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Non-chemical weed control in sugar beet crop under intensive and conservation soil tillage: I. Crop weediness

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Abstract. The effect of non-chemical weed control under different soil tillage on sugar beet crop weediness was investigated at the Experimental Station of the Lithuanian University of Agriculture in a silty loam Luvisol during the period of 2004–2005. The aim of the experiment was to establish the influence of soil tillage intensity, living and straw mulch on the number and dry mass of weeds in the sugar beet crop. Treatments of the trial were the following: I. Soil tillage (factor A): 1. intensive (straw loosening, moldboard ploughing; control variant) (IT); 2. conservation (straw loosening) (CT); II. Non-chemical weed control (factor B): 1. hand weeding, twice (control variant) (HW); 2. spring barley living mulch (SBM); 3. annual ryegrass living mulch (ARM); 4. white mustard living mulch (WMM); 5. spring oilseed rape living mulch (SRM); 6. winter wheat straw mulch (WSM).

According to the results of investigations, in conditions of intensive soil tillage the highest choking of weeds was observed by annual ryegrass (ARM) and white mustard (WMM) living mulches. In sugar beet row spaces, which were mulched with winter wheat straw mulch (WSM) there was a large number of weeds but their mass was not high. Conversely, in conservation soil tillage conditions the lowest weed infestation and dry mass of weeds were observed in straw mulch (WSM) up to 4 cm. White mustard living mulch (WMM) also influenced weed dry mass decrease though its number was high.

Key words: non-chemical weed control, intensive and conservation soil tillage, sugar beet crop, mulch, weeds

INTRODUCTION

The system of organic agriculture becomes popular in the world. There are more than 2400 organic farms in Lithuania at this moment. The main production of such farms are cereals and vegetables, however sugar beet is still grown in chemical conditions of intensive farming. In the European, Union Lithuania has not a large quota of white sugar – about 80 thousands tons, sugar factories are small; therefore there is a real possibility to produce organic sugar. The agents of "Danisco Sugar", the owners of Kėdainiai sugar factory (Lithuania) are discussing this.

In organic farming system the most serious problem is effective weed control due to high weed concurrence in the sugar beet crop. The increase in weed infestation in minimally tilled soil is the second challenge (Munkholm et al, 1998). Weeds compete with the crop for light, water and nutrients. Weeds that grow above the crop canopy

and shade the crop plants are most detrimental to yield. Short weeds become very competitive if allowed to grow undisturbed when the crop plants are still small (Draycott, 2006).

Living mulch could be an effective method of controlling weed infestation in a non-chemical way. Living mulches control weeds in two ways. When they are sown before weed establishment, they suppress weeds by competition (Hartwing, 1977). In some situations, the allelopatic properties of living mulches can be used to control weeds. For example, the allelopatic properties of winter rye *(Secale cereale)*, ryegrasses *(Lolium spp)*, and subterrain clover *(Trifolium subterraneum)* can be used to control weeds in sweet corn (*Zea mays*) and snap beans *(Phaseolus vulgaris)* (De Gregorio & Ashley, 1986).

However, living mulches compete for nutrients and water with the main crop and this can reduce yields (Echtenkamp & Moomaw, 1989). On the other hand, legumes used as living mulches have greater N contents and a low C to N ratio (Lehmann et al, 2000). Because most living mulches compete with the main crop, they may eventually need to be mechanically or chemically killed (Brandsaeter et al. 1998, Tharp & Kells, 2001).

So, the aim of our trial was to investigate the influence of living and straw mulches on sugar beet crop weediness in conditions of intensive and conservation tillage because of the lack of such data in Lithuania. This data will help promote the adoption of the non-chemical weed control approach in organic farming system.

MATERIALS AND METHODS

The experiment was fulfilled with a silty loam (*Hipogleyic Luvisol (Calcaric)*) (WRB, 2006) at the Experimental Station of Lithuanian University of Agriculture during 2004-2005. Soil agrochemical properties are presented in Table 1.

Table 1. Soil agrochemical properties.
Lithuanian University of Agriculture, Research Station, average data of 2004–2005.

Index	Amount of elements mg kg^{-1} of soil	Evaluation
pH	6.96	Neutral reaction
humus*	25.6	Average
P_2O_5	101.0	Average
K_2O	40.6	Little
Mg	326.2	Average
Ca	2079.0	Sufficient
B	0.94	Average
Mn	50.7	Average

Note: * - amount of humus g kg^{-1}

The trial was established according to the scheme: I. soil tillage (factor A): 1. intensive (control variant) (IT); 2. conservation (CT); II. non-chemical weed control (factor B): 1. hand weeding, twice (control variant) (HW); 2. spring barley living mulch (SBM); 3. annual ryegrass living mulch (ARM); 4. white mustard living mulch (WMM); 5. spring oilseed rape living mulch (SRM); 6. winter wheat straw mulch (WSM).

The number of field trial replications was four. The estimated plot size was 3.6 m^2. The crop before sugar beet was winter wheat. In October, plots were loosened by disc harrow and ploughed with a mouldboard plough two weeks later (IT plots). Chemical weed, disease and insect control were not used. Plots were tilled by compound cultivator to a depth of 3–4 cm before sowing the sugar beet. The spaces between rows of sugar beet were 45 cm. Seeds were sown with a pneumatic drill with wedge-type coulters. Distance between seeds was 14.5 cm. In 2004, the sugar beet crop was fertilized with N_{60} P_{40} K_{80} before sowing and, in 2005, the amount of fertilizers was geminate. Plants of living mulch were sown into spaces between sugar beet rows after sugar beet sowing. The quantity of mustard, rape and ryegrass seeds sown was 10 kg ha^{-1}, spring barley – 200 kg ha^{-1}. Straw of winter wheat was also used as mulching material according to the scheme of the trial. Width of the straw mulch cover was 3-4 cm.

The dry mass of weeds was evaluated by the method of weighing. Samples were taken from every trial plot in 6 places using a frame 30 x 20 cm (the area was 600 cm^2) before the first cutting and second weeding. The same frames were used for counting seedlings and more mature weed plants. The living mulch was cut 2–3 times during sugar beet vegetation, except annual ryegrass. Annual ryegrass was cut 4–5 times. First hand weeding was made after sugar beet germination, second - at the time of first living mulch cut. Green mass of living mulch was laid into the spaces between sugar beet rows. Density of weeds was determined by the quantitative method (Dospechov et al., 1977). The results of crop weediness were recalculated into square metres. Latin names of weeds were presented according to Jankeviciene (1998). The trial data were analysed by Sigma Stat.

The weather conditions. In 2004, only vegetation beginning and end fulfilled the temperature conditions of many years. In May, June and July, the average air temperature of 24 hours was lower as usual. Regime of precipitation was near the annual mean, except August. In August, the amount of precipitation was about 30% higher than usual. In 2005, sugar beet vegetation was warmer than normal. April, July and September temperatures were particularly high. The regime of precipitation was not even. Dry phases alternated with wet conditions. July was especially dry and sugar beet plants were damaged by such conditions which negatively influenced root yield.

RESULTS AND DISCUSSION

According to the average results of 2004, in conditions of intensive soil tillage (IT) there were more species of weeds than in conditions of conservation tillage (CT) (Table 2).

In IT tilled soil before the first cutting of living mulch non-chemical weed control methods had no significant effect on different species weed number and mass. However, there was the significant effect on total weed mass. In first time hand weeded plots (HW) the total mass of weeds was 112.6 g m^{-2} or significantly higher than in other treatments. The most effective weed control methods were living mulch of spring barley (SBM), white mustard (WMM) and straw mulch of winter wheat (WSM).

Table 2. The influence of weed control system on number m^{-2} and dry mass g m^{-2} of weed under intensive soil tillage, 2004.

Index	Species of weeds								Total weeds
	Chenopodium album	*Stellaria media*	*Tripleurospermum inodorum*	*Capsella bursa-pastoris*	*Poligonum aviculare*	*Fallopia convolvulus*	*Veronica chamaedrys*	*Taraxacum officinale*	
Non -chemical weed control system:									
Hand weeding (HW)									
number	30.0	0.0	0.0	13.4	0.0	0.0	0.0	0.0	63.6
mass	87.2	0.0	0.0	14.7	0.0	0.0	0.0	0.0	112.2
Spring barley living mulch (SBM)									
number	43.2	0.0	6.8	6.8	0.0	3.4	6.8	3.4	63.2
mass	2.5	0.0	3.0	0.1	0.0	1.6	2.0	0.3	12.4**
Annual ryegrass living mulch (ARM)									
number	26.8	0.8	3.4	0.0	3.4	0.0	0.0	0.0	46.6
mass	41.2	0.04	4.1	0.0	3.9	0.0	0.0	0.0	49.9*
White mustard living mulch (WMM)									
number	16.8	41.5	0.0	0.0	0.0	4.2	8.5	0.0	71.0
mass	7.6	3.3	0.0	0.0	0.0	1.4	0.1	0.0	12.3**
Spring oilseed rape living mulch (SRM)									
number	16.8	36.8	3.4	20.0	0.0	3.4	3.4	0.0	50.0
mass	4.0	3.9	2.0	5.5	0.0	2.3	4.5	0.0	22.3*
Winter wheat straw mulch (WSM)									
number	6.6	6.6	0.0	13.4	3.4	0.0	13.4	3.4	43.4
mass	3.5	0.03	0.0	4.1	4.0	0.0	6.6	3.3	9.9**
Number of weeds									
P	0.415	0.214	0.405	0.516	0.592	0.654	0.132	0.592	0.872
±SE	5.18	6.53	1.11	3.46	0.81	0.98	1.69	0.81	6.99
Dry mass of weeds									
P	0.053	0.341	0.659	0.461	0.592	0.666	0.567	0.490	0.013
±SE	9.94	0.69	0.88	2.39	0.95	0.51	1.27	0.58	10.44

Note: ± SE – standard error, ∗ – significant differences at $P < 0.05$ and ** - at $P < 0.01$

In CT conditions, there was a lower number of weed species; however its mass mostly was higher than in IT. As in IT, non-chemical weed control methods had no significant effect on weed infestation and dry mass, except plants of *Stellaria media*. The greatest density of *Stellaria media* plants was observed in hand weeded plots and its mass was significantly higher than in other treatments (Table 3).

Table 3. The influence of weed control system on number m^{-2} and dry mass g m^{-2} of weed under conservation soil tillage, 2004.

Index	Species of weeds						Total weeds
	Stellaria media	*Tripleuro-spermum inodorum*	*Capsella bursa-pastoris*	*Fallopia convolvulus*	*Veronica chamaedrys*	*Taraxacum officinale*	
Non -chemical weed control system:							
Hand weeding (HW)							
number	173.4	3.4	0.0	0.0	3.4	0.0	193.2
mass	104.1	1.9	0.0	0.0	0.17	0.0	112.6
Spring barley living mulch (SBM)							
number	133.2	0.0	0.0	3.4	0.0	3.4	163.4
mass	40.2*	0.0	0.0	1.7	0.0	1.5	44.6*
Annual ryegrass living mulch (ARM)							
number	137.2	0.0	20.0	0.0	0.0	0.0	260.6
mass	20.1**	0.0	6.9	0.0	0.0	0.0	65.3
White mustard living mulch (WMM)							
number	200.0	0.0	0.0	0.0	0.0	0.0	213.4
mass	34.8**	0.0	0.0	0.0	0.0	0.0	37.0**
Spring oilseed rape living mulch (SRM)							
number	130.0	3.4	10.2	0.0	3.4	0.0	148.0
mass	33.7**	0.03	5.2	0.0	0.17	0.0	39.2**
Winter wheat straw mulch (WSM)							
number	90.2	10.2	0.0	0.0	0.0	0.0	106.4
mass	18.7**	3.6	0.0	0.0	0.0	0.0	23.6**
Number of weeds							
P	0.355	0.072	0.218	0.439	0.561	0.439	0.098
±SE	14.61	1.17	2.89	0.57	0.79	0.57	16.51
Dry mass of weeds							
P	0.007	0.461	0.198	0.439	0.471	0.439	0.010
±SE	7.87	0.63	1.08	0.28	0.20	0.25	8.08

Note: ± SE – standard error, ∗ – significant differences at $P < 0.05$ and ** - at $P < 0.01$

Generally, use of a living and straw mulch was the most effective method compared with hand weeding, however there were more weeds in the CT than in IT plots. The increase of weed infestation due to reducing of soil tillage has been observed by other scientists too (Børresen, 1993).

In 2005, in conditions of intensive soil tillage (IT) the most dispersed weed was *Capsella bursa-pastoris* in plots with barley (SMB) living mulch. As in 2004, in hand weeded plots there were more weeds than in other treatments (Table 4).

Table 4. The influence of weed control system on number m^{-2} and dry mass g m^{-2} of weed under intensive soil tillage, 2005.

Index	Species of weeds					Total weeds
	Chenopodium album	*Stellaria media*	*Tripleurospermum inodorum*	*Capsella bursa-pastoris*	*Taraxacum officinale*	
Non -chemical weed control system:						
Hand weeding (HW)						
number	58.0	54.0	0.0	16.5	4.0	132.5*
mass	101.2	10.1	0.0	10.8	35.6	157.7
Spring barley living mulch (SBM)						
number	4.0	0.0	0.0	86.3**	0.0	90.2
mass	23.1	0.0	0.0	38.2**	0.0	40.4*
Annual ryegrass living mulch (ARM)						
number	8.0	8.3	0.0	4.0	0.0	20.3**
mass	20.2	0.1	0.0	3.5	0.0	23.7**
White mustard living mulch (WMM)						
number	8.3	0.0	0.0	0.0	0.0	8.3**
mass	2.3	0.0	0.0	0.0	0.0	2.3**
Spring oilseed rape living mulch (SRM)						
number	20.8	0.0	16.8	12.3	0.0	49.8*
mass	71.2	0.0	25.8	4.3	0.0	101.3
Winter wheat straw mulch (WSM)						
number	37.5	29.0	0.0	12.5	4.0	83.0
mass	31.7	3.7	0.0	4.9	1.7	41.9*
Number of weeds						
P	0.430	0.164	0.446	0.002	0.564	0.007
±SE	8.55	7.28	2.79	7.70	0.92	11.89
Dry mass of weeds						
P	0.446	0.133	0.446	0.001	0.456	0.015
±SE	15.15	1.31	4.31	3.17	5.39	15.24

Note: ± SE – standard error, ∗ – significant differences at $P < 0.05$ and ** - at $P < 0.01$

However, in 2005, we established a higher influence on weed number than on its mass. The lowest weed infestation was investigated in conditions of white mustard (WMM) and annual ryegrass (ARM) living mulch. The allopathic properties of ryegrass species in the corn crop were established by other authors (De Gregorio & Ashley, 1986).

In conditions of CT, weed control methods had a slightly different influence on weed infestation than in 2004. Generally, the highest sugar beet crop weed infestation was observed in hand weeded plots; however its mass was lower than in conditions of IT. The most effective weed control methods were white mustard living mulch and straw mulch. Differences were not significant (Table 5).

Table 5. The influence of weed control system on number m^{-2} and dry mass g m^{-2} of weed under conservation soil tillage, 2005.

Index	Species of weeds									Total weeds
	Chenopodium album	*Stellaria media*	*Poa annua*	*Tripleurospermum inodorum*	*Capsella bursa-pastoris*	*Veronica chamaedrys*	*Taraxacum officinale*	*Sinapis arvensis*	*Poligonum aviculare*	
Non -chemical weed control system:										
Hand weeding (HW)										
number	54.0	65.3	12.3	0.0	4.0	0.0	0.0	0.0	0.0	136.0
mass	18.8	5.8	2.2	0.0	1.4	0.0	0.0	0.0	0.0	28.3
Spring barley living mulch (SBM)										
number	8.3	4.3	0.0	12.3	83.5**	0.0	0.0	4.0	0.0	112.0
mass	58.7	0.1	0.0	3.0	73.1**	0.0	0.0	7.6	0.0	142.5
Annual ryegrass living mulch (ARM)										
number	16.5	37.5	0.0	4.0	83.3**	0.0	4.0	0.0	0.0	145.0
mass	12.5	1.3	0.0	1.3	53.4**	0.0	0.8	0.0	0.0	69.1
White mustard living mulch (WMM)										
number	12.5	70.8	0.0	0.0	8.3	4.0	0.0	0.0	4.0	108.0
mass	0.6	9.7	0.0	0.0	0.7	0.4	0.0	0.0	0.1	11.6
Spring oilseed rape living mulch (SRM)										
number	24.8	12.5	44.3	0.0	20.8	0.0	0.0	0.0	4.0	106.0
mass	50.3	0.2	4.6	0.0	10.6	0.0	0.0	0.0	5.9	71.6
Winter wheat straw mulch (WSM)										
number	4.0	25.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	41.0
mass	0.7	1.3	0.6	3.5	0.0	0.0	0.0	0.0	0.0	7.4
Number of weeds										
P	0.641	0.206	0.380	0.254	0.001	0.446	0.446	0.446	0.564	0.615
±SE	8.63	9.36	6.77	1.69	8.53	0.67	0.67	0.67	0.92	16.99
Dry mass of weeds										
P	0.688	0.025	0.481	0.577	0.001	0.446	0.446	0.446	0.564	0.020
±SE	12.49	1.05	0.78	0.72	6.73	0.07	1.25	1.26	0.98	13.82

Note: ± SE – standard error, ∗ – significant differences at $P < 0.05$ and ** - at $P < 0.01$

CONCLUSIONS

In conditions of intensive soil tillage the highest choking of weeds was obtained by annual reygrass (ARM) and white mustard (WMM) living mulch. In sugar beet row spaces, which were mulched with winter wheat straw mulch (WSM) there was a large number of weeds but their mass was not high. Conversely, in conservation soil tillage conditions the lowest weed infestation and dry mass of weeds were observed in straw mulch (WSM) up to 4 cm. White mustard living mulch (WMM) also influenced weed dry mass decrease though its number was high.

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