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Influence of Winter Cover Crops Incorporation on Weed Infestation in Popcorn Maize (*Zea mays everta* Sturt.) Organic Production

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Summary

Cover cropping in fallow period brings many benefits in organic farming and weed suppression is one of the possible effect. The main aim of this two year research (2008/09-2010) was to determine the influence of winter cover crops incorporation on weediness in organic popcorn (*Zea mays everta* Sturt) production. The field trial was set up at the lessive soil of the Eastern Croatia (45°38' 46, 52'' N / 18°23' 32, 73'' E) as complete randomized block design in four repetitions. The five cover crops treatments were used: Wr – winter rye, Ww – winter wheat and V - hairy vetch, as single crops, and cover crops mixtures WrV and WwV. Fallow area was used as a control: Z (zero). Sampling to quantify the dry matter and incorporation of cover crops were performed just before full flowering period of cover crops and the popcorn maize was sown right after. Dominant weed species determined in this trial were *Ambrosia artemisiifolia* L., *Amaranthus retroflexus* L., *Echinochloa crus – galli* (L.) PB. and *Setaria glauca* (L.) PB. Treatments with the highest shoot production were Wr and WrV. The weediness in popcorn maize was higher at winter cover crops treatments compared to control. Looking at winter cover crops treatments only, the least weeded was WwV mixture regarding total weed number, and V and Wr treatment showed the lowest weed height, whereas height of the popcorn maize was the lowest at Wr treatment. The highest weed aboveground biomass was recorded on WrV treatment. Results of this experiment indicate the increasing of weed infestation caused by winter cover crops incorporation.

Key words

cover cropping, weediness, organic farming, *Zea mays everta*

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Introduction

Cover crops represents very important component in organic agriculture and should be a regular part of crop rotation (Rosa, 2015). With multiple positive impact on agroecosystem they contribute to greater yield stability in organic farming linking soil, crop, pest and weed management (Barberi, 2002). Winter cover crops are grown primarily for soil covering and so they contribute to the maintance of soil tilth, soil protection against environmental deterioration, soil nutrients and moisture conservation; even pest and weed control (Wall et al., 1991; Sorensen, 2004; Stipešević et al., 2008; De Bruin et al., 2005; Brozović, 2014). Weed control and fertilization are the main factors which affecting the organic farming system (Liebman and Davis, 2000) requiring a complex approach that includes various direct and indirect measures (Locke et al., 2002). Weediness can cause severe damage in maize production such as yield reductions to even 70% (Teasdale, 1995) and weed supression is recognized as the biggest challenge and the most serious threat to organic crop production (Clark et al., 1998; Dorner et al., 2012). This is even more pronounced in organic popcorn maize production because of lower ability of popcorn maize for adaption to adverse environmental factors comparing to standard maize (Ziegler et al., 1985). But there are certain possibilities for improving organic maize popcorn production by cover crop management (Pajančić et al., 2009). Cover crops are the most studied objects regarding weed management in organic farming and their impact on weeds depends on cover crop species, vegetation period duration and killing method (Barberi and Mazzoncini, 2001). Cover crops suppress weeds in different ways: as a living mulches by competition for light, water, nutrients and vegetation space (Brennan and Smith, 2005) and as surface placed or incorporated residues (Lemessa and Wakjira, 2014). Incorporated cover crops residues can be toxic to weeds due to allelopathic compounds producing during decomposition, thus causing inhibition and retardation of weed germination and establishment (Kruindhof et al., 2009), as well as retarding emergence and early growth of seedling (Sarrantonio and Gallandt, 2003; Teasdale et al., 2007). Weed suppression efficacy of incorporated cover crops depends on their quantity and quality which affect the rate of decomposition (Liebman and Mohler, 2001). Therefore, when selecting cover crops species for that purpose, biomass production efficiency, proven allelopathic activity as well as climatic and soil characteristic of specific area should be considered. Hairy vetch, rye and wheat can be used as cover crops and several studies have showed that they can suppress weeds in maize (Malik et al., 2008). For that reason, in this research, winter rye, winter wheat and hairy vetch were selected as winter cover crops for incorporation just before popcorn maize seeding. Mentioned species are tolerant to a low temperature with the prompt starting growth and development with efficient aboveground biomass production (Boyd et al., 2009; Brozović et al., 2017) and negative allelopathic effects on weeds (Bradow et al., 1990; Teasdale et al., 1991). Weed management in maize is important and more experiments should be done to help understand if cover crops can help to suppress weeds in maize fields. From all of the above, the target winter cover crops are included in the research with the popcorn maize whose production and breeding potentials in organic agriculture in the Republic of Croatia are insufficiently investigated.

Materials and methods

The experiment was conducted over the 2008/09 and 2009/10 growing seasons in Valpovo, Eastern Croatia on a lessive soil with pH $_{(KCl)}$ 4.79, 1.55 % organic matter, AL-P_2O_5 8.6 mg 100 g^{-1} and AL-K_2O 12.59 mg 100 g^{-1}. The field trial was carried out as a complete randomized block design in for repetition, with the basic experimentl plot site of 4.5 x 12.5 m. The experiment started with winter cover crops seeding in fall (first week of October) 2008 and 2009 to produce biomass for incorporation before popcorn maize seeding in spring 2009 and 2010. The following winter cover crops were grown: Wr – winter rye (*Secale cereale* L.), Ww – winter wheat (*Triticum aestivum* L.), V - hairy vetch (*Vicia villosa* L.) as single crops and mixtures WrV and WwV. Fallow area, without cover crop, was used as control: Z (zero). All cover crops were sown by hand broadcasting seed over the soil surface, discharrowed after the harvest of the previous soybean crop. Their seeds were sown at the following rates: Wr - 150 kg ha^{-1}, Ww - 300 kg ha^{-1}, V – 120 kg ha^{-1}. Cover crops mixtures WrV and WwV were sown in the 50% ratio of single crops. Cover crop aboveground biomass was collected in full growing stage just before incorporation by cutting and collecting plant material from ¼ m^2 frame on four randomly selected places in each experimental plot. The total cover crop aboveground biomass was dried up at 60 °C until constant weight for dry weight determination. Incorporation of cover crops in soil was performed by moulboard ploughing at 30 cm depth (first week of May 2009 and 2010). Popcorn maize (*Zea mays everta* Sturt.) hybrid 504 PC (FAO 550) was sown five days after cover crops incorporation (both years) in all plots with aimed plant density of 65 000 ha^{-1}. Preseeding soil preparation was performed by seed harrow and seeding was conducted with maize seeder. Mechanical weed control in popcorn maize was preformed at BBCH 16 growing stage, (5-6 leafs unfolded) in both years. The total weed density and number of single weed species (data are not shown in this paper) from 1 m^2 was determined at BBCH 36 growing stage (6 nodes detectable) of maize by counting each weed species from ¼ m^2 frame on four randomly selected places in each experimental plot. Additionally, weed and popcorn maize height was recorded. Weed height of each species was measured on the length of 2 m in the two centre rows of each plot together with height of 10 randomly selected popcorn maize plants with meter rod. The popcorn maize stalk height was measured from the soil level to the top of the highest standing leaf. Second weed and popcorn maize height was recorded as described at BBCH 67 growing stage of maize (flowering completed). Weed species height is presented as average height of total weeds, and heigh of 10 popcorn maize plants as average of all plants per plot. At the beginning of heading, (BBCH 52) aboveground biomass of total weeds was sampled from 1 m^2 area in each plot. The total weed biomass was dried up at 60 °C until the constant weight for dry weight determination. Weather data (air temperature and precipitation) were collected from Meteorological station Osijek, nearest to the experimental site. Analysis of variance (ANOVA) was performed on collected data using the GLM procedure of SAS (1999) with the Year as the main level and the CC as the sub-level of treatments. Differences among the treatments means were determined by Fisher protected LSD-test at a significance level of 0.05.

Weather conditions

Two experimental years differed in terms of total precipitation (Table 1). The precipitation observed in the sowing period and the initial growth of the winter cover crops (2008) was about 20% lower compared to the long term average (1961/91) with an average temperature higher for 2.3 ˚C.

Table 1. Temperatures and precipitation in winter cover crops and popcorn maize vegetation (2008-2010) and long term average (1961-1990)

Year	Months												Total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
						Precipitation (mm)							
2008	33.1	4.7	82.4	48.8	66.9	76.3	67.6	46.2	86.3	29.8	47.9	40.8	630.8
2009	60.3	28.6	26.5	18.7	39.4	62.8	13.8	60.6	10	55.3	67.8	101	544.6
2010	83.9	58.6	22.2	71.1	120.8	234	31.5	110.8	108.4	67.1	56.3	73.5	1038
Averages 1961/90	46.9	40.2	44.8	53.8	58.5	88	64.8	58.5	44.8	41.3	57.3	51.6	650.5
						Temperature (°C)							Mean
2008	1.5	4.9	7.6	12.5	18.1	21.5	21.8	21.8	15.6	13	7.5	3.8	12.5
2009	-1.2	2	6.8	14.6	18.3	19.2	23.2	22.9	19.1	11.5	8.2	3.1	12.3
2010	-0.8	1.3	6.8	12.4	16.5	20.4	23.2	21.7	15.6	9.1	8.9	0.2	11.3
Averages 1961/90	-1.2	1.6	6.1	11.3	16.5	19.5	21.1	20.3	16.6	11.2	5.4	0.9	10.8

Results and discussion

Cover crops aboveground biomass production

First experimental year (2009) was characterized by a lack of precipitation and temperatures above the long term average (Table 1). The second cover crop growing season (October 2009-April 2010) was wetter than the first one (October 2008-April 2009) with 460 mm vs. 253 mm of precipitation while the average temperatures were similar.

Weather conditions influenced cover crops biomass production which varied between years. Significantly higher average biomass of cover crops was obtained in wetter 2010 year (Figure 1) similar with research of Caporali et al. (2004). The cover crops biomass have ranged from 140.01 g m^{-2} on Ww treatment in 2009 to 651.84 g m^{-2} on WrV treatment in 2010. The most productive cover crop was winter rye with the average of 457.14 g m^{-2} which is also reported by Rosa (2015).

Winter rye establish more quickly than other mentioned cover crops with ground cover of 30 % already in autumn, which is confirmed by Boyd et al. (2009) thus resulting with high aboveground biomass. Next to Wr was WrV, followed by WwV, V and Ww with only 227.00 g m^{-2} which is opposite to Stipešević et al. (2008) who pointed out winter wheat as the most productive treatment regarding biomass production.

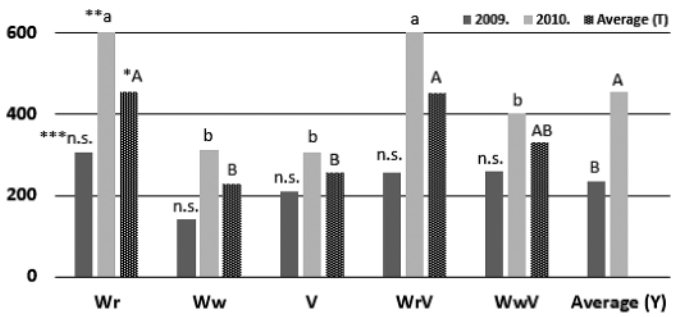

Figure 1. Biomass of cover crops (2009 and 2010)
* Values marked with the same uppercase letters are not significantly different at P=0.05; ** Values marked with the same lowercase are not significantly different at P=0.05; *** For values marked with n.s. statistically significant differences are not confirmed

Weed infestation in popcorn maize

In two vegetation periods of popcorn maize, 15 weed species were recorded, mainly annual. The most dominant annual grasses were *Echinochloa crus-galli* (L.) PB and *Setaria glauca* (L.) PB. Moreover, *Digitaria sanguinalis* (L.) Scop was also noted. Annual broad-leaved weeds were presented with *Ambrosia artemisiifolia* L., *Amaranthus retroflexus* L., *Chenopodium album* L. *Chenopodium hybridum* L., *Chenopodium polyspermum* L. and *Polygonum persicaria* L. The most abounded annual broad – leaved species was *Ambrosia artemisiifolia* L. The highest occurrence of perennial broad – leaved species had *Cirsium arvense* L. and *Convolvulus arvensis* L. while perennial grasses were presented with *Sorghum halepense* (L.) Pers. and *Agropyron repens* (L.) PB.

Contrary to the expected, cover crops incorporation led to the increase of weed infestation in popcor maize. Compared to fallow area (Z), weed biomass and weed density increased in popcorn maize, following all cover crops incorporation in both experimental years (Table 2). This is opposite to Caporali et al. (2004) who reported the reducing weed density and weed biomass due to cover crops incorporation before maize seeding as well as Dyck et al. (1995). The highest weed biomass was detected in 2010 year on WrV treatment which is the only one with confirmed statistically significant differences compared to control, followed by V.

Weather conditions influenced both, biomass and weed density. The higher amount of precipitation in vegetation period of popcorn maize in 2010 caused the increase of weed biomass for more than 3 times compared to 2009. The total amount of precipitation in vegetation period of popcorn maize in 2010 was higher for 320 mm compared to the same period in 2009 which is 230 mm more than long term average. Excessive precipitation has also affected the total number of weeds which was significantly higher in year 2010. The great soil moisture favored the rapid and intensive weed growth and development what differs from the results of Abdin et al. (1999) who reported higher weed infestation in maize during drier vegetation period in two years research. The ploughing of winter wheat and winter rye – hairy vetch mixture proved to be the least efficient regarding total weed density. Although allelopathic negative effects of winter rye, hairy vetch and winter wheat is proven (Putnam and DeFrank 1983; Bradow and Connick 1990; Khanh et al. 2005) in this research it was not confirmed. The higher occurrence of weeds after cover crops incorporation is probably due to effects of green manuring as the only form of fertilization that was performed. Availability of nitrogen to the weeds by cycling and certain amount of organic matter caused higher weed

Table 2. Total weed biomass (BBCH 52) and weed density in popcorn maize (BBCH 36)

Cover crop (T)	Weed biomass (g m^{-2}) 2009		2010		Average (T)		Weed density (shoots m^{-2}) 2009		2010		Average (T)	
Z	64.98	a*	248.4	b	156.69	B**	6.53	a	20.57	c	13.55	B
Wr	90.66	a	329.31	ab	209.99	AB	12.67	a	22.21	bc	17.44	AB
Ww	83.08	a	272.31	b	177.70	AB	11.71	a	28.75	ab	20.23	A
V	115.02	a	325.27	ab	220.15	AB	11.32	a	25.14	ab	18.23	AB
WrV	84.89	a	421.95	a	253.42	A	7.68	a	31.11	ab	19.40	A
WwV	112.48	a	263.86	b	188.17	AB	8.71	a	23.89	ab	16.30	AB
Average (Y)	91.85	B	310.18	A			9.77	B	25.28	A		
	LSD0.05 (Y) 10.2513						LSD0.05 (Y) 12.02734					
	LSD0.05 (T) 94.93393						LSD0.05 (T) 5.437283					
	LSD0.05 (T/Y) 134.2568						LSD0.05 (T/Y) 7.689479					

*Values marked with the same lowercase letters are not significantly different at P=0.05; **Values marked with the same uppercase are not significantly different at P=0.05

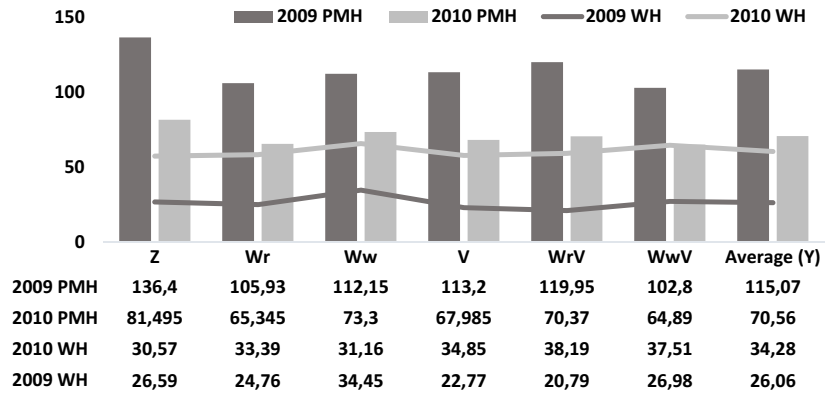

Figure 2. Popcorn maize and weed height (cm) in 2009 and 2010 (BBCH 36); $LSD_{0.05}$ (Y):PMH = 48.301552, WH = 11.252695; $LSD_{0.05}$ (T/Y):PMH = 25.046497, WH = 13.436834

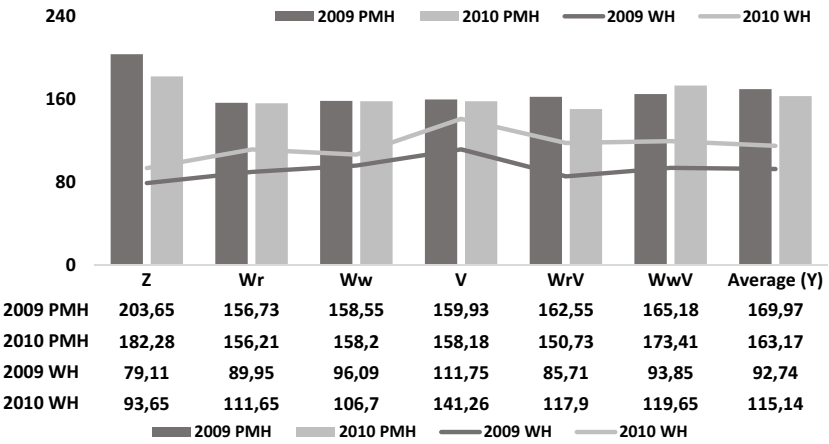

Figure 3. Popcorn maize and weed height (cm) in 2009 and 2010 (BBCH 67); $LSD_{0.05}$ (Y):PMH = 47.58641 , WH = 12.616; $LSD_{0.05}$ (T/Y):PMH = 23.91221, WH = 38.48575

infestation on cover crop treatments which is also confirmed by Blum et al. (1997). It can be assumed that available nitrogen after cereal/legume (WrV) and legume (V) incorporation induced emergence and growth of weeds which is also reported by Mohler and Teasdale (1993).

Popcorn maize/weed height relation

Average weed height did not differ significantly among two experimental years in first observation (Figure 2) although it was higher in 2010. On the other side, average popcorn maize plants height was lower which is probably direct consequence of weed/maize competition. According to Nayital et al. (1989) the critical period of weed competition in maize is from 20 to 60 days after sowing. The highest popcorn maize plant was recorded on control treatment in both years of investigation. Same treatment had the lowest weed height in 2010. This can be explained by less expressed maize/weed competition in the critical period. Incorporation of cover crops proved to be ineffective to weed height decreasing.

In second opservation, (BBCH 67) weather conditions affected the average weed height which was significantly higher in second popcorn maize vegetation season (Figure 3). This can be attributed to a large amount of precipitation (376 mm) in particular popcorn maize vegetation period (June – August) that is 165 mm more

comparing to a long term average (Table 1). The maximum popcorn maize plant height was obtained on control treatment with the smallest average height of weeds. Incorporation of cover crops increased average weed height so the maize/weed competition was more present and thus caused average popcorn maize height decreasing. Importance of maize/weed competition in this vegetation period of maize is also confirmed from Makhdoom (1986) which specifies the competition duration to flowering stage of maize.

Conclusion

Winter rye and mixture of winter rye and hairy vetch were the cover crops with the highest aboveground dry biomass. Weed infestation in popcorn maize was affected with winter cover crops incorporation. All cover crops treatments increased weed abundance comparing to control. Average aboveground dry biomass, weed density and weed height were increased after cover crops incorporation. Greather average weed height caused a decrease of popcorn maize plant height. The result of this study point out the increased weediness in organic maize popcorn production after winter cover crop incorporation with negative influence on crop development.

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