, Slobodana Bajića 1,11185 Belgrade, Serbia

**Corresponding author: smilena@mrizp.rs*

Received: 10 November 2020

Accepted: 1 December 2020

SUMMARY

Johnsongrass (*Sorghum halepense* (L.) Pers.) is a very common weed in maize fields in Serbia. Dense Johnsongrass infestations severely limit maize production, especially under continuous maize cropping. The key tool to manage this weed is to implement multiple control strategies when Johnsongrass is first observed and not to wait until it is firmly established.

Experiments were conducted in the Maize Research Institute (MRI), Zemun Polje, Belgrade, in order to examine how economically driven continuous cropping of maize influences weed infestation, especially the distribution and abundance of Jonhsongrass, as well as maize productivity. The maize hybrid ZP 606 was grown in continuous cropping from 2009 to 2018 at a density of 59,500 plants ha^{-1}. The experimental field was split into a part treated with the pre-emergence herbicide isoxaflutole + metolachlor (750 + 960 g a.i.) and untreated control. The level of complete weed infestation was evaluated 4-5 weeks after herbicide application by determining the number of weed individuals per species (NI), total fresh biomass (TB) and total dry weight (TDW) of all weeds and Johnsongrass fresh biomass (JB) and dry weight (JDW). Maize harvest index (HI) and grain yield (GY) were determined at the end of each growing period.

All measured weed parameters were highly dependent on agro-meteorological conditions of the year, herbicide application and their interaction. On average, TDW was 760.7 g m^{-2} in the control plot, and 142.2 g m^{-2} in the treated plot, while Johnsongrass participated with 34.8% and 48.7%, respectively. Herbicide application reduced JDW by 77.6% on average, even though its biomass increased over the years. A regression analysis revealed that GY was negatively influenced by JDW (R^2= - 0.094) in untreated control, while GY was higher with a lower JDW under herbicide treatment (R^2=-0.4439). Continuous cropping of maize should be replaced with crop rotation in order to prevent Johnsongrass prevalence and to obtain higher crop productivity.

Keywords: *Sorghum halepense,* maize, cropping system, weed control

INTRODUCTION

Maize cultivation is currently challenged by a need to attain higher biomass production and grain yield. The availability of resources and weed competition are usually the main limiting factors to achieve that goal. Johnsongrass (*Sorghum halepense* (Pers.) L.), which is native to the Mediterranean region, is a very common and competitive weed in maize fields in Serbia. It is a troublesome, perennial grass that shares a similar life cycle and growth conditions with maize. It grows quickly, produces a large number of seeds and rhizome biomass, and may produce allelophatic substances that inhibit seed germination, plant height and biomass of maize and soybean plants (Monaghan, 1979; Stef et al., 2015). Dense Johnsongrass infestation severely limits maize production (Ghosheh & Chandler, 1998; Barroso et al., 2016). Maize grain yield has been shown to decrease with increasing Johnsongrass density, and a maximum of three rhizomes per 9.8 m of maize row is allowed in order to avoid yield reduction higher than 5% in comparison with full-season weed-free maize. In order to avoid losses higher than 5%, this weed has to be controlled between 3 and 6.5 weeks after maize emergence (Ghosheh & Chandler, 1998).

Continuous maize cropping, driven by economic and market demands, suits Johnsongrass (Videnović et al., 2013). The key tool for Johnsongrass control is the implementation of multiple control strategies when it is first observed and not to wait until it is firmly established (Karkanis et al., 2020). This weed can be managed with a consistent integrated programme, combining preventive measures, cropping practices, mechanical and chemical methods. The effectiveness of crop rotation and soil tillage in Johnsongrass control was proved in a previous long-term period of investigation from 1978 to 1994 (Stefanović et al., 1995). The findings showed that crop rotation and soil tillage had an important role in the system of maize growing, regarding the occurrence and control of troublesome weed species, such as Johnsongrass. Johnsongrass coverage decreased in maize-soybean rotation by 60%, compared to continuous maize cropping, while conventional soil tillage resulted in a 47 % decrease of Johnsongrass, compared to no-tillage.

The most common measure for Johnsongrass control is chemical treatment but after many years of permanent herbicide application, different types of Johnsongrass resistance have been developed. Some investigations have shown that Johnsongrass is difficult to control only by herbicides, while better efficacy is achievable with mixed applications of two or even three active ingredients (Stanković & Šinžar, 1994). Marković (1987) reported that the distribution of Jonhsnongrass in maize fields increased in Vojvodina and particularly in Banat, while herbicides of the sulfonilurea group were the most effective for its control. Some studies have recently shown resistance of Johnsongrass to ALS-inhibitors and new problems in the control of this troublesome weed have arisen (Malidža, 2015). The most efficient herbicide for Johnsongrass control is glyphosate (Travlos et al., 2019). Maize infestation with Johnsongrass and its complex control is one of the reasons for the development of Roundup Ready technology (Ferrell & Witt, 2000). An effective measure for Johnsongrass control, also connected to crop rotation and soil cultivation, is chemical treatment of weed re-growth on stubble, which has been a well-known practice since 1960 (Čuturilo & Mijatović, 1969). Other studies have also confirmed a high efficacy of glyphosate against Jonhsnongrass when it is used as a late-summer or autmn treatment (Brown et al., 1988).

According to previous studies, maize production under continuous cropping increases the level of Johnsongrass infestation, supporting its rhizomes and seed propagation, and diminishing the efficacy of applied herbicides (Bendixen, 1988; Dražić et al., 1999). Another reason to exclude continuous cropping from maize cultivation is the possibility of more efficient Johnsongrass chemical control in different crops, such as soybean, cereals, and other. Crop rotation is also connected with rotation of herbicides with different modes of action, which is a recommended practice for resistance prevention (Beckie, 2006; Simić et al., 2014).

Successful control of Johnsongrass has to be based on the integrated application of preventive, mechanical, physical, chemical, biological and other measures (Simić et al., 2020; Travlos et al., 2019). Combined application of different cropping practices can facilitate optimal crop productivity, since repetitive application of the same measures in agricultural practice leads to disturbances in the agro-ecosystem (Liebman & Staver, 2001). Maize is usually very competitive with weeds, and a strong decrease in dry matter accumulation of weeds may occur in this crop (Faria et al., 2014). Our previous results showed that crop morphological and physiological parameters, as well as grain production, decreased significantly with high weed infestation (Simić et al., 2012). Thus, weed density (or biomass) acts as an important parameter in the crop-weed competition relationship. The fresh weight of three maize hybrids was lower under prolonged duration of Johnsongrass interference; especially it was lower when Johnsongrass developed from rhizomes, rather than from seed (Mitskas et al., 2003). Johnsongrass plants developing from rhizomes emerge earlier, grow faster, and produce greater fresh weight than plants grown from seed. However, the fresh weight and stem number of Johnsongrass plants grown either from seed or rhizomes were unaffected by the maize crop. Crop rotation plays an important role in Johnsongrass control, especially by herbicide application, while continuous maize cropping was found to have no influence on Johnsongrass reduction or maize productivity (Ghosheh & Chandler, 1998).

The objective of this study was to investigate the influence of continuous maize cropping and herbicide application on Johnsongrass weed infestation and crop productivity, as well as their possible relationships.

MATERIAL AND METHODS

Field investigation was conducted on a slightly calcareous chernozem soil under rain-fed conditions in the field of the Maize Research Institute in Zemun Polje over the period 2009-2018. A four-replicate experiment was carried out as a split-plot block design with the aim to examine the effects of economically driven continuous maize cropping on weed infestation and crop productivity, especially on the distribution of perennial Johnsongrass. The experimental area with continuous cropping of maize was divided into two plots: one treated with the pre-emergence herbicide isoxaflutole + metolachlor (750 + 960 g a.i.) (T), and an untreated control (C).

Deep tillage (25-30 cm) was performed in autumn, while pre-sowing soil preparation was done in the spring of each year. The maize hybrid ZPSC 606 (FAO 600) was sown in the second decade of April at a density of 59.500 plants ha^{-1}. Herbicides were applied with a hand-held sprayer calibrated to deliver 15 l at 300 kPa (3 bar) with a flat-fan nozzle (TeeJet, 1.4 mm E 04-80). The level of infestation with all weeds and with Johnsongrass was established by counting weed individuals per species (NI), total fresh biomass of all weeds (TB) and Jonhnsongrass (JB) per 1 m^2, 4-5 weeks after the herbicides application. The plants were dried at 60°C in a ventilation dryer and total dry weight of weeds (TDW) and Johnsongrass dry weight (JDW) were measured. The maize harvest index (HI) as the ratio of harvested grain yield to total aboveground maize biomass, was evaluated at the end of the maize growing period. Maize grain yield (GY) was measured from two inner rows and calculated in t ha^{-1} at 14% moisture.

The experimental data were statistically processed by the analysis of variance (ANOVA) and further analysed by the LSD-test (5 %). Interdependences of the weed and maize parameters were processed by regression analysis.

Meteorological conditions. Precipitation sums recorded over the investigated period show that the following three years were very dry – 2013, 2015 and 2017, while 2012 was an extremely dry year with the highest average temperature. The following four years were moderate with satisfactory amounts of precipitation – 2009, 2011, 2016 and 2018, while two years were favourable for maize production – 2010 and 2014 (Table 1). The highest average temperature during the growing period April-September was recorded in 2012, while an exceptionally high amount of precipitation was recorded in 2014, a year of extensive flooding.

Considering the precipitation average records for the investigation period 2009-2018, April was the month with insufficient rainfall, as well as July, August and September (Figure 1).

Table 1. Meteorological data for the growing period of maize (April-September) over the years of investigation, 2009-2018

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
oC	21.1	19.8	20.8	22.0	20.2	19.3	21.1	20.3	20.9	21.9
mm	321.0	453.9	301.6	174.8	245.4	652.5	285.4	320.1	222.3	336.5

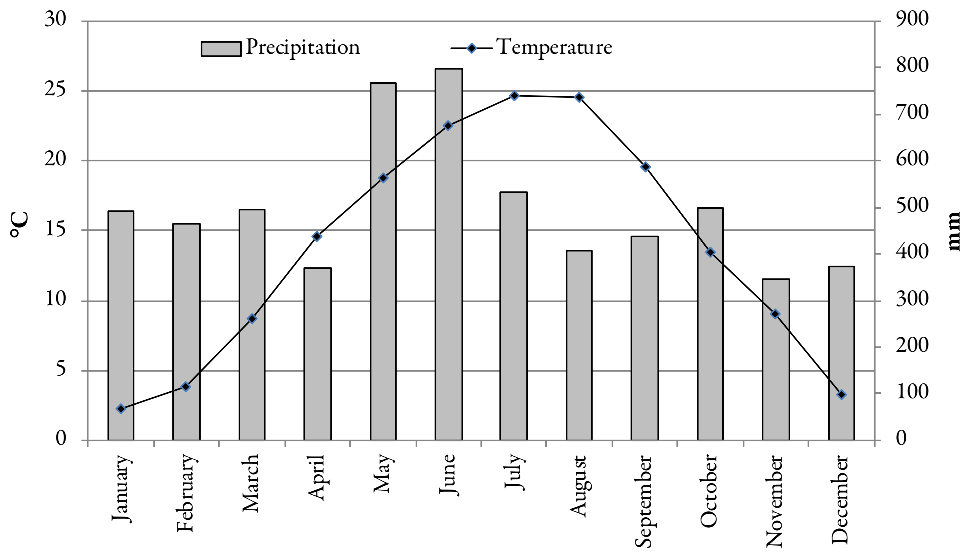

Figure 1. The average monthly temperatures and sums of precipitation (on average, 2009-2018)

RESULTS

The experiment was set up as a stationary trial and conducted in the same field over the trial period. It means that the composition of weed association was determined by microclimatic conditions characteristic for fields with continuous maize cultivation in the central part of Serbia. During the whole period of investigation, the following annual broadleaf weed species were the most abundant: *Chenopodium hybridum, Ch. album, Datura stramonium, Amaranthus sp., Abuthilon theophrasti, Solanum nigrum and Hibiscus trionum,* while perennials were represented by *Convolvulus arvensis, Sorghum halepense, Cirsium arvense* and rarely *Cynodon dactylon* (Table 2).

The total number of weed species and their biomass were higher in untreated control than in the treated plot. In both plots, T and C, the biomass of perennials increased over the years and it was extremely high in the control plot in 2013 (4649.5 g m^{-2}). The highest percentage of total biomass belonged to Johnsongrass, especially in 2013 (4305.4 g m^{-2}), 2016 (1523.7 g m^{-2}) and 2018 (1472.1 g m^{-2}).

The statistical analysis of data showed that all investigated weed parameters, i.e. NI, TB, JB, TDW and JDW, varied over the years, herbicide treatments and their interactions (Table 3). All weed parameters had an increasing trend in the first five years, but the trend turned to a decreasing one during 2014-2016.

Table 2. Weed species abundance (biomass, g m^{-2}) under continuous maize cropping

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
TREATMENT										
Annual weed species*										
CHEHY	137.6	8.8	43.6	116.6	22.4		1,9	69.8		
CHEAL		13.3	50.9	14.7				34.4		
DATST	47.9	19.4			15.8			99.4		
ABUTE	7.0		9.4	1.0				15.2		
AMARE	28.1									
AMAHY								62.1		
HIBTR		16.4			35.9					
POLCO				91.5		7.4		419.4		124.7
ANAAR				3.7						
Total biomass	220.6	57.9	103.9	227.5	74.1	7.4	0	700.3	0	124.7
Total No of sp.	4	4	3	5	3	1	1	6	0	1
Perennial weed species										
CIRAR	30.8	92.4				2,9				
CONAR	188.7	295.7	51.3	52.4	136.7	121.6	68.8	17.8		82.5
SORHA		184.4	262.7	256.1	310.2	56.1	176.5	559.9	250.7	341.0
CYNDA				5.7	52.1		58.3	50.9	63.0	141.2
Total biomass	188.7	480.1	314.0	314.2	499.0	177.7	303.6	628.6	313.7	564.7
Total No of sp.	2	3	2	3	3	3	3	3	2	3
CONTROL										
Annual weed species*										
CHEHY	1509.9	318.6	389.8	321.4	68.5	6.2	50.9	50.7	275.4	35.8
CHEAL	361.9	197.5	466.1	379.7	84.7	30.2	100.1	296.5	611.8	46.2
DATST	1133.7	140.7	257.2	616.5	199.6	39.5	51.9	152.5	148.9	63.1
ABUTE	272.1	39.9	150.1	47.1	14.8	6.1	40.4	23.1	21.8	78.5
SOLNI	59.1	200.9	111.9	170.4	215.9	43.8	38.9	84.2	84.3	59.7
AMARE	104.6	119.4	124.1	65.2	140.0	6.9	116.8	214.0	199.0	75.5
AMAHY	230.9	110.3	294.1	201.4	264.8	59.0	207.3	251.8	127.8	25.7
HIBTR	144.1	1.3	15.1	16.6	15.9	17.8	12.8	26.2	5.5	63.7
POLCO						3.0	198.4			
VERPE		124.7	4.5	4.7		27.6			29.3	
Total biomass	3816.3	1253.3	1812.9	1823.0	1004.2	240.1	817.5	1099.0	1503.8	448.2
Total No of sp.	8	9	9	9	8	10	9	8	9	8
Perennial weed species										
CIRAR	84.5	317.1	71.5	119.0	192.3	201.4	58.9			
CONAR	122.9	282.8	44.9	96.9	151.8	142.1	5.9		11.3	21.5
SORHA	25.9	105.3	121.9	585.5	4305.4	682.0	432.3	1523.7	705.2	1472.1
CYNDA						6.3				14.3
Total biomass	233.3	705.2	238.3	801.4	4649.5	1091.8	497.1	1523.7	716.5	1507.9
Total No of sp.	3	3	3	3	3	4	3	1	2	3

*Ten most abundant annual weed species

Table 3. The average number of weed plants per species (NI), total weed biomass (TB), Johnsongrass biomass (JB), total dry weight (TDW), Johnsongrass dry weight (JDW), maize harvest index (HI), maize grain yield (GY), and ANOVA results as affected by the year (Y) and herbicide treatment (T)

	NI	TB	SB	TDW	SDW	HI	GY
	per m^2	g m^{-2}	g m^{-2}	g m^{-2}	g m^{-2}		t ha^{-1}
Years							
2009	0.5 ab	13.0 b	2302.0 a	4.3 b	759.5 a	0.84 a	14.04 a
2010	3.5 ab	120.0 b	1309.0 ab	44.5 b	416.0 ab	0.42 bc	7.37 b
2011	4.5 ab	192.0 b	1248.0 ab	35.1 b	226.7 b	0.55 b	6.74 b
2012	9.5 ab	421.0 b	1594.0 ab	127.4 b	485.9 ab	0.46 bc	3.75 c
2013	33.5 a	2308.0 a	3113.0 a	761.6 a	1027.4 a	0.83 a	7.98 b
2014	23.5 ab	393.0 b	743.0 b	116.5 b	218.8 b	0.88 a	9.96 b
2015	11.0 ab	304.0 b	810.0 b	62.9 b	166.6 b	0.48 bc	5.22b c
2016	13.5 ab	1042.0 b	2075.0 a	284.2 b	542.1 ab	0.59 b	8.12 b
2017	33.5 a	478.0 b	1270.0 ab	129.4 b	337.9 b	0.37 c	1.82 c
2018	24.5 ab	907.0 b	1325.0 ab	211.6 b	334.6 b	0.53 b	4.98 c
Herbicide treatment (HT)							
Control (C)	26.2 a	991.0 a	2614.0 a	298.1 a	760.7 a	0.58 a	5.73 a
Herbicides (T)	5.3 a	245.0 a	543.0 b	64.9 a	142.4 b	0.61 a	8.27 a
				ANOVA			
Source of variation				P-value			
Y	0.042*	0.002*	0.080*	0.001*	0.014*	0.000*	0.000*
T	0.000*	0.004*	0.000*	0.005*	0.000*	0.539 ns	0.002*
Y × T	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

* Significant at the 0.05 probability level

† Means in columns followed by the same letter are not significantly different according to Fisher's least significant difference values (P = 0.05)

Then the weed parameters increased again, but to a smaller extent. Regarding biomass and dry matter, Johnsongrass was the predominant species from the beginning of investigation; its fresh biomass and dry matter were always a few folds higher than the total biomass and dry weight of weeds. Differences between the average biomass of Johnsongrass and its dry matter were significantly lower in the T variant (543.0 and 142.4 g m^{-2}) than in C (2614.0 and 760.7 g m^{-2}).

Maize parameters, HI and GY, were also influenced by the meteorological conditions of each year, herbicide treatment and their interactions, even though the average values were not significantly different (Table 3). HI was significantly affected by the Y × HT interaction. The lowest values of HI were recorded in the dry years: 2012, 2015 and 2017 (0.46, 0.48 and 0.37, respectively), while herbicide treatments did not cause significant differences in maize productivity. Contrary to HI, GY was under a significant influence of both investigated parameters and their interaction. The highest values of this parameter were observed at the beginning of investigation and in the years with satisfactory precipitation – 2009, 2014 and 2016 (14.04, 9.96 and 8.12 t ha^{-1}, respectively). Considering the average data for each year, GY was higher by over 2 t ha^{-1} (8.27 t ha^{-1}) in the treated plot than in the untreated control plot (5.73 t ha^{-1}), even though differences were not significant.

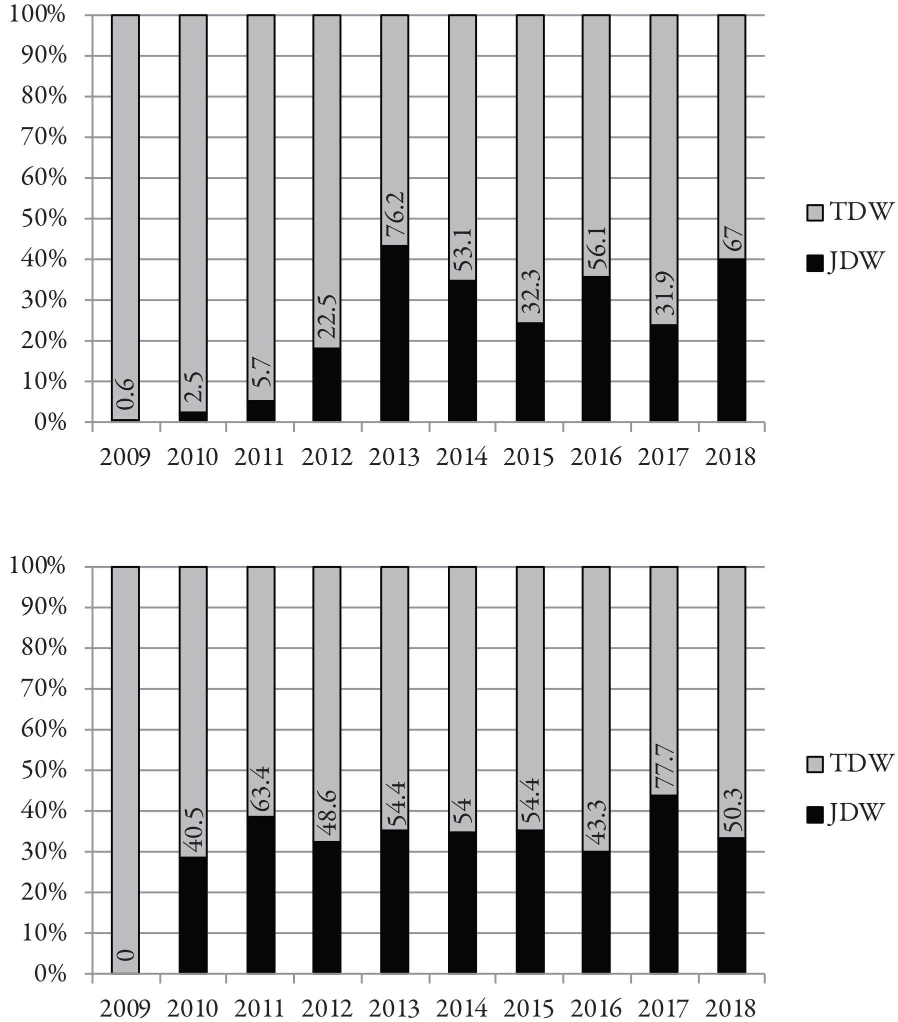

Figure 2. Participation (%) of Johnsongrass dry weight (JDW) in total dry weight of weeds (TDW) over the years of investigation in control (C) and herbicide treated (T) plots

Jonhnsongrass participation in total weediness is presented in Figure 2. It is clear that JDW participation in TDW was more pronounced (48.7%) in the treated plot than in the control plot (34.8%). It is particularly interesting that Johnsongrass participation in TDW in unfavourably dry years, such as 2012, 2015 and 2017, was noticeably higher in the treated plot (48.6%, 54.4% and 77.7%, respectively) than in control (22.5%, 32.3% and 31.9%, respectively).

The regression analysis of interference between weeds and maize, showed clear, almost linear trends between the GY increase and NI decrease (Figure 3), particularly in the T plot (R^2=0.6248). JB and JDW also decreased with GY increase, but not linearly in either C or T, and it was especially pronounced in the T plot, where a rapidly decreasing trend was found with GY ≥ 7 t ha^{-1}. Nevertheless, when TB and TDW were considered, some opposite trends occurred as an increasing trend was observed in TB and TDW, together with GY, in the C plot (R^2=0.2158 and R^2=0.1808, respectively), while a decreasing trend of both occurred with GY increase (R^2=0.0929 and R^2=0.1541, respectively) in the T plot.

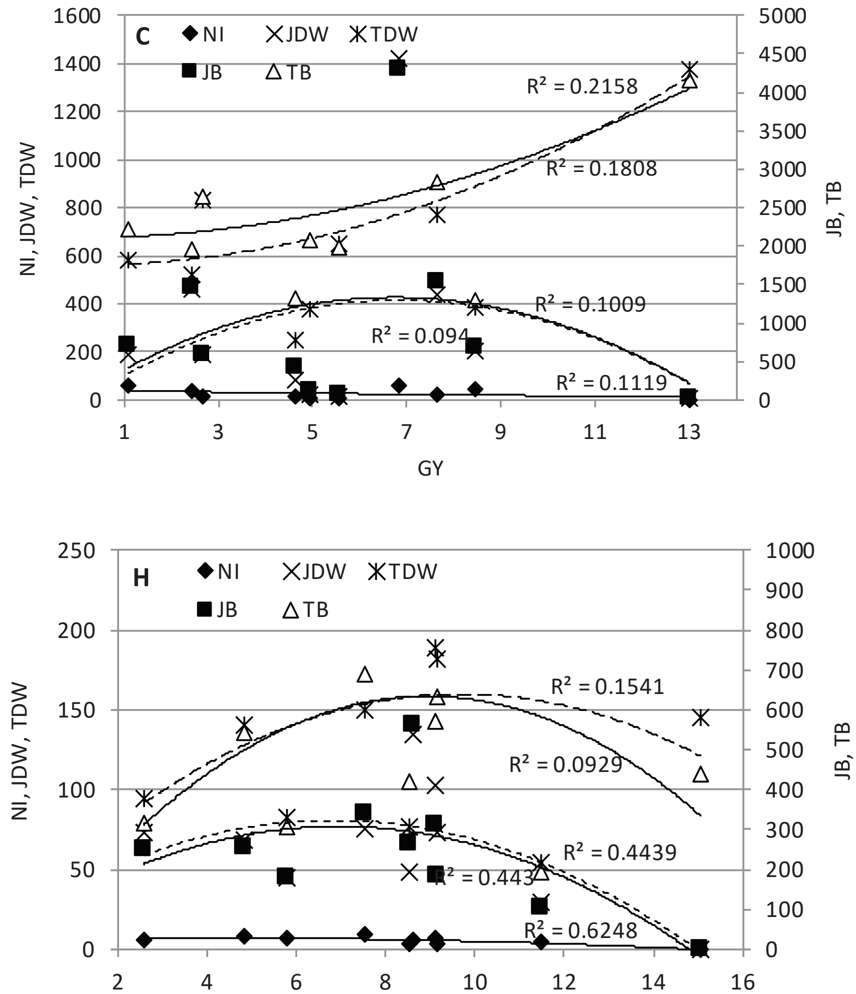

Figure 3. Interdependence between weed parameters and maize grain yield in control (C) and treated (T) plots, 2009-2018

DISCUSSION

The composition of weed associations in continuously cropped maize was determined by microclimatic conditions characteristic for maize fields in the central part of Serbia (Stefanović et al., 2011). According to previous data, the presence of the species *Chenopodium* genus, *Datura stramonium* and *Solanum nigrum,* as well as the invasive species *Abuthilon theophrasti,* was increasing, while perennials were represented by *Sorghum halepense* (Simić et al., 2020). *S. halepense* can disperse by rhizomes and seeds, producing more than 70 m of rhizomes per year and more than 28000 seeds per plant (Monaghan, 1979). But it is also able to produce a great amount of aboveground biomass, especially in summer row crops such as maize, whose growing in wide rows leaves enough space and light for Johnsongass to develop (Mitskas et al., 2003).

According to the obtained results, meteorological conditions of the year, especially precipitation, had a noticeable influence on weeds and crop parameters under maize continuous cropping. The increasing trend in total weed abundance over the first five years was broken by an extremely high precipitation amount (flooding) in 2014 and extreme drought in 2015. As a result, the number of weed individuals and their biomass were lower. Even though meteorological conditions were variable during the ten years of investigation, the effects of the herbicide mixture applied were considerable. The effects of unfavourable meteorological conditions were especially pronounced in the untreated control plot, even though the applied pre-emergence herbicides were not efficient against perennials, except their seedlings. Differences in the abundance of annual and perennial weeds are interconnected as the biomass of annual weed species generally decreased over the years, while the biomass of perennials had an increasing trend both in treated and untreated plots. As a common species in continuously cropped maize, *S. halepense* was dominant from the beginning of the investigation due to its great fresh and dry matter biomass that was always severalfold higher than the fresh and dry biomass of all other weeds. After significant reductions in the number of annual weeds, as a result of intraspecific competition, *S. halepence* increased its abundance even more in maize. It means that maize growing under continuous cropping favoured the extended distribution of Johnsongrass, irrespective of herbicide application (Bendixen, 1988). It suggests that herbicides are not a sufficient measure for successful Johnsongrass control in maize. It is known that continuous cropping, which favours very few weeds, enables the dominance of a single weed that is well-adapted to the main crop (Liebman & Staver, 2001).

According to the obtained results, maize HI was significantly affected by the Y × HT interaction and it was higher in T (0.61) than in C (0.58) by 4.92%. That parameter continually decreased over the years. Interference between Johnsongrass grown from seed or rhizome, and three maize hybrids also showed that fresh weights of the maize hybrids had a decreasing trend with extending duration of Johnsongrass interference (Mitskas et al., 2003; Karkanis et al., 2020). The negative impact of maize continuous cropping, in terms of significantly lower LAI and GY, was also observed in some other studies (Wozniak, 2008; Salifu, 2018).

The results of the regression analysis confirm the impact of Johnsongrass on maize yield potential, but they also underline the importance of herbicide application for weed biomass control and for achieving high maize GY in continuous maize cropping. On the average for all years, GY was higher by over 2 t ha^{-1} (8.27 t ha^{-1}) in the T plot than in the untreated C plot (5.73 t ha^{-1}), even though differences were not significant. It means that meteorological conditions may cause great variations in weed abundance and crop productivity under continuous maize cropping, while herbicide application could help reduce weed infestation and accordingly increase HI and GY. However, the longer maize is in the regime of continuous cropping, the more pronounced the year effect is, while the effect of herbicides is less pronounced. An analysis of 748,374 datasets from commercial farmers' fields in the U.S. Midwest has shown that meteorological conditions of the year have the highest impact on maize GY when it is grown under continuous cropping. The GY reduction was greater in locations with low moisture, while it increased with the number of years a field had been continuously cropped and levelled off after 3 years, 4.3% (Seifert et al., 2017). It is important to underline that maize GY was 14% lower when Johnsongrass plants developed from rhizomes four weeks after sowing, in contrast to Johnsongrass plants developing from seeds six weeks after sowing. Maize GY affected by season-long interference by Johnsongrass developed from rhizomes or seeds was 88% and 57% lower, respectively, than it was in weed-free maize (Mitskas et al., 2003). Regression analysis also showed that Johnsongrass had a negative impact on maize yield, while herbicide application helped in weed biomass control (Karkanis et al., 2020).

The presented results indicate that a decrease in maize yielding potential under continuous cropping is related to the trend of increasing weed infestation (irrespective of herbicide application), as well as to stress caused by variable meteorological conditions, which reflect on reduced HI and GY (Spasojević et al., 2015; Simić et al., 2017).

CONCLUSIONS

- Maize can be grown continuously over brief periods, while longer periods of continuous cropping will provoke a weed infestation problem, especially by perennials such as Johnsongrass;
- The efficacy of a pre-emergence herbicide mixture is affected by meteorological conditions but successful suppression of *S. halepense* and other perennials needs an additional application of herbicides, i.e. a post-emergence treatment;
- Maize cultivation under long-term continuous cropping reduced maize productivity;
- Considering the weed infestation increase, and decrease in crop productivity (i.e. harvest index and grain yield), continuous cropping of maize should be avoided as a maize growing technology.

ACKNOWLEDGMENT

This study received a grant from the Ministry of Education, Science and Technological Development of the Republic of Serbia under the project TR-31037.

REFERENCES

Barroso, J., Maxwell, B.D., Dorado, J., Andujar, D., San Martin, C., & Fernandez-Quintanilla, C. (2016). Response of *Sorghum halepense* demographic processes to plant density and rimsulfuron dose in maize crop. *Weed Research*, *56*(4), 304-312. doi: https://doi.org/10.1111/wre.12208

Beckie, H.J. (2006). Herbicide-resistant weeds: Management tactics and practices. *Weed Technology*, *20*(3), 793–814. doi: //doi.org/10.1614/WT-05-084R1.1

Bendixen, L.E. (1988). Johnsongras (*Sorghum halepense*) management systems. *Weed Technology*, *2*(1), 64-67. https://www.jstor.org/stable/3987269

Brown, S.M., Chandler, J.M., & Morrison, J.E. Jr. (1988). Glyphosate for Johnsongrass (*Sorghum halepense*) control in no-till sorghum (*Sorghum Bicolor*). *Weed Science*, *36*(4), 510-513. http://www.jstor.org/stable/4044676

Čuturilo, S., & Mijatović, K. (1969). Suzbijanje divljeg sirka u kukuruzu primenom herbicida na strnjištu (Control of *Sorghum halepense* in maize by applying herbicides on stubble). *Savremena poljoprivreda/Contemporary agriculture, 17,* 1-6.

Dražić, D., Malidža G., & Orbović B. (1999). Johnsongrass control in corn monoculture. *Zbornik radova – Naučni institut za ratarstvo i povrtarstvo (Proceedings - Scientific Institute of Field and Vegetable Crops)*, *132*, 127-136.

Ghosheh, H., & Chandler, J. (1998). Johnsongrass (*Sorghum halepense*) control systems for field corn (*Zea mays*) utilizing crop rotation and herbicides. *Weed Technology*, *12*(4), 623-630, 1998. doi:10.1017/S0890037X0004447X

Faria, R.M., Barros, R.E., & Tuffi Santos, L.D. (2014). Weed interference on growth and yield of transgenic maize. *Planta Daninha, 32*(3), 515-520. doi: 10.1590/S0100-83582014000300007

Ferrell, A.J., & Witt, W.W. (2000). Comparison of weed management strategies with Roundup Ready ®Corn. *Agronomy Notes* (University of Kentucky), *32*(2). https://uknowledge.uky.edu/pss_notes

Karkanis, A., Athanasiadou D., Giannoulis, K., Karanasou, K., Zografos, S., Souipas, S. ... Danalotos N. (2020). Johnsongrass (*Sorghum halepense* (L.) Pers.) interference, control and recovery under different management practices and its effects on the grain yield and quality of maize crop. *Agronomy, 10*, 266. doi: 10.3390/agronomy10020266

Liebman, M., & Staver, P.C. (2001). Crop diversification for weed management. In M. Liebman, L.C. Mohler & P.C. Staver (Eds.), *Ecological management of agricultural weeds* (pp 322-374). Cambridge, UK: Cambridge University Press.

Malidža, G. (2015). Identification and distribution of ALS resistant *Sorghum halepense* populations in Serbia. In B. Gerowitt, J. Soukup & H. Darmency (Eds.), *Proceedings of the 17th European Weed Research Society Symposium* (pp 115). Montpellier, France: AFPP.

Marković, M. (1987). Dosadašnji rezultati i perspektiva hemijskog suzbijanja divljeg sirka u kukuruzu. *Fragmenta herbologica Jugoslavica*, *16*(1-2), 209-220.

Mitskas, M.B., Tsolis, C.E., Eleftherohorinos, I., & Damalas, A.C. (2003). Interference between corn and Johnsongrass (*Sorghum halepense*) from seed or rhizomes. *Weed Science*, *51*(4), 540-545. doi: 10.1614/0043-1745(2003)051[0540:IBCAJS]2.0.CO;2

Monaghan, N. (1979). The biology of Johnson grass (*Sorghum halepense*). *Weed Research*, *19*(4), 261-267. doi: https://doi.org/10.1111/j.1365-3180.1979.tb01536.x

Salifu, M. (2018). The Impact of Crop Rotation and Nutrient Levels on Nutrition Quality, Yield and Yield Components of Maize (Zea maize L). *International Journal of Environment, Agriculture and Biotechnology, 3*(2), 522-524. doi: 10.22161/ijeab/3.2.27

Seifert, C.A., Roberts, M.J., & Lobell, D.B. (2017). Continuous corn and soybean yield penalties across hundreds of thousands of fields. *Agronomy Journal*, *109*(2), 541-548. doi: https://doi.org/10.2134/agronj2016.03.0134

Simić, M., Dolijanović, Ž., Maletić, R., Stefanović, L., & Filipović M. (2012). Weed suppression and maize productivity by different arrangement patterns. *Plant, Soil and Environment, 58*, 148-153. https://www.researchgate.net/publication/286933009

Simić, M., Dragičević, V., Chachalis, D., Dolijanović, Ž., & Brankov, M. (2020). Integrated weed management in long-term maize cultivation. *Zemdirbyste-Agriculture*, *107*(1), 33–40. doi: 10.13080/z-a.2020.107.005

Simić, M., Spasojević, I., Brankov, M. & Dragičević, V. (2014). Integrisana primena plodoreda i herbicidaza kontrolu korova u kukuruzu (Integrated application of crop rotation and herbicides for weed control in maize). *Biljni lekar/Plant doctor*, *42*, 2-3. https://core.ac.uk/download/pdf/236678192.pdf

Simić, M., Spasojević, I., Dragičević, V., Kovačević, D., Dolijanović, Ž., & Brankov M. (2017). Plant height and grain yield of maize in different cropping systems. In *Proceeding of the 6th International Scientific Agricultural Symposium "Agrosym 2017"* (pp 583-589). Jahorina, Bosnia and Herzegovina: Faculty of East Sarajevo.

Spasojević, I., Simić, M., Kovacević, D., Dragicević, V., Brankov, M., & Dolijanović, Ž. (2015). Comparison of different crop sequences and their influences on maize growing parameters and yield. In *Proceeding of the 6th International Scientific Agricultural Symposium "Agrosym 2015"* (pp 413-417), Jahorina, Bosnia and Herzegovina: Faculty of East Sarajevo.

Stanković, R., & Šinžar, B. (1994). Suzbijanje korova u usevu semenskog kukuruza s posebnim osvrtom na *Sorghum halepense* (Weed control in the crop of maize seed with special reference to *Sorghum halepense*). *Pesticidi/Pesticides*, *9*(3), 101-106.

Stef, R., Carabet, A., Grozea, I., Radulov, I., Manea, D. & Berbecea, A. (2015). Allelopathic effects produced by Johnson grass extracts over germination and growth of crop plants. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca Agriculture*, *72*(1), 239-245. doi: 10.15835/buasvmcn-agr:11180

Stefanović, L., Videnović, Ž., & Jovanović, Ž. (1995). Uticaj plodoreda i obrade zemljišta na pojavu sirka u usevu kukuruza (Influence of crop rotation and tillage on the occurrence of *Sorghum halepense* in maize crop). In *Simpozijum „Oplemenjivanje, proizvodnja i iskorišćavanje kukuruza - 50. godina Instituta za kukuruz Zemun Polje“* (Symposium *"Maize breeding, production and utilization - 50th anniversary of the Maize Research Institute Zemun Polje",* pp 375-379*).* Belgrade, Serbia: Maize Research Institute Zemun Polje.

Stefanović L., Simić M., & Šinžar B. (2011): *Kontrola korova u agroekosistemu kukuruza (Weed control in the maize agroecosystem,* pp.1-680). Belgrade, Serbia: Maize Research Institute Zemun Polje.

Travlos, I.S., Montull, J.M., Kukorelli, G., Malidza, G., Dogan, M.N., Cheimona, N. ... Peteinatos, G. (2019). Key aspects on the biology, ecology and impacts of Johnsongrass [*Sorghum halepense* (L.) Pers] and the role of glyphosate and non-chemical alternative practices for the management of this weed in Europe. *Agronomy*, *9*(11), 717. doi:10.3390/agronomy9110717

Videnović, Ž., Dumanović, Z., Simić, M., Srdić, J., Babić, M., & Dragičević, V. (2013). Genentic potential and maize production in Serbia. *Genetika*, *45*(3), 667-678. doi: 10.2298/GENSR1303667V

Wozniak, A. (2008). Influence of different share of spring wheat in crop rotation on leaf area index (LAI). *Acta Agrophysica, 12*, 269 – 276.

Da li gajenje kukuruza u monokultiri pospešuje zakorovljenost divljim sirkom (*Sorghum halepense* (L.) Pers.)?

REZIME

Divlji siriak (*Sorghum halepense* (L.) Pers.) je vrlo čest korov na poljima u Srbiji. Intenzivna zakorovljenost divljim sirkom ozbiljno ograničava proizvodnju kukuruza, naročito kada se on gaji u monokulturi. Suština borbe protiv ovog korova je pravovremena primena više mera suzbijanja čim se divlji sirak uoči i pre nego što razvije veliku masu rizoma i dobro se ukoreni.

Poljski ogled je izveden u Institutu za kukuruz Zemun Polje, sa ciljem da se utvrdi kako profitom dirigovano gajenje kukuruza u monokulturi utiče na zakorovljenost, naročito na rasprostranjenost i brojnost divljeg sirka, kao i na produktivnost kukuruza. Hibrid ZP 606 je gajen u monokulturi u periodu 2009-2018. godine u gustini od 59.500 biljaka ha^{-1}. Polje pod kukuruzom u monokulturi je podeljeno na deo na kome je primenjivan herbicid pre nicanja useva (isoksaflutol + metolahlor (750 + 960 g am) i deo koji nije bio tretiran - kontrola. Intenzitet zakorovljenosti je određen 4-5 nedelja nakon primene herbicida merenjem broja jedinki vrsta (NI), ukupne sveže biomase (TB) i ukupne suve mase (TDW) svih korova i sveže biomase divljeg sirka (SB) i njegove suve mase (JDW). Žetveni indeks (HI) i prinos zrna (GY) određeni su na kraju vegetacionog perioda kukuruza.

Svi parametri korova u velikoj meri su zavisili od agro-meteoroloških uslova godine, primene herbicida i njihove interakcje. U proseku, TDW je iznosila 760,7 g m^{-2} u kontroli i 142,2 g m^{-2} na tretiranoj parceli, od čega je udeo suve mase divljeg sirka bio 34,8% u kontroli i 48.7% na tretiranoj parceli. Primena herbicida smanjila je suvu masu divljeg sirka prosečno za 77.6%, iako se ona sa godinima povećavala. Prema regresionoj analizi, JDW je negativno uticala na GY (R^2= - 0,094) u kontroli, dok se GY povećavao sa smanjenjem JDW u varijanti sa primenjenim herbicidom (R^2=-0,4439). Monokulturu kukuruza bi trebalo zameniti plodoredom da bi se sprečilo zakorovljavanje divljim sirkom i postigla veća produktivnost useva.

Ključne reči: *Sorghum halepense*, kukuruz, sistem gajenja, suzbijanje korova