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WEED CONTROL ABILITY IN SWEET MAIZE OF SINGLE SOWN LEGUME COVER CROPS COMPARED TO THEIR MIXTURES

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Abstract

To achieve efficient weed control through cover cropping, the plant species chosen is very important. Growing different legume cover crop (CC) species single and in mixtures with grass may increase the number of provided ecosystem services, including reliable suppression of weeds. We conducted an experiment using randomized complete block design with four replications in 2014/15 - 2015/16 growing seasons, at the Experimental Field of Maize Research Institute in Zemun Polje (Serbia). Single cover crops were considered as the main factor (common vetch and field pea), mixtures common vetch and field pea with winter oats and traditional variant, without coverage on biomass. Green biomass of the cover crops was incorporated in the soil, and treatments with favorable establishment and above-average biomass yields tended to suppress weeds by showing lower weed dry matter and weed numbers. The weediness of sweet maize was much higher in the second year of investigation. The number of weed species, fresh and dry biomass of weeds were the least in the variants with mixtures, while the number of plants per specieswas the lowest in the single cover crops. So, mixtures were not as effective as legume single sown CCs, species combinations increased resilience against adverse weather conditions, an advantage to achieving efficient weed control over a long-term period. The statistically significant difference in the fresh biomass of weeds obtained in the control variant (540.46 and 385.88 g) was especially pronounced compared to the variants with single cover crops (391.63 and 486.53 g) and their mixtures (260.00 and 250.78 g), indicating a higher proportion of perennial weed species.

Keywords: *cover crops, plant diversity, main crop, weed management.*

Introduction

One of the major problems in growing broad-leaved crops is weediness, especially in the initial stages of vegetative growth and development. In conventional production, this problem is usually solved by direct weed control measures, i.e. by applying herbicides. In sustainable farming systems, which today's producers need and generally approaching, weed control is mainly based on preventive management practices and corrective herbicide application. In such circumstances, on the one hand, and global climate change, on the other hand, measures of increased land cover during the year, such as crop rotation, cultivation of inter- and cover crops (CC), play a significant role. The integration of cover crops into crop rotations has become a practical strategy by producers (Schappert et al., 2019). Cover crops are normally grown between two main crops to reduce erosion and to improve soil characteristics like nitrogen content, phosphor availability and soil structure (Hartwig and Ammon, 2002), increase efficiency of water usage, improve to weed control (Dolijanović et al., 2012) and they also provide services that reduce pests, and pathogens (Fourie et al., 2016). Some cover crop species growing single or in mixture with grass are able to survive the harsh conditions over winter and continue to provide this service in early spring and after sowing the main crop they remain on the surface as an undercrop and it is a living mulch. Another strategy is to grow during the fall and winter, and in the spring, cover crops are normally terminated by mechanical or chemical methods before sowing following main crop, and then it is dead mulch. Under both strategies, plant residues continue to release the remaining allelochemicals that are contained in the dead (Tabaglio et al., 2013) or living plant material (Dolijanović et al., 2013). Examining the influence of live and dead mulch on weediness and yield of sweet maize, Dolijanović et al. (2013) states that living mulch in spring-sown cover crops had a positive impact on lower weediness, and opositelly, negative impacts on sweet maize yield. The main crop of sweet maize was not competitive enough with ground cover, mainly because of limited soil moisture and nutrients, especially between the rows of sweet maize being possessed by living mulch. Single sown cover crops (common and hairy vetch, oats and fodder kale) were more successful in weed control than mixtures (common and hairy vetch + oats). Schappert et al. (2019) states that CC mixtures might substantially contribute to the success of biological weed control if the weed suppression mechanisms of different plant species and their ideal composition within mixtures can be identified. The objective of this study was to determine the effect of different winter (dead mulch) and single sown legume cover crops and their mixtures with oats on weed infestation of sweet maize.

Material and methods

The experiment included two single *winter cover crops* (common vetch and field pea), mixtures winter cover crops with oat and traditional production method, classical plowing in the fall and keeping bare soil uncovered during the winter. All of the varieties being used as a cover crops belongs to theInstitute of Field and Vegatble Crop, Novi Sad. Crops were grown under rainfed conditions. Field experiments were conducted in 2014/15 and 2015/16 at Maize Research Institute, Zemun Polje, in the vicinity of Belgrade (44°52'N 20°20'E). The soil was slightly calcareous chernozem with 47% clay and silt, and 53% of sand. The soil properties in layer 0-30-cm of depth were as fallow: 3.22% organic matter, 0.19% total N, 1.9% organic C, 16.2 and 22.4 mg per 100 g soil of available P_2O_5 and extractable K_2O, respectively, 1.38% total $CaCO_3$ and pH 7.3. The experiments were located in different plots in each year and winter wheat was the precceding crop. Fallowing nitrogen fixation rates in legume crops, as well recommended fertilization, we came up to the required amount of macronutrients for sweet maize (120 kg ha^{-1} N, 90 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O). In the fall period, before planting of cover crops we have entered the entire amount of P and K in the forms of monopotassium phosphate plus additional quantity of nitrogen 50 kg ha^{-1} by ammonium nitrate, and on the two control variants, also all of P_2O_5 i K_2O and 40 kg ha^{-1} N in the form AN. In the next spring (May 21 2015 and April 28 2016) leguminous cover crops had received another 30 kg ha^{-1} N in the form of AN (remaining 40 kg ha^{-1} considered to be provided by nitrogen fixation), and control plots another 80 kg ha^{-1} N, also in the form of AN. The experimental plots being ploughed in the autumn, have followed one pass of a disk harrow and a field cultivator prior to sowing. The entire quantityof nitrogen, phosphorousand potassiumforspring cover cropswere applied just prior to planting, with soil preparation.
Sowing of cover crops were done manually in November 13, 2014 and November 04, 2015.Mowing the above-ground biomass of winter cover crops were performed 7-10 days before planting of sweetmaize. Sowing of sweet maize were done on May 21 in 2015, and April 28 in 2016 year. The estimation of weed infestation in sweet maize was conducted in early July for both years. Crops were harvested 22-24 days after pollination. harvest was performed on August 21, 2015 and August 03, in 2016.

Experimental design

The experiment was in factorial setting with two factors in RCBD with four replications. Sweet maize was sown in density of 65.000 plants ha^{-1}. The inter-row distance was 70 cm, while within-row plant distance was 22 cm. The Zemun Polje (ZP) sweet maize hybrids ZP 424su (FAO maturity group 400) was sown. The basic plot size was 16.8 m^2 (2.8 m by 6.0 m).

Measurements and statistical analysis

Total numberweed species, the number of plants per species, fresh and dry biomass of weeds in sweet maize crops were analysed in this study. All stated parameters in weeds were determined from samples taken from 1m^2. The weed infestation analysis was performed at beginning of July. Following weed sampling, manual hoeing was done in order to suppress weeds pressure in sweet maize. The yield data were underwent to ANOVA for the factorial trials set up according to the plan for two factors, where means differences were tested by the least significant difference (LSD) test (Gomez and Gomez, 1984). The meteorological conditions during the maize growing season are presented in Table 1.

Table 1. Mean monthly air temperatures and precipitation sums from April to August at ZemunPolje

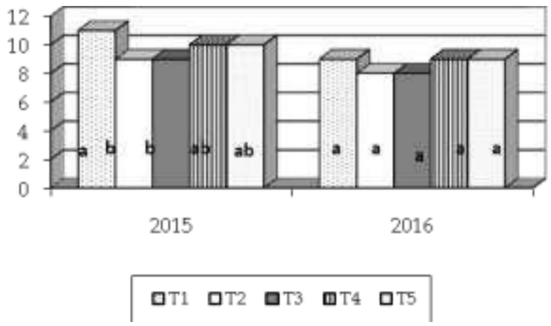
Months	Temperature (°C)		Precipitation (mm)	
	2015	2016	2015	2016
April	13.5	15.5	30.7	53.9
May	19.1	17.5	80.7	71.3
June	21.9	22.5	38.6	152.2
July	26.8	24.4	10.6	35.0
August	26.0	22.3	49.5	60.8
Average/Sum	21.5	20.4	210.1	373.2

The first year of the research is characterized by a higher average air temperature and a significantly lower amount of precipitation (Table 1). In such a situation, only the number of weed species in sweet maize increased, while the number of plants per species, fresh and dry biomass, was significantly higher in 2016. Therefore, the growing of cover crops is completely justified in drier years, which have become more frequent in the conditions of climate change in recent years.

Results and discussion

The number of weed species

In all cover crop treatments and control, a larger number of species was observed in the first year of investigating. A statistically significant difference in the number of species was observed only between T1 (common vetch) and T2 and T3 (field pea and a mixture of common vetch and oats) (graph 1). A larger number of weed species in mixtures in relation to single cover crops was observed in previous papers (Dolijanović et al., 2015; Finney et al., 2016; Baraibar et al., 2018).

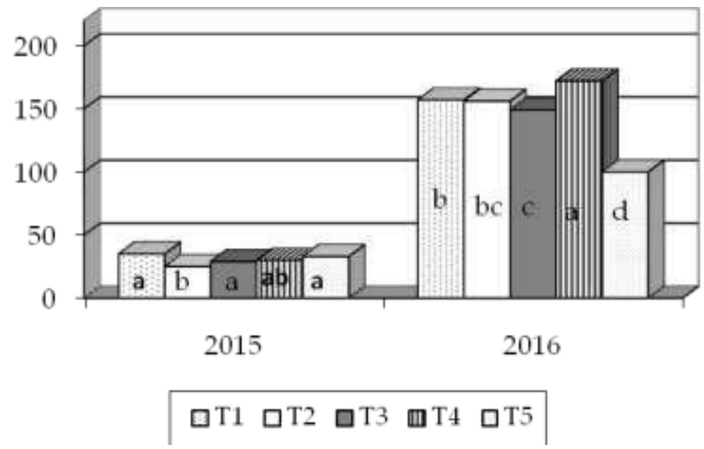


Graph. 1. The number of weedsin sweet maize after cover crops in 2015 and 2016year
Different letters indicate significant difference between treatments at $p < 0.05$; LSD test

Total number of plants per species

Table2.Total number of plants per species ($N^o m^{-2}$) in sweet maize growing after cover crops

Weed species 2015	T1	T2	T3	T4	T5	Average
Chenopodium album L.	13	7	5	9	9	8.6
*Datura stramonium*L.	5	4	2	6	4	4.2
Amaranthusretroflexus L.	3	3	4	1	1	2.4
Amaranthushybridus L.	3	4	3	5	4	3.8
Amaranthusalbus L.	2	3	4	2	4	3.0
Sorghum halepense (Pers.) L.	2		3	1	1	1.4
Solanum nigrum L.	2	1	6	3	3	3.0
Chenopodiumhybridum L.	2		1	1		0.8
Bilderdykia convolvulus L.	1	1	1	1	3	1.4
*Ambrosia artemisiifolia*L.	1					0.2
Panicum crus-galli	1				1	0.4
*Convolvulus arvensis*L.		1				0.2
Portulacaoleracea		1		1	3	1.0
Total	35	25	29	30	33	30.4
		2016				
Solanum nigrum L.	98	97	98	89	57	87.8
Bilderdykia convolvulus L.	8	4		7	12	6.2
Chenopodium album L.	4	1	6	4	2	3.4
Sorghum halepense (Pers.) L.	18	21	1	2	3	9.0
Amaranthusretroflexus L.	9	14	8	25	8	12.8
Chenopodiumhybridum L.	1		6		1	1.6
*Datura stramonium*L.	1		3	4	3	2.2
Amaranthushybridus L.	5	7	11	26	6	11.0
Amaranthusalbus L.	13	12		6	8	7.8
*Amaranthusblitoides*L.			16			3.2
Portulacaoleracea				9		9.0
Total	157	156	149	172	100	146.8



Graph.2. Total number of plants per species (N°m^{-2}) in sweet maize after cover crops
Different letters indicate significant difference between treatments at $p < 0.05$; LSD test.

Dominant weed species are characteristic of the southeastern Srem locality and sweet maize. In contrast to the number of species, the number of weeds, a statistically significantly smaller number was observed in 2015. (table 2; graph 2). The advantage of treatment with cover crops is more pronounced in a climatologically less favorable year of investigating. In the second year, single sown legume cover crops showed an advantage over the mixtures and the control variant.

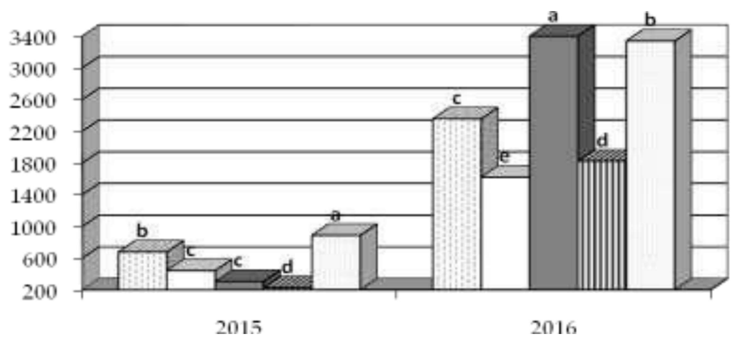
Fresh biomass of weeds

Significantly higher fresh mass of weeds was measured in 2016, which indicates a higher presence of broadleaf weeds in conditions of increased precipitation and lower air temperatures. The highest total fresh weight was 886.4 g m^{-2} (conventional system) in 2015 and 3892.0 g m^{-2} in 2016 in mixture common vetch and oats and the lowest in single field pea and mixture field pea and oat (table 3).In addition to the influence of the cover crop, the rapid growth of the main crop after sowing and the increase of competitive ability also affected the reduction of weeds (Dorn et al., 2015). Good choice of mixture CC species with physical and chemical weed suppression mechanisms may increase the weed control success (Schappert et al., 2019).

Table3.Fresh biomass of weeds (g m^{-2}) in sweet maize after cover crops

Weed species	2015	T1	T2	T3	T4	T5	Average
Chenopodium album L.		414.4	319.1	47.2	91.6	425.6	259.6
*Datura stramonium*L.		41.1	31.1	6.1	30.2	43.8	30.5
Amaranthu sretroflexus L.		117.2	13.5	61.0	5.2	16.3	42.6
Amaranthus hybridus L.		12.1	24.1	27.6	21.5	101.9	37.4
Amaranthus albus L.		8.3	10.3	26.5	12.7	29.3	17.4
Sorghum halepense (Pers.) L.		11.7		41.6	7.1	14.8	15.0
Solanum nigrum L.		17.4	7.7	25.4	18.4	17.1	17.2
Chenopodium hybridum L.		24.0		9.1	1.0		6.8
Bilderdykia convolvulus L.		8.5	17.3	60.9	30.8	157.2	54.9
Ambrosia artemisiifolia L.		15.2					3.0
Panicum crus-galli		7.0				28.5	7.1

Convolvulus arvensis L.		10.2				2.0
Portulaca oleracea		7.1		7.8	51.9	13.4
Total	676.9	440.4	305.4	226.3	886.4	507.1
		2016				
Solanum nigrum L.	1065.1	723.0	1982.5	474.8	1597.5	1168.6
Bilderdykia convolvulus L.	31.4	10.1		47.0	369.7	91.6
Chenopodium album L.	124.0	24.2	243.0	125.9	49.5	113.3
Sorghum halepense (Pers.) L.	199.5	350.8	24.5	40.5	34.7	130.0
Amaranthu sretroflexus L.	464.8	467.8	535.4	602.8	756.2	565.4
Chenopodium hybridum L.	7.6		202.4		22.3	46.5
*Datura stramonium*L.	20.9		100.5	15.9	69.9	41.4
Amaranthus hybridus L.	139.4		561.4	419.6	225.7	269.2
Amaranthus albus L.	303.4	44.8		60.6	211.8	124.1
Amaranthus blitoides L.			242.3			48.5
Portulaca oleracea				36.6		7.3
Total	2356.1	1620.7	3892.0	1823.7	3337.3	2606.0



Graph.3. Fresh biomass of weeds (g m^{-2}) in sweet maize after cover crops
Different letters indicate significant difference between sites at $p < 0.05$; LSD test.

Air dried biomass (g m^{-2})

Results of air dried above-ground biomass of cover crops are presented in table 4.The highest air dried biomass of weeds in both years of investigating was measured in the control variant, and the lowest mainly in mixtures of cover crops with oats (first year) and in single cover crops of winter field pea and mixture of pea with oats (second year). Air dried biomass of weeds is an indirect indicator of the presence of broadleaf (annual and perennial) weeds. In organic cereal cropping systems, with or without a cover-crop, perennial weeds such as *C. arvense*, *Sonchusarvensis* and *E. repens* are of great concern in many temperate countries (Melander et al., 2012). Researchers and farmers claim that perennial creeping weeds threaten the future of organic cereal production, unless the management of these weeds is given due consideration in crop rotation (Sundheim et al., 2014).

Table 4.Air dried biomass of weeds (g m^{-2}) in sweet maize after cover crops

	T1	T2	T3	T4	T5	Average
2015	169.6^{b}	126.5^{c}	71.2^{d}	60.0^{d}	259.2^{a}	137.3
2016	436.7^{c}	409.7^{c}	651.9^{a}	350.9^{d}	569.7^{b}	483.8
Average	303.2	268.1	361.6	205.5	414.5	310.6

Different letters indicate significant difference between sites at $p < 0.05$; LSD test.

Conclusion

Favorable weather conditions during the second year of investigation have resulted in an increasing weed infestation of main crop. Among all variants with winter cover crops, plot weediness of main crop was lower comparing to control variants in both years of investigation. In the first year of investigating, the number of weeds and number of plants per species was higher in the mixtures compared to single cover crops, while the fresh and air-dry mass of weeds was higher in single cover crops. In the second year of the study, the opposite trend was observed. In addition, cost inputs were reduced, but no other common benefits in the long term were found on winter cover crops and their mixtures (increase of organic matter, increase of biodiversity, conservation of water, N, etc.).

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