Original scientific paper

Fall and spring sown legume-cereal cover crops for sweet maize production

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Abstract

Sweet maize (*Zea mays saccharata* Sturt.) has been grown in a small acreage, e.g. 5 000 ha in Serbia because of limited processing and serious weed infestation as much as in a field maize crop. Sweet maize is considered a week competitor because of it's shorter and less developed habit, which makes improved weed management systems a main priority. Growing both fall and spring sown cover crops is an approach for environmental protection trough decreasing weed populations and increasing grain yield of sweet maize. The objective of the study was to determine the effect of different winter and spring grown cover crops, and legume-cereal based mixtures on yield of sweet maize. The experiment includes two control treatments: dead organic mulch - soil covered with straw in autumn and winter time, and conventional (traditional) variant – bare soil uncovered during fall and winter time.

The various cover crops and it's mixtures had significantly different effects on sweet maize yield during the period of investigations (2010/11 and 2011/12). Along legume species, favorable effect on grain yield of sweet maize had been recorded on winter hairy vetch, as well on a kind of non legume species, winter fodder kale. Spring cover crops had lowered weed infestation of sweet maize and grain yields in comparison to the winter cover crops and control treatments.

Key words: cover crops, legume-cereal mixtures, sweet maize, weed infestation, yield

Introduction

Modern society, as mach as it could must be related to sustainable management of renewable natural resources trough ecologicaly based agricultural development. An ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity should be based on minimal use of „off-farm“ inputs and on management practices that restore, maintain, or enhance ecological harmony. The primary goal of these systems is to optimize the health and productivity of interdependent communities of soil biota, growing plants and animals, and people. Perceived benefits of the alternative technology over conventional one, have been considered mostly in terms of grain yield of the main crop (Dolijanović et al., 2012).

Sweet maize has been grown in a small acre, e.g. 5 000 ha in Serbia, mainly because of limited processing capacities. On the other side, due to increasing usage for fresh consumption sweet maize could become another valuable cash crop for small farmers, why certain expansion of growing areas might be expected (Pajić and Srdić, 2007). Weeds infestation represents a major problem in sweet maize crops, as well as in field maize. Commercially grown sweet maize hybrids (*Zea mays saccharata* Sturt.) varying widely in competitive ability against weeds, which interference differentially affects yields and cob quality important for processing and fresh markets (Simić et al., 2012). In order to obtain high yields of good quality the scientists have been searching for the most appropriate growing practices.

Sweet maize is considered a week competitor against weeds, because of its shorter and less developed habitus, which makes improved weed management systems a certain priority. Both broadleaf and gramineae weeds could infest sweet maize fields. In organically grown sweet maize, the most dominant weeds were *Digitaria sanguinalis* (L.) Scop., *Setaria faberi* (Herrm.) *Amaranthus hybridus* L. (Silvernail, 2005). *Panicum milliaceum*, *Ambrosia trifida*, and *Sinapis arvensis*, and should considered the most troublesome weeds in sweet maize (Williams et al., 2007).

Increasing environmental problems and big concern on health issues has driven to development of new techniques and systems to deal with weeds, pests and diseases. Cover crops being often used to design new strategy that preserves farm natural resources while remaining it's cost-effectivity. Cover crops can decrease weed infestation, increase yields and at the same time, they can reduce costs, increase profits and even create new sources of income.

Cover crops can play an important role in managing weeds by shading and interfering with weed germination and establishment. Among cereals,it is knowen that rye produces allelochemicals, naturally occuring compounds that can control or suppress weeds.

Once researchers find the appropriate combination of maize and ground cover, they believe yields will not be impacted, and soil quality will be maintained. Nevertheless, cover crops can also become weeds and must be carefully managed to prevent it's competitivity toward main crops regarding soil moisture, nutrients etc. The possibility to reduce weediness on the basis of the increased crop competitive abilities by growing high yielding hybrids that "tolerate" a higher plant density, depends on traits of each hybrid and climatic conditions in the specific growing region (Williams et al., 2007).

Many farmers viewed climatic factors as possible barriers to establish cover crops, but uncertainty was also high: rarely enough time between harvest and winter to justify use; cover crops can delay spring planting; if shorter-season varieties yielded the same as longer-season, would be more likely to plant.

The objective of this study was to determine the effect of different winter (dead mulch) and spring grown (living mulch) cover crops and their mixtures with oats on weed infestation and sweet maize grain yield.

Material and methods

The experiment included four kinds of *winter cover crops* (common and hairy vetch, oat and fodder kale, as well mixtures of legume crops with oats), another variant in which the land was covered with dead organic mulch, and traditional variant, classical plowing in the fall and keeping bare land uncovered during the winter, as well *different spring crops species* (common vetch, oat and it's mixtures) growth as a living mulch. All of the varieties being used as a cover crops belongs to Novi Sad Field Crops Institute. Crops were grown under rainfed conditions.

Field experiments were conducted in 2010/11 and 2011/12 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 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 previous 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 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 (April 07 2011 and April 09 2012) 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), oats an fodder kale 70 kg ha^{-1} N, 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 quantity of nitrogen, phosphorous and potassium for spring cover crops were applied just prior to planting, with soil preparation.

Sowing of cover crops were done manually in October 2010 and 2011. Mowing the above-ground biomass of winter cover crops were performed 7-10 days before planting of sweet maize. Planting of of sweet maize seedlings were done on May 26.th in 2011, and May 21.st in 2012 year. The estimation of weed infestation in sweet maize was conducted on early July in both years. Crops were harvested 22-24 days after pollination. In 2011 harvest was performed on August 18th whereas in growing season 2012 there was a crop failure because of extreme drought and high temperatures. The meteorological conditions during the maize growing season are presented in Table 1.

Table 1. Average air temperatures and precipitation sums from April to September at Zemun Polje

Months	Temperature (°C)		Precipitation (mm)	
	2011	2012	2011	2012
April	14.6	14.4	11	67
May	17.3	17.9	63	128
June	22.4	24.6	40	14
July	24.1	27.1	107	39
August	24.7	26.2	9	4
September	23.2	22.0	49	31
Average/Sum	21.1	22.0	279	283

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 new 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

The fresh and air dried weed biomass 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 on July 3, 2011 and July 04, 2012. Following weed sampling, manual hoeing was done in order to suppress weeds pressure in sweet maize.

All ears in two inner rows of each subplot were harvested and weighed directly from the field, 25 days after silking. Furthermore, a shelling percentage, as a kernel weight to cob weight ratio, was determined in a sample of 10 randomly selected cobs.

The yield data were underwent to ANOVA for the factorial trials set up according to the plan for two years, eleven variants, where means differences were tested by the least significant difference (LSD) test (Gomez and Gomez, 1984).

Results and discussion

Results of fresh and air dried above-ground biomass of cover crops are presented in Table 2. Meteorological conditions in both years of investigations were extremely unfavorable (Table 1), as it was for winter and spring cover crops, as well for main crop of sweet maize.

Table 2. The growing season (A) and cropping system (B) effects on weed infestation of sweet maize

Cropping system (B)		Fresh biomass ($g\ m^{-2}$)		Air dried biomass ($g\ m^{-2}$)	
		2011	2012	2011	2012
Winter cover crops and mixtures (dead mulch)	Common vetch	291.4	255.1	70.2	79.3
	Hairy vetch	288.6	262.1	69.7	74.2
	Oats	311.6	302.3	78.8	80.7
	Fodder kale	301.0	296.5	80.2	78.7
	Common vetch+oats	310.1	307.4	90.6	91.1
	Hairy vetch+oats	304.5	303.9	94.2	101.8
	Average	301.2	287.9	80.6	84.3
Control treatment	Organic mulch	381.1	326.7	102.3	85.4
	Conventional system	834.1	728.8	121.1	132.6
	Average	607.6	527.7	111.7	109.0
Spring cover crops and mixtures (living mulch)	Common vetch	212.6	198.4	56.9	59.8
	Oats	304.8	299.7	65.2	61.8
	Common vetch+oats	291.3	289.7	70.2	55.6
	Average	269,6	262,6	64,1	59,1
	Average	392,8	359,4	85,5	84,1

Fresh biomass LSD	A	B	AB	Air dried biomass LSD	A	B	AB
0.05	0.52	1.21	1.71	0.05	0.69	1.42	2.04
0.01	0.71	1.66	2.35	0.01	0.91	1.83	2.63

Weeds species were weaker competitor in this situation. The highest total fresh weight was 834. 1 g m^{-2} (conventional system) in 2011 and 728.8 g m^{-2} in 2012 while the lowest fresh weight was measured in hairy vetch (winter cover crops) and common vetch (spring cover crops) in both years. In spring sown cover crops the fresh weight was smaller comparing to winter cover crops, mainly because of extreme conditions of drought and high temperatures, so far during the growing season 2012th there was a crop failure. By covering bare soil with straw (organic mulch) weediness becoming somewhat higher comparing plots among winter and spring cover crops, even though sweet maize yield significantly was higher using this system of growing. In addition, cost inputs were reduced, but no other common benefits in the long term were found on winter and spring cover crops (increase of organic matter, increase of biodiversity, etc.).

Favorable weather conditions during the first year of trials have resulted in an increasing weed infestation of main crop. Among all variants with winter and especially with spring cover crops, plot weediness of main crop was lower comparing to control variants in both years of investigation.

In conventional production of sweet maize at the trial location the dominant species being detected, in the first year only was: *Amaranthus albus*, *Convolvulus sepium*, and *Digitaria sanguinalis* while in the second year of investigation it was *Amaranthus hybridus*, *Chenopodium album*, *Cirsium arvense* and *Xanthium strumarium* (Simić et al., 2012). Weeds fresh biomass was dependent of density of sweet maize crops (40-70.000 plants ha^{-1}), varying from 486.7, 612.3, 257.6 and 228.9 in the year 2008. and 894.4, 772.7, 934.0 and 520.4 g m^{-2} in the year 2009.

Table 3. The cropping system effects on grain yield of sweet maize

Cropping system		Yield (t ha^{-1})		Percent shelling	
		2011**	2012	2011*	2012
Winter cover crops and mixtures	Common vetch	8.84	-	62.58	-
	Hairy vetch	9.98	-	74.69	-
	Oats	9.07	-	57.88	-
	Fodder kale	8.32	-	69.17	-
	Common vetch+oats	8.72	-	56.07	-
	Hairy vetch+oats	8.61	-	62.05	-
	Average	8.92		63.74	
Control treatment	Organic mulch	10.00	-	68.09	-
	Conventional system	8.09	-	60.79	-
	Average	9.05	-	64.44	-
Spring cover crops and mixtures	Common vetch	7.61	-	60.05	-
	Oats	7.49	-	63.70	-
	Common vetch+oats	6.21	-	56.63	-
	Average	7.10	-	60.13	-
	Average	8.36	-	62.77	-

** P=0,01; *P=0.05; Yield of grain LSD 0.05 0.41; 0.01 0.57. Percent shelling LSD 0.05 3.06; 0.01 4.20

Results of grain yield and shelling percentage of sweet maize cobs in the analyzed samples are presented in Table 3. The highest yield was obtained in the variant with dead organic mulch (10.00 t ha^{-1}), primarily due to the fact that for its decomposition was significantly more time alone and the planting of corn was thus greatly facilitated. The lowest yield was obtained following the conventional system (8.09 t ha^{-1}) as well spring cover crops. Yield of sweet maize in this study was below average yields in similar experiments (Dolijanović et al., 2012), and the main reason was the way of growing. Simic et al., (2012) reported that average yield of grain was 10.35 in 2008 and 10.04 t ha^{-1} in 2009.

The estimates of shelling percentage were at common level for particular hybrid, which is so far the best seller for many years, among range of ZP sweet maize hybrids, including recent achievements of breeding with specific properties of increased sugar content.

The variants covered by dead mulch, and especially variants being covered by living mulch mixtures gave higher yields of biomass and consequently lower grain yield of sweet maize as a main crop.

Weeds represents one of the major threats to crop production in sustainable and organic farming systems. The risk of high weed infestations is not only yield reduction of the main crop but also the decrease of the commercial quality and the feeding palatability of main crops (Rahman et al., 2006) and enrichment of the soil seed bank of weeds (Buhler, 1999), which may cause severe weed infestation in subsequent crop production (Uchino et al., 2009).

Cover crop sowing date is one of the important cover crop management issues. Abdin et al., (2000) reported that weeds could be suppressed significantly with a little effect on maize yield by sowing cover crops at 10 and 20 days after maize emergence.

Conclusions

Meteorological conditions prevailing during the trial period had an important impact on weediness and grain yield of sweet maize. Growing cover crops is one extremely important tool for the appropriate management of weeds in long-term weed control under sustainable and organic agricultural systems. Perceived benefits of the alternative technology over conventional one should considered mostly in terms of grain yield of the main crop. Currently, living mulch in spring-sown cover crops have had 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.

Acknowlegdement

A part of this study was supported by the Ministry of Education and Science of the Republic of Serbia through the scientific project “Integrated system of field crop cultivation: conservation of biodiversity and soil fertility”, Reg. No. TR-31037.

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