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Weed response to soil tillage, catch crops and farmyard manure in sustainable and organic agriculture

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Abstract

The influence of soil tillage, different catch crop species (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Sinapis alba* L., *Brassica napus* L.) for green manure as well as farmyard manure on weed infestation in a barley stand under the conditions of sustainable and organic agriculture was investigated. Field experiments showed that weed density and dry matter mass in barley depended on tillage time, catch crops for green manure and farmyard manure application. Shallow rotovating of the catch crops and farmyard manure in spring increased the number and dry matter mass of weeds in sustainable agriculture compared to deep ploughing in autumn. Spraying of catch crops with glyphosate shortly after barley direct drilling in spring significantly reduced the number of weed seedlings in sustainable agriculture, compared to deep ploughing in autumn. In organic agriculture, shallow rotovating of catch crops in spring stimulated the occurrence of perennial weeds in 1999. Shallow ploughing in spring had no influence on weed density in 2000, but significantly reduceding it in 2001.

Key words: soil tillage, catch crops, farmyard manure, weed, sustainable agriculture, organic agriculture.

Introduction

Weeds are a natural component of arable land communities (Koch, Kunisch, 1990; Rasmussen, Ascard, 1995). The problem of weed infestation in agrocenosis becomes very important when reliance on herbicides is reduced or eliminated (Liebman, Davis, 2000).

Catch crops are an alternative to the chemical weed control in organic farming (Rasmussen et al., 1994; Hampl, 1996; Derylo, 1997; Sharda et al., 1999; Liebman, Davis, 2000; Barberi, 2002). Catch crops supress weeds by competing for the use of light, nutrients and moisture (Diercks, 1986; Auler, 1998; Kahnt, Eusterschulte, 1998). In heavy catch crops higher competitive ability significantly reduced weed infestation (Schumann, 1994; Börner, 1995; Ivaschenko, 1996). Catch crops cover the soil for a short time, as a result the weeds, which grow in them, fail to mature seeds and to accumulate more nutrients, necessary for vegetative reproduction (Lazauskas, 1990). But in unfavourable conditions in a thin catch crop weed density can increase (Kvist, 1992). Soil tillage influences weed infestation. Cesevičius (2007) findings suggest that different soil tillage did not have any significant effect on the variation of the number of annual weeds per rotation. The variation of the number of perennial weeds differed significantly: in ploughed plots and ploughless deep loosening plots the number of these weeds per rotation declined by on average 77% in shallowly stubble-cultivated plots by 57%, and in the direct-drilled plots by 56%. In the crop of spring barley, a significant increase in perennial weeds herbage mass, compared with conventional tillage involving ploughing, was determined in the direct-drilled plots. Feiza et al. (2010) reported that a combination of no-tillage and glyphosate application on sandy loam was less effective for weed control than mechanical weed control in conventional and reduced tillage systems. Findings of other research showed that shallow ploughing or shallow loosening with a heavy cultivator and disc harrows in autumn did not increase the number of weeds, compared to conventional deep ploughing. No-tillage and shallow rotary cultivation in spring significantly in-

crease crop weediness at spring barley tillering and milky ripe stages, compared to conventional deep ploughing, and enhances the spread of perennial weeds (Kairytė, 2005).

The objective of this investigation was to determine the influence of soil tillage time, catch crops (red clover, Italian ryegrass, white mustard, winter rape) for green manure and farmyard manure (40 Mg ha^{-1}) on weed number and dry matter mass in the main crop of barley in sustainable and organic agriculture.

Materials and methods

The investigations were carried out under the conditions of sustainable agriculture (trial I) at the Experimental Station of the Lithuanian University of Agriculture (54°53′ N, 23°50′ E) and under the conditions of organic agriculture (trial II) in Kazliškiai organic farm, Kaunas distr., during 1998–2001. In trial I, the soil was *Calc(ar)i-Endohypogleyic Luvisol* (*LVg-n-w-cc*) with a texture of medium loam on light sandy loam. In trial II, the soil was *Endohypogleyic-Eutric Planosol* (*PLe-gln-w*) with a texture of medium loam on light sandy loam.

The treatments of the experiments are presented in Tables 1 and 2. Different catch crops for green manure were sown into wheat or after its harvesting (factor B). Red clover *Trifolium pratense* L. 'Liepsna' (8 kg ha^{-1}) and Italian ryegrass *Lolium multiflorum* Lam. 'Rapid' (14 kg ha^{-1}) were undersown into wheat in early spring. White mustard *Sinapis alba* L. 'Karla' (35 kg ha^{-1}) and winter rape *Brassica napus* L. (in 1998 – 'Apex', in 1999 – 'Accord', in 2000 – 'Valesca' 20 kg ha^{-1}) after wheat harvesting were direct drilled into stubble. After wheat harvesting, in the plots without a catch crop the stubble was no-tilled until the primary soil tillage. The plots intended for fertilization with farmyard manure after wheat harvesting were shallowly ploughed at the depth of 10–12 cm.

Catch crops for green manure and farmyard manure were incorporated in autumn or in spring (factor A). In one part, catch crops for green manure and farmyard manure were deeply ploughed (at the depth of 23–25 cm) in late autumn. In the other part, they were left not incorporated during winter until the following spring. In 1999, the plots of this treatment were shallowly rotovated with a rotary cultivator before barley sowing. In the spring of 2000 and 2001, in organic agriculture catch crops for green manure were shallowly ploughed at the depth of 10–12 cm. In sustainable agriculture, only farmyard manure was shallowly ploughed in, while the no-tilled soil with catch crops and plant residue was sprayed with glyphosate in spring (4.0 l ha^{-1}).

To evaluate the influence of soil tillage and catch crops' combination on weed infestation barley 'Ūla' (180 kg ha^{-1}) was grown every year. During the period 2000–2001, in sustainable agriculture barley was sown with no-till drill "John Deere 750 A", in organic agriculture with "Saxonia" anchor ploughshares. In sustainable agriculture, barley was fertilized with complex fertilizers ($N_{60}P_{60}K_{60}$) and sprayed with herbicides MCPA (1.0 l ha^{-1}).

Experiments in sustainable and organic agriculture were carried out in three replicates following the split-plot design. Weeds in barley were evaluated twice: at the stage of intensive germination of weeds (in May) and at barley milky ripeness stage. In spring, the number of weed seedlings was calculated, while at the barley milky ripeness stage – the number of weeds m^{-2} and the weight of their dry matter g m^{-2}. Analyses of variance ($P < 0.05$) based on a 2-factorial split-plot design model, were performed using the SAS GLM procedure (SAS User's Guide, 1999). The *Fisher LSD* test was used to determine significant treatment effects. The weed data that did not meet normal distribution was transformed by using the function $y = lnx$ before statistical evaluation.

Results and discussion

Sustainable agricultural system. In sustainable agricultural system, on average 53 weed seedlings m^{-2} were found at barley tillering stage in 1999. By 28.3 and 39.6% more weeds germinated in barley in 2000 and 2001, respectively than in 1999.

The highest number of weed seedlings in 1999 after autumn soil tillage was found in barley stand with farmyard manure (Table 1). Farmyard manure application, compared with other treatments, except for green manure of white mustard, significantly (from 55.1 to 118.4%) increased the number of weed seedlings. Farmyard manure can serve as a vector for weed seeds (Cudney et al., 1992; Tompkins et al., 1998). It is indicated, that 60 Mg ha^{-1} farmyard manure brings 0.5–40 million viable weed seeds (Lazauskas, 1990). The number of weed seedlings in barley after green manure (treatments 2–5) was the same as without catch crops. Significantly more weeds (from 100.0 to 209.0%) germinated after shallow incorporation of farmyard manure in spring, compared to other treatments. Shallow incorporation of farmyard manure and green manure of catch crops with a rotary cultivator in spring caused formation of lumps, which dwarfed not only barley germination but also weed germination. Therefore, compared to deep ploughing of

farmyard manure and green manure in autumn, the number of weed seedlings decreased from 36.4 to 61.3%.

Deep ploughing of catch crops and farmyard manure, compared with treatment without catch crop, had no significant influence on the number of weed seedlings at the stage of intensive germination of weeds in 2000. In barley, which was fertilized with farmyard manure in spring, compared to other treatments, the number of germinated weeds was significantly (from 96.6 to 235.3%) higher. Direct drilling into no-tilled soil with a no-till air drill "John Deere 750 A" and spraying with glyphosate shortly after sowing, compared with deep ploughing of catch crops in autumn, significantly (from 74.8 to 86.2%) decreased the number of weed seedlings.

Table 1. The influence of soil tillage combination with catch crops on weed density (seedlings m^{-2}) in sustainable agriculture at the stage of intensive germination of weeds (in May)

Catch crops for green manure and farmyard manure (Factor B)	Time of soil tillage (Factor A)					
	in autumn			in spring		
	1999	2000	2001	1999	2000	2001
1. Without catch crop	69bc	104a*	57a	29bc	23bc*	146a
2. Red clover	65bc	82a*	64a	34b	17c*	144a
3. Italian ryegrass	49c	123a*	56a	22c	17c*	115a
4. White mustard	75ab	115a*	50a	34b	29b*	80b
5. Winter rape	62bc	130a*	48a	24bc	22bc*	44c
6. Farmyard manure 40 Mg ha^{-1}	107a	95a	47a	68a	57a	38c

Note. Asterisks (for factor A) and different letters (for factor B) indicate significant differences between treatments within the same year at $P \leq 0.05$.

Shallow rotovation of catch crops for green manure in spring and spraying with glyphosate, compared to deep ploughing of catch crops and farmyard manure in autumn, had no significant influence on weed seedlings in 2001. Significantly more weeds germinated in plots without catch crop and after red clover and rye grass sprayed with glyphosate, than in plots after white mustard and rape sprayed with glyphosate and in fertilized with farmyard manure in spring.

An average of 1999–2001 at the barley milky ripeness stage from 24 to 30 weed species was found (15–19 annual and 8–11 perennial).

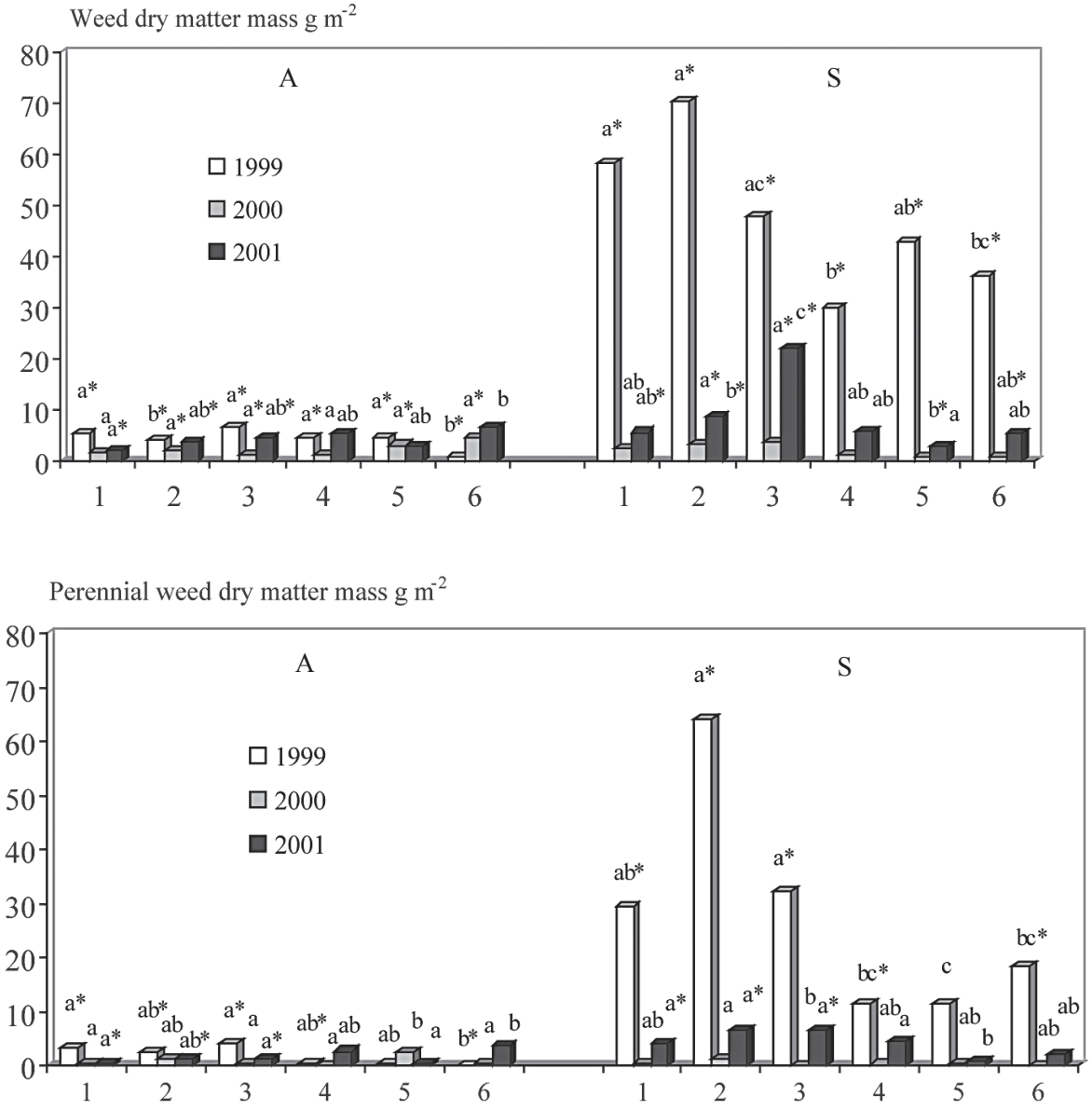
The highest weed infestation in barley at the milky ripeness stage was in 1999 (Figure 1). Average weed dry matter mass was 25.6 g m^{-2} and it was respectively 11.3 and 4.0 times higher, compared to average weed dry matter mass in 2000 and in 2001.

Deeply ploughed green manure catch crops and farmyard manure determined better barley germination and development. As a result, heavy barley stand suppressed weeds.

Shallowly rotovated catch crops and farmyard manure in spring in 1999, compared to deep ploughing in autumn, influenced mass of weeds in barley. Dry matter mass of all weeds increased from 25.4 to 66.2 g m^{-2} and dry matter mass of perennial weeds from 10.8 to 61.9 g m^{-2}. According to Kundler et al. (1985), Diercks and Heitefuss (1990), when catch crops had been shallowly incorporated in spring, compared to deep ploughing in autumn, the weed density doubled. Shallowly incorporated red clover in the spring of 1999 stimulated growing of perennial weeds: dry matter mass of perennial weeds was significantly 3.5–5.7 times higher, compared to white mustard, winter rape and farmyard manure.

In 2000 and 2001, weed mass in barley did not increase in the soil sprayed with glyphosate (2–5 treatments), compared to deep ploughing in autumn, except for red clover and Italian ryegrass. Incorporation of this catch crop in autumn is more effective (Figure 1). Spraying of winter rape with glyphosate after barley sowing in spring significantly reduced total weed density, compared to other treatments.

Organic agricultural system. The weather conditions in spring in 1999 were favourable for germination of weed seeds (Table 2). The average number of weed seedlings at barley tillering stage was respectively 3.8 and 5.6 times higher, compared to the average number of weed seedlings in 2000 and 2001.



Notes. Factor A: A – in autumn, S – in spring. Factor B: 1) without catch crop, 2) red clover, 3) Italian ryegrass, 4) white mustard, 5) winter rape, 6) farmyard manure 40 Mg ha^{-1}. Asterisks (for factor A) and different letters (for factor B) indicate significant differences between treatments within the same year at $P \leq 0.05$.

Figure 1. The influence of soil tillage combination with catch crops on weed dry matter mass in barley in sustainable agriculture at the barley milky ripeness stage

The highest number of weed seedlings in 1999 was found in barley fertilized with farmyard manure in spring. Fertilization with farmyard manure, compared to other treatments, significantly (from 96.5 to 323.8%) increased the number of weeds. The number of weeds in barley after shallow incorporation of green manure, except mustard, was as in the plots without catch crop. Significantly lower weed emergence was observed in barley after deep ploughing of catch crops and farmyard manure (from 36.6 to 59.5%) compared to without farmyard manure. Shallowly incorporated red clover and farmyard manure in spring, compared to deep ploughing, significantly (respectively 48.9 and 169.2%) increased the number of weed seedlings in barley.

Significantly lower number of weeds (from 28.9 to 38.6%) in 2000 germinated after deep ploughing of farmyard manure and catch crops, than without catch crop. Weed density in barley

after shallow incorporation of mustard and rape in spring was significantly, respectively 27.6 and 28.3% lower, than in barley without organic fertilizers. The time of incorporation of catch crops and farmyard manure had no influence on weed density in barley in 2000.

Fertilization with farmyard manure in autumn in 2001 significantly (50.0%) decreased weed density, compared without organic fertilizers. Significantly, respectively 41.0 and 44.9% lower number of weeds was found after shallow spring incorporation of ryegrass and rape than in barley, which was fertilized with farmyard manure. The time of incorporation of catch crops and farmyard manure had no influence on weed emergence.

From 28 to 41 weed species were found at the stage of barley milky ripeness (17–23 annual and 11–8 perennial). The growing number of weed species suggests that the problem of weed infestation in organic agriculture is of great relevance.

Table 2. The influence of soil tillage combination with catch crops on weed density (seedlings m^{-2}) in organic agriculture at the stage of intensive germination of weeds (in May)

Catch crops for green manure and farmyard manure (Factor B)	Time of soil tillage (Factor A)					
	in autumn			in spring		
	1999	2000	2001	1999	2000	2001
1. Without catch crop	575a	142a	104a	446bc	127a	63ab
2. Red clover	323bc*	96b	102a	481b*	113ab	82a
3. Italian ryegrass	366b	101b	83ab	325cd	119ab	46b
4. White mustard	233c	108ab	76ab	223d	92b	77a
5. Winter rape	325bc	87b	79ab	321cd	91b	43b
6. Farmyard manure 40 Mg ha^{-1}	351b*	97b	52b	945a*	116ab	78a

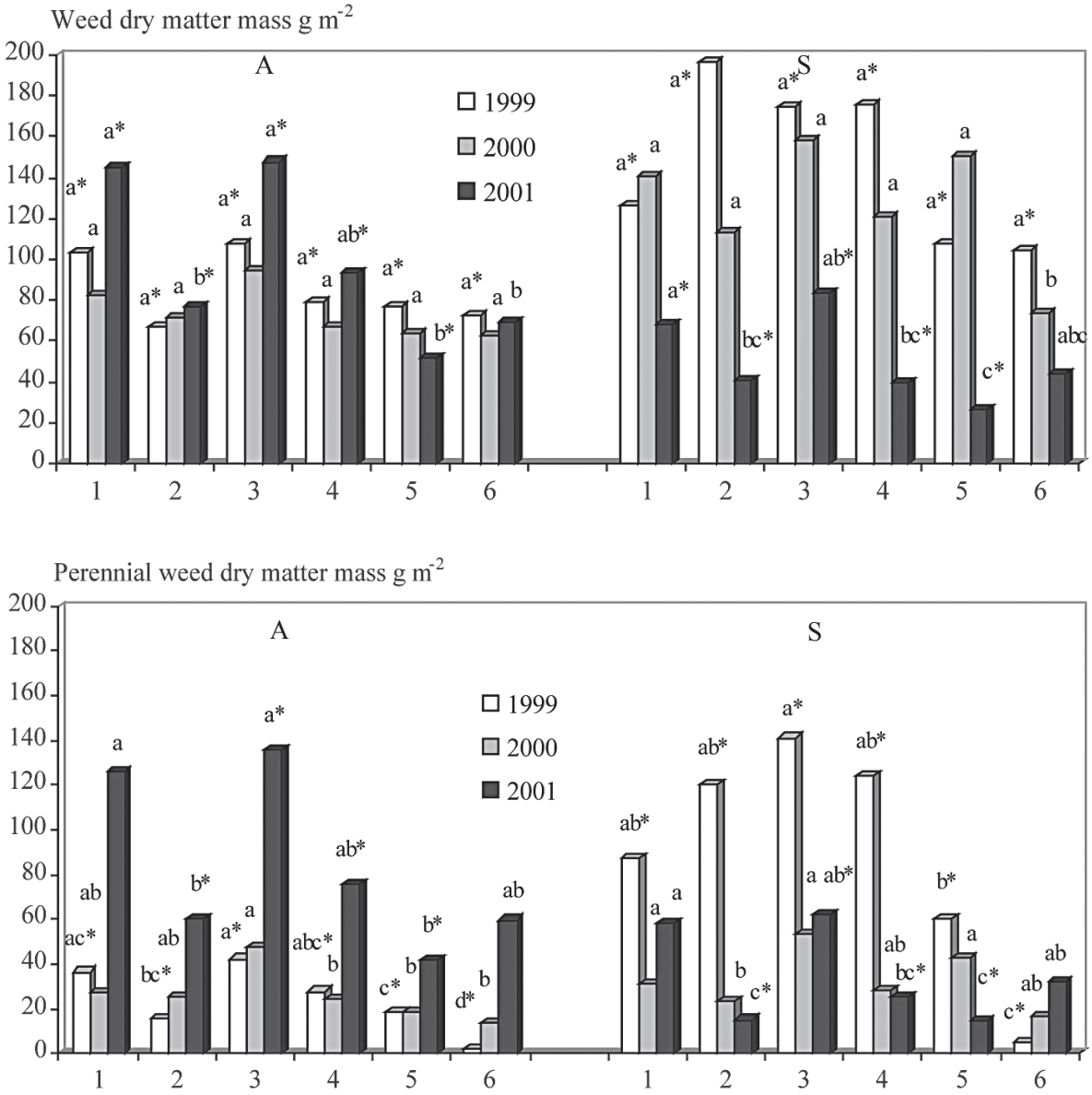
Note. Asterisks (for factor A) and different letters (for factor B) indicate significant differences between treatments within the same year at $P \leq 0.05$.

The highest weed dry matter mass in barley was after all tillage treatments in spring in 1999 (Figure 2). The average weed dry matter mass reached 147.6 g m^{-2} and it was respectively 15.6 and 192.3% higher, than in 2000 and 2001.

The influence of catch crops for green manure and farmyard manure on the spread of perennial weeds in barley in 1999 was higher, than that on the spread of annual weeds. According to Pupaliene (2004), the methods applied in organic agricultural system created the most favourable conditions for the spread of perennial weeds, especially *Cirsium arvense* and *Sonchus arvensis*. The findings of Stancevicius and Raudonius (1990) showed, that systematic direct drilling of catch crops into the stubble increased the amount of *Elytrigia repens* rhizomes. Compared to other treatments, dry matter mass of perennial weeds was significantly influenced by fertilization with farmyard manure in 1999. Dry matter mass of perennial weeds after deep ploughing of farmyard manure decreased from 84.1 to 94.1%, after shallow incorporation from 90.6 to 96.0%. Time of catch crops and farmyard manure incorporation exerted a greater influence on weed mass. Shallowly incorporated catch crops and farmyard manure in spring, compared to deep ploughing in autumn, determined an increase in perennial weeds in barley: the dry matter mass of these weeds increased from 2.4 to 7.6 times.

Ryegrass, incorporated for green manure, compared to other treatments, stimulated the spread of perennial weeds in barley in 2000. Deep ploughing of ryegrass increased dry matter mass of perennial weeds from 73.6 to 229.2%, shallow incorporation in spring from 24.2 to 213.4%. Bogužas (1993) reported that ryegrass, sown into the cereals, decreased annual weeds, but increased *Elytrigia repens*. In our experiment, the time of catch crops and farmyard manure incorporation had no influence on weeds in barley (Figure 2).

The highest spread of perennial weeds in 2001 was in barley without organic fertilizers and



Notes. Factor A: A – in autumn, S – in spring. Factor B: 1) without catch crop, 2) red clover, 3) Italian ryegrass, 4) white mustard, 5) winter rape, 6) farmyard manure 40 Mg ha^{-1}. Asterisks (for factor A) and different letters (for factor B) indicate significant differences between treatments within the same year at $P \leq 0.05$.

Figure 2. The influence of soil tillage combination with catch crops on weed dry matter mass in barley in organic agriculture at the barley milky ripeness stage

in barley grown after ryegrass ploughed for green manure in autumn. Shallow incorporation of catch crops, compared to deep ploughing in autumn, significantly decreased the dry matter mass of perennial weeds from 53.3 to 74.5%. The time of farmyard manure incorporation had no influence on weed mass in barley.

Conclusions

1. Weed infestation in barley depended on soil tillage time, catch crops (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Sinapis alba* L., *Brassica napus* L.) for green manure and farmyard manure application.

2. In sustainable agriculture, shallow catch crops and farmyard manure incorporation with a rotary cultivator in spring, compared to deep ploughing in autumn, increased dry matter mass of weeds. However, spraying of catch crops with glyphosate shortly after barley sowing in spring significantly reduced weed emergence, compared to deep ploughing in autumn.

3. In organic agriculture, shallow incorporation of catch crops and farmyard manure with

a rotary cultivator in spring, compared to deep ploughing in autumn, stimulated the spread of perennial weeds in 1999. Shallow ploughing in spring had no influence on weed density in 2000, but significantly reduced it in 2001.

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Pasėlio piktžolėtumo kitimas skirtingai dirbant žemę, naudojant tarpinius pasėlius ir mėšlą tausojamojoje bei ekologinėje žemdirbystėje

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Santrauka

Tirtas žemės dirbimo, įvairių rūšių tarpinių pasėlių (*Trifolium pratense* L., *Lolium multiflorum* Lam., *Sinapis alba* L., *Brassica napus* L.) kaip žaliosios trąšos ir mėšlo kompleksinis poveikis piktžolėms miežių pasėlyje taikant tausojamąją bei ekologinę žemdirbystės sistemas. Atlikus lauko bandymus nustatyta, kad miežių pasėlio piktžolėtumas priklausė nuo žemės dirbimo laiko, tarpinių pasėlių kaip žaliosios trąšos ir mėšlo panaudojimo. Taikant tausojamosios žemdirbystės sistemą, tarpinių pasėlių ir mėšlo seklus įterpimas rotoriniu kultivatoriumi pavasarį, palyginti su giliu arimu rudenį, didino piktžolių kiekį ir sausųjų medžiagų masę. Taikant tausojamosios žemdirbystės sistemą, piktžolių daigų kiekį esmingai mažino tarpinių pasėlių purškimas glifosatu pavasarį tuoj po miežių sėjos į neįdirbtą dirvą, palyginti su giliu užarimu rudenį. Taikant ekologinės žemdirbystės sistemą, tarpinių pasėlių kaip žaliosios trąšos ir mėšlo seklus įterpimas rotoriniu kultivatoriumi pavasarį skatino daugiamečių piktžolių plitimą 1999 m. Seklus arimas pavasarį piktžolių kiekiui 2000 m. neturėjo įtakos, o 2001 m. jį esmingai sumažino.

Reikšminiai žodžiai: žemės dirbimas, tarpiniai pasėliai, mėšlas, piktžolės, tausojamoji žemdirbystė, ekologinė žemdirbystė.