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The influence of primary soil tillage on soil weed seed bank and weed incidence in a cereal-grass crop rotation

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Abstract

A field experiment was carried out at Vėžaičiai Branch of Lithuanian Research Centre for Agriculture and Forestry during the period 2008–2011. The study was aimed to determine the effects of various soil tillage methods: deep ploughing (20–25 cm), shallow ploughing (10–12 cm), shallow ploughless tillage (8–10 cm) and soil fertility improvement measures (plant residues, plant residues + straw, green manure 1st cut + straw, green manure 2nd cut + straw, farmyard manure 40 t ha⁻¹ + straw) on the soil weed seed bank and weed incidence in a cereal-grass crop rotation. The soil of the experimental site is *Dystric-Epihypogleyic Albelvisol* (ABg-p-w-dy) with a texture of sandy loam.

In all experimental years, primary soil tillage had a significant influence on weed incidence in the crops of the rotation and on soil weed seed bank. The greatest amount of weeds, both in numbers and dry mass, in the crops of winter triticale and spring rape was determined in the shallow ploughless tillage treatment, in the crops of spring barley in the shallow ploughing treatment, and in the sward of red clover in deep and shallow ploughing treatments. All soil fertility improvement measures and their interaction with soil tillage methods did not have any substantial influence on the weed incidence in the rotation crops. The soil weed seed bank was 1.5 and 2.2 times greater in the shallow ploughing and shallow ploughless tillage treatments, compared with the conventional tillage treatment (deep ploughing). The influence of soil tillage methods manifested itself not only directly, but also through its interaction with soil fertility improvement measures. Regardless of the chosen soil fertility improvement measure, in all the treatments of shallow ploughless tillage, the soil weed seed bank was significantly greater, compared with the conventional soil tillage treatments.

In the shallow ploughing and shallow ploughless tillage treatments there were found 25.5% and 41.5% more weed seed species in the soil, compared with the conventional tillage treatment. The seeds of *Chenopodium album* L., *Persicaria lapathifolia* L., *Fallopia convolvulus* L. and *Viola arvensis* Murray were found in all tillage treatments. The distribution of *F. convolvulus* L., *P. lapathifolia* L. seeds was significantly influenced by soil tillage only, that of *V. arvensis* Murray by soil tillage and its interaction with soil fertility improvement measures, and that of *Ch. album* L. by soil fertility improvement measures only.

Key words: amount and mass of weeds, autumn soil tillage, crop rotation, seed bank, soil fertility improvement measures.

Introduction

Weed incidence in field crops has been comprehensively investigated in Lithuania and abroad. Numerous studies have indicated that soil nutrient status, crop rotation and its structure, as well as soil tillage system influence weed incidence in crops. Researchers have highlighted the importance of creating optimum growth and development conditions for crop rotation plants. With declining soil acidity, the number of acid-loving weeds consistently decreased (Čiuberkis, 2009), while the total number of weeds significantly ($r = 0.84–0.96^{**}$) depended on the amount of available aluminium in the soil (Skuodienė, Repšienė, 2009). When improving the

soil with organic fertilizers, all organic fertilizers were found to increase the weed incidence in cereal crops, but manure increased it more than the biomass of legumes incorporated into the soil as green manure (Arlauskienė, Maikštėnienė, 2005).

Shallow ploughing promoted the spread of weeds (Stancevičius et al., 1996; Čiuberkis, 2008). In a light loam soil, the number of annual weeds increased in ploughed treatments compared with reduced tillage treatments. The number of perennial weeds and air dried mass were substantially greater in the crops of spring wheat and spring rape in the direct drilling treatment,

compared with ploughing treatment (Deveikytė et al., 2008). In a clay loam soil, the application of non-inversion soil tillage for two years in succession resulted in a decrease in annual weeds and an increase in perennial weeds (Velykis, Satkus, 2003).

The weed seed bank is the main source of weeds in agricultural fields. Soil weed seed banks are reserves of viable seeds present on the surface and in the soil. The seed bank consists of new seeds recently shed by a weed plant as well as older seeds that have persisted in the soil for several years. The seed bank is an indicator of past and present weed populations. There are enormous numbers of viable weed seeds in the soil. Although a great number of the buried seeds die within a few years, seeds of some species can remain viable for decades. It has been estimated that only 1–9% of the viable seeds produced in a given year develop into seedlings; the rest remain viable and will germinate in subsequent years depending on the depth of their burial (Swanton et al., 2000). Seeds are dispersed both horizontally and vertically in the soil profile. The greatest seed reserves were in the surface layer (0–5 cm) of the soil (Gselman, Kramberger, 2004; Janicka, 2006).

Soil tillage has a significant influence on the dynamics of weed seeds (Moonen, Barberi, 2004). The highest number of weed seed species was found in the treatments with reduced and no-tillage treatments in a soil layer of 0–5 cm. In deeper soil layers (5–10, 10–20 cm), no differences in weed seed species number were found (Auškalnienė, Auškalnis, 2009). The tillage system influenced weed seed bank size and composition to a much greater extent than crop rotation. Crop rotation did not influence either weed seed bank size or seedling distribution among soil layers, and only had a small influence on major species abundance (Bārberi, Lo Cascio, 2001). Weeds are not only the indicators of ecological conditions, but also they show the degree of soil cultivation.

The aim of the current research was to determine the impact of various soil primary tillage methods and soil fertility improvement measures on soil weed seed bank and weed incidence in a cereal-grass crop rotation.

Materials and methods

Site and soil description. The soil of the experimental site is *Dystric Epihypogleyic Albeluvisol* (ABg-p-w-dy) with a texture of sandy loam (clay particles <0.002 mm – 13–15%), whose pH at the beginning of the trial was 5.1–5.3. The soil is moderate in humus status (humus – 2.43%, organic carbon – 1.41%), moderate in phosphorus content and high in potassium (106 and 270 mg kg⁻¹ soil, respectively).

The trial was established in 2003 in the experimental field of crop rotation of Vėžaičiai Branch of Lithuanian Institute of Agriculture (currently – Vėžaičiai Branch of Lithuanian Research Centre for Agriculture and Forestry). In 2007, the trial was continued for the second crop rotation by sowing winter triticale in the autumn. The four-course crop rotation consisted of winter triticale (*Triticosecale* Wittm) ‘SW Talentro’ sown at a seed rate of 5.5 million ha⁻¹ (2008), spring rape (*Brassica napus* L. ssp. *oleifera annua* Metzq) ‘Lindmark’ sown at a seed rate of 8.0 kg ha⁻¹ (2009), spring barley (*Hordeum*

vulgare L.) ‘Luokė’ sown at a seed rate of 4.0 million ha⁻¹ undersown with red clover at a seed rate of 14.0 kg ha⁻¹ (2010), red clover (*Trifolium pratense* L.) ‘Liepsna’ of the first year of use (2011). The total plot size amounted to 20 × 5 = 100 m². The harvested area for cereals and rape amounted to 16 × 2.2 = 35.2 m² and for clover 16 × 1.4 = 22.4 m². The trial was replicated four times.

Trial factors and treatments. Factor A – primary soil tillage (in autumn): 1) deep ploughing (20–25 cm), 2) shallow ploughing (10–12 cm), 3) shallow ploughless tillage (8–10 cm); factor B – soil fertility improvement measures: 1) plant residues (R), 2) plant residues + straw (R + S), 3) green manure 1st cut + straw (GI + S), 4) green manure 2nd cut + straw (GII + S), 5) farmyard manure 40 t ha⁻¹ + straw (M + S).

In 2007, the phytomass of red clover was incorporated into the soil according to the scheme of factor B. The phytomass of clover was removed from the plots of the first, the second, and the fifth treatments. The phytomass of clover from the plots of the third and the fourth treatments was spread: 3.2 t ha⁻¹ dry matter (DM) of the 1st cut and 2.2 t ha⁻¹ DM of the 2nd cut, respectively. In the plots of the fifth treatment 40 t ha⁻¹ manure was spread. Organic fertilizers were incorporated with a disc stubble cultivator. After three weeks, the plots of the first treatment, of factor A were deeply ploughed with a plough fitted with semi screw blades; those of the second treatment were shallow ploughed, and the plots of the third treatment were cultivated with a spring-tine cultivator, applying shallow ploughless tillage. Before sowing, the soil was cultivated with a pre-sowing soil tillage cultivator and on the 17th of September the winter triticale ‘SW Talentro’ was sown with a disc seed drill ‘Fiona SD-977’ (‘Fiona Maskinfabrik A/S’, Denmark).

In 2008, after winter triticale harvesting, in the first treatment of factor B, the straw was removed from the plots; the straw (8.9 t ha⁻¹) of the second–fifth treatments was chopped at harvesting with a combine harvester ‘Sampo 500’ (‘Sampo Rosenlew’, Finland) and spread in the plots. A rate of 10 kg nitrogen (calcium ammonium nitrate) was applied per ton of straw. To prevent soil acidification and to compensate for the loss of calcium which is leached from the soil and is removed with the yield, 400 kg ha⁻¹ lime fertilizers (in 2007 dolomite and in 2008 limestone dust) were applied throughout the whole experimental area; lime fertilizers and straw were incorporated with a disc stubble cultivator. In 2008 and in the autumn of 2009, the soil was cultivated according to the experimental design. The crops of the rotation, except for clover, were sprayed with herbicides. To protect the record sites, they were covered with a polyethylene film.

The spring in 2009 was early. Warm and normally humid weather prevailed in March and May, while April was dry. There was a shortage of moisture during the spring rape emergence. In summer, the weather was warm and normally wet. The conditions were favourable for the growth of spring rape and weeds.

The spring in 2010 was late. In April, not cold and dry weather prevailed, and in May it was warm and rainy. Adequate soil moisture and warm weather had a positive influence on the germination of spring barley and weeds and their further growth in June. The rainy weather of June was replaced by a heat wave in July.

The compacted soil dried off and cracked. The moisture content at a depth of seedbed on July 12 was 5.9–7.5%, which is below the plant wilting humidity. Although the amount of rainfall that fell during the summer was 43% higher than the long-term mean, its distribution was very uneven. The growth and development conditions for the spring barley and under-sown red clover were satisfactory. For the greater part of September the weather was moderately warm and rainy. Growing conditions for red clover were good. Although the cold weather of October and November prompted the plans for better wintering preparation, very low temperatures in February 2011 damaged clover, especially at the hilltops and waterlogged places. In spring, the prevailing weather was dry (in March the precipitation was 40%, in April – 93% and in May – 85% of the long-term mean). The average air temperature of spring period was close to the long-term mean. The growing conditions for red clover were satisfactory.

The experimental data were analysed by a two-factor analysis of variance recommended in agronomy science. Significance of the differences between the means was determined according to the least significant difference (LSD) at 0.05 probability level. The data were processed using software ANOVA (Tarakanovas, Raudonius, 2003).

Table 1. The effect of primary soil tillage and soil fertility improvement measures on the weed incidence in the crop rotation

Treatment	Winter triticale 2008		Spring rape 2009		Spring barley 2010		Red clover 2011	
	plants m ⁻²	mass of DM g m ⁻²	plants m ⁻²	mass of DM g m ⁻²	plants m ⁻²	mass of DM g m ⁻²	plants m ⁻²	mass of DM g m ⁻²
Weediness								
Primary soil tillage (factor A)								
Deep ploughing	7.6	14.8	49.6	106.1	39.1	16.0	192.4	50.8
Shallow ploughing	7.5	14.1	48.4	102.1	46.2	19.8	174.8	39.9*
Shallow ploughless tillage	11.1**	23.3**	79.7**	173.3**	22.7**	10.6	159.0*	48.5
LSD ₀₅	2.187	5.925	25.351	53.174	10.881	5.836	32.213	10.734
Soil fertility improvement measures (factor B)								
Plant residues	9.3	15.1	61.6	122.3	31.7	15.2	167.9	42.2
Plant residues + straw	8.5	19.6	61.2	126.9	43.7	15.3	195.3*	45.8
Green manure	8.3	17.4	57.9	128.2	31.5	12.1	177.7	43.4
1 st cut + straw	9.5	17.6	57.2	131.8	36.5	19.0	153.3	49.9
Green manure	8.0	17.4	58.2	126.8	36.7	15.9	182.7	50.7
2 nd cut + straw								
Farmyard manure								
40 t ha ⁻¹ + straw								
LSD ₀₅	2.823	7.649	14.356	12.965	14.047	7.534	41.586	13.857
Interaction of factors A and B								
A1 × B1	9.8	12.7	52.2	92.6	39.0	14.2	147.0	38.5
A1 × B2	7.0	19.6	47.2	107.5	43.0	13.3	257.0**	53.7
A1 × B3	8.0	12.4	48.5	105.1	34.5	7.8	204.0	58.8
A1 × B4	6.8	13.2	48.8	114.5	48.0	31.0*	160.0	56.3
A1 × B5	6.2	16.2	51.2	110.9	31.0	14.0	194.0	46.9
A2 × B1	7.5	15.4	54.5	106.2	31.5	16.4	191.0	37.0
A2 × B2	6.0	15.0	48.5	100.6	66.0*	19.3	154.0	39.1
A2 × B3	6.8	16.9	45.0	106.6	42.0	21.4	163.0	30.6
A2 × B4	8.8	11.4	48.2	101.9	38.5	17.4	180.0	48.9
A2 × B5	8.5	11.8	45.8	95.0	53.0	24.7	186.0	43.8
A3 × B1	10.8	17.2	78.0	168.0*	24.5	15.0	165.8	51.2
A3 × B2	12.5	24.0	87.8	172.5*	22.0	13.2	175.0	44.5
A3 × B3	10.2	22.7	80.2	172.8*	18.0	7.0	166.0	40.9
A3 × B4	13.0	28.2	74.8	178.9*	23.0	8.6	120.0	44.6
A3 × B5	9.2	24.3	77.8	174.4*	26.0	8.9	168.0	61.5
LSD ₀₅	4.890	13.248	45.312	36.735	24.330	13.050	72.030	24.001

DM – dry matter; * – significant at $P < 0.05$, and ** – significant at $P < 0.01$

Results and discussion

The weed incidence in the crop rotation.

Phytocenoses are not constant. They change in response to changing environmental conditions and different agricultural practices. Analysis of weed incidence in separate crops of the rotation shows that in 2008 the prolonged drought lasting from April 20 to June 16 (57 days with the amount of precipitation as low as 15.6 mm) resulted in a low weed incidence in the crops of winter triticale (Table 1). Literature sources indicate that weed incidence in field crops is determined by meteorological conditions, especially the amount of precipitation in spring (Auškalnienė, 2006; Deveikytė et al., 2008) and soil moisture (Jursík et al., 2010). Analysis of variance indicated that soil tillage method had a significant impact on the weed incidence in winter triticale crops (the amount of weeds $F_{act.} = 7.46 > F_{tabl.0.1} = 5.15$ and their dry matter mass $F_{act.} = 6.00 > F_{tabl.0.1} = 5.15$, respectively). The significantly greatest number of weeds 11.1 m⁻² was determined in the treatment of shallow ploughless tillage. In the deep and shallow ploughing treatments, the amount of weeds in the crops of winter triticale was 1.5 times lower than in the shallow ploughless tillage treatment. This could be influenced by the soil moisture because the topsoil layer in shallow ploughed and shallow tilled soil was by 2–3 percentage points wetter, compared to the deep ploughed soil.

The weed incidence did not depend on the soil fertility improvement measures. The differences were not significant.

The interaction of these two factors did not have any influence on the weed incidence in winter triticale either. Similar trend was found for dry matter mass of weeds. The significantly greatest (23.3 g m⁻²) mass of weed dry matter was determined in the shallow ploughless tillage treatment. Different soil fertility improvement measures and their interaction with soil tillage methods did not have any significant influence. However, it was noted that weed dry matter mass was 15–30% greater when shallow ploughless tillage and the phytomass of red clover or manure for the improvement of soil fertility had been applied compared with only plant residues' usage. According to Menalled et al. (2001), aboveground weed biomass, species density, and diversity were lowest in the conventional system, intermediate in the no-till system, and highest in the low-input and organic systems, but there were significant year-by-system interactions.

Soil tillage methods in the autumn had a significant influence on the weed incidence in spring rape crops. Significantly greatest number of weeds and their dry matter mass was determined in the shallow ploughless tillage treatment (79.7 weeds m⁻² and 173.3 g m⁻², respectively) (Table 1). Having used deep and shallow ploughing, the amount of weeds and their dry matter mass in spring rape crops was 1.6–1.7 times lower compared with shallow ploughless tillage. The weed incidence did not depend on the soil fertility improvement measures. The differences were not significant. The interaction of these two factors did not have any influence on the weed incidence in crops either. Regardless of the chosen soil fertility improvement measure, in all shallow ploughless tillage treatments weed dry matter mass was significantly greater (168.0–178.9 g m⁻²) in comparison with shallow ploughing and conventional soil tillage methods.

In July 2010, the rainy weather of June was replaced by a heat wave (the mean air temperature within 11th–17th rose to 24.0°C and there was no rainfall within 1st–13th), which resulted in a low weed incidence in the crops of spring barley. Soil tillage method had a significant influence on the amount of weeds and their dry matter mass, respectively $F_{act.} = 9.99 > F_{tabl.0.1} = 5.15$ and $F_{act.} = 5.21 > F_{tabl.0.1} = 5.15$. The significantly lowest amount of weeds and their dry matter mass was determined in the shallow ploughless tillage treatment (22.7 weeds m⁻² and 10.6 g m⁻², respectively) (Table 1), where barley suppressed weeds better compared with deep and shallow ploughing. In terms of moisture preservation, the minimal soil tillage is superior to the conventional deep ploughing (Velykis, Maikštėnienė, 1995; Šimanskaitė, 2002).

The weed incidence in crops did not depend on the soil improvement measures. The differences were not significant. Red clover, which was the last course of the crop rotation sequence, formed a thinner sward after the cold winter. In such a lawn the sown plants are more exuberant; however, the conditions within such a lawn are favourable for weed species, especially those tolerant

of shade and preferring wet environments. Weeds were numerous but small in the sward of red clover. The highest amount of weeds and their dry matter mass 192.4 plants m⁻² and 50.8 g m⁻² respectively was determined in the deep ploughing treatment (Table 1). The weed incidence did not depend on the different soil fertility improvement measures. The differences were not significant. Because of the interaction of deep ploughing and plant residues + straw used as soil fertility improvement measure the amount of weeds was significantly higher.

In order to compare the species composition of the weed seed bank with the weed species composition in the last course of the rotation sequence – red clover sward, the weeds in the red clover sward were divided into families. The weeds identified in the different soil tillage treatments of red clover swards belonged to 11 families: *Asteraceae*, *Boraginaceae*, *Brassicaceae*, *Caryophyllaceae*, *Chenopodiaceae*, *Plantaginaceae*, *Poaceae*, *Polygonaceae*, *Ranunculaceae*, *Scrophulariaceae*, *Violaceae*. The majority of weeds belonged to the *Asteraceae* family and included 7 species, of which *Tripleurospermum perforatum* (Mérat) M. Lainz was the most common. Irrespective of the soil tillage method, *T. perforatum* (Mérat) M. Lainz, *Capsella bursa-pastoris* L., *Veronica arvensis* Murray in *Chenopodium album* L. were most frequent in all experimental treatments: 46.0–134.0, 2.8–54.2, 7.2–20.0 and 6.0–11.6 plants m⁻², respectively. *Fallopia convolvulus* L., *Cerastium holosteoides* Fr., *Plantago major* L. were also found in all treatments, but at lower abundance.

The soil weed seed bank was evaluated after the completion of the second crop rotation. According to Čiuberkis (2008), primary soil tillage of different intensity did not have any significant influence on the number of weed seeds in the soil after the completion of the first crop rotation.

Literature sources indicate that the soil seed banks are a key to understanding the dynamics of plant populations, species and ecosystems (Cabin et al., 1998). The composition of the soil seed bank depends on the plant communities appearing in a particular area both at the present moment and also in the past, as well as on the biological properties of plants. Changes in land-use and management practices influence the distribution of seeds in the soil and the established vegetation (Reine et al., 2004).

Evaluation of the influence of primary soil tillage methods and soil fertility improvement measures on the soil weed seed bank after the second rotation showed that the primary soil tillage had already had a significant influence ($F_{act.} = 33.2 > F_{tabl.0.1} = 5.01$). In the deep ploughing treatment, the soil weed seed bank was significantly less abundant (15643 seeds m⁻²) compared with the shallow tillage and shallow ploughless tillage treatments (Table 2). In the shallow ploughing and shallow ploughless tillage treatments the soil weed seed bank was 1.5 and 2.2 times greater compared with conventional (deep ploughing) tillage treatments.

Table 2. The influence of primary soil tillage methods and soil fertility improvement measures on the soil weed seed bank (seeds m⁻²).

Vėžaičiai, 2011

Soil fertility improvement measures (factor B)	Primary soil tillage (factor A)			Mean of factor B LSD ₀₅ = 7939.274
	deep ploughing	shallow ploughing	shallow ploughless tillage	
Plant residues	15480	23478	25908*	21622
Plant residues + straw	21280	27750*	31488**	26839
Green manure 1 st cut + straw	11438	17802	47092**	25444
Green manure 2 nd cut + straw	14204	19840	31944**	21996
Farmyard manure 40 t ha ⁻¹ + straw	15812	18408*	35328**	26516
Mean of factor A LSD ₀₅ = 6149.735	15643	23456**	34352**	

* – significant at $P < 0.05$, and ** – significant at $P < 0.01$

The soil weed seed bank did not depend on the soil fertility improvement measures. The differences were not essential. Although we did not establish any statistically significant influence of the soil fertility improvement measures on the soil weed seed bank, after ploughing down plant residues + straw or straw together with 40 t ha⁻¹ of farmyard manure, the soil weed seed bank was by 4.6% to 19.0% greater than in the soil where only plant residues had been ploughed down or straw had been applied with the phytomass of red clover for the soil fertility improvement.

The influence of the soil tillage methods manifested itself not only directly, but also through the interaction with soil fertility improvement measures. Significantly more weed seeds was determined under shallow ploughing and using plant residues + straw, or straw together with 40 t ha⁻¹ of farmyard manure.

Regardless of the chosen soil fertility improvement measures, in all treatments of shallow ploughless tillage, the soil weed seed bank was significantly greater (25908–47092 seeds m⁻²), compared with the conventional soil tillage method.

The diversity of weed seed species in the ploughlayer. The data of the analysis of variance showed that only the soil tillage method had a significant influence on the number of weed seed species in the ploughlayer ($F_{act} = 15.6 > F_{tabl.0.1} = 5.01$). In the ploughlayer, significantly fewer weed seed species (on average 4.2 m⁻²) were found in the deep ploughing treatment, compared with the shallow ploughing and shallow ploughless tillage treatments (Table 3). In shallow ploughing and shallow ploughless tillage treatments, 25.5% and 41.5% more weed seed species were found than in the conventional (deep ploughing) treatment.

Table 3. The influence of primary soil tillage methods and soil fertility improvement measures on the diversity of weed seed species (m⁻²) in the ploughlayer

Vėžaičiai, 2011

Soil fertility improvement measures (factor B)	Primary soil tillage (factor A)			Mean of factor B LSD ₀₅ = 1.11
	deep ploughing	shallow ploughing	shallow ploughless tillage	
Plant residues	3.6	4.4	5.8**	4.6
Plant residues + straw	5.4*	5.8**	5.6**	5.6*
Green manure 1 st cut + straw	3.2	4.6	7.4**	5.1
Green manure 2 nd cut + straw	3.8	5.0	6.2**	5.0
Farmyard manure 40 t ha ⁻¹ + straw	5.2*	6.8**	5.0	5.7*
Mean of factor A LSD ₀₅ = 0.86	4.2	5.3**	6.0**	

* – significant at $P < 0.05$, and ** – significant at $P < 0.01$

The influence of soil fertility improvement measures on the number weed seed species in the ploughlayer was not distinct. Significantly more weed seed species were found after ploughing plant residues + straw or straw together with 40 t ha⁻¹ of farmyard manure (on average 21.7% and 23.3% more than under ploughing only plant residues). Among other soil fertility improvement measures the differences were smaller than the least significant difference (LSD₀₅).

The analysis of the interaction between soil fertility improvement measures and soil tillage shows that the significantly higher number of weed seed species in the ploughlayer was found in deep and/or shallow ploughing treatment, when plant residues + straw or

straw together with 40 t ha⁻¹ of farmyard manure had been used to improve soil fertility. Regardless of the chosen soil fertility improvement measure, almost in all treatments of shallow ploughless tillage the number of weed seed species in the ploughlayer was significantly higher (5.6–7.4 weed seed species m⁻²), compared with the conventional soil tillage treatment.

During the study period, the following 20 weed seed species, belonging to 11 families, were found in the ploughlayer: *Asteraceae*, *Brassicaceae*, *Caryophyllaceae*, *Chenopodiaceae*, *Euphorbiaceae*, *Fabaceae*, *Lamiaceae*, *Plantaginaceae*, *Poaceae*, *Polygonaceae*, *Violaceae*.

It should be noted that the major part (78.0–90.0%) of the weed seed bank is composed of several weed

species. The seeds of *Chenopodium album* L. account for the largest share in the seed bank (Grigas, 1995). The averaged data from the trial carried out in Vėžaičiai Branch of Lithuanian Research Centre for Agriculture and Forestry showed that the seeds of *Chenopodium album* L., *Persicaria lapathifolia* L., *Fallopia convolvulus*

L. and *Viola arvensis* Murray occurred in all treatments (Table 4). The seeds of *Chenopodium album* L. accounted for 34.3%, *Fallopia convolvulus* L. for 18.4%, *Viola arvensis* Murray for 12.2%, *Persicaria lapathifolia* L. for 10.0% of the total soil seed bank.

Table 4. Relative abundance of weed seed species (%) in the ploughlayer as influenced by the soil tillage methods Vėžaičiai, 2011

Plant family	Weed species	Soil fertility improvement measures				
		R	R + S	GI + S	GII + S	M + S
Deep ploughing						
<i>Brassicaceae</i>	<i>Capsella bursa-pastoris</i> L.	–	6.2	–	5.7	18.6
	<i>Sinapsis arvensis</i> L.	1.6	–	–	–	–
<i>Polygonaceae</i>	<i>Persicaria lapathifolia</i> L.	5.0	10.0	14.0	1.9	13.6
	<i>Fallopia convolvulus</i> L.	21.7	16.3	32.6	39.6	22.0
<i>Caryophyllaceae</i>	<i>Spergula arvensis</i> L.	–	13.7	4.6	–	5.0
	<i>Stellaria media</i> (L.) Vill.	5.0	8.8	–	1.9	–
<i>Plantaginaceae</i>	<i>Plantago major</i> L.	–	1.3	–	–	–
<i>Violaceae</i>	<i>Viola arvensis</i> Murray	15.0	10.0	14.0	20.7	11.9
<i>Chenopodiaceae</i>	<i>Chenopodium album</i> L.	51.7	33.7	34.8	30.2	28.9
Shallow ploughing						
<i>Brassicaceae</i>	<i>Erysimum cheiranthoides</i> L.	–	–	–	–	1.9
	<i>Capsella bursa-pastoris</i> L.	12.0	7.2	20.4	36.3	20.8
	<i>Sinapsis arvensis</i> L.	–	2.7	–	–	–
<i>Polygonaceae</i>	<i>Persicaria lapathifolia</i> L.	5.5	15.4	1.4	7.5	2.8
	<i>Fallopia convolvulus</i> L.	22.0	16.2	18.8	21.3	11.3
<i>Caryophyllaceae</i>	<i>Scleranthus annuus</i> L.	–	–	–	1.2	–
	<i>Spergula arvensis</i> L.	2.2	9.9	–	1.3	4.7
<i>Asteraceae</i>	<i>Tripleurospermum perforatum</i> (Merat.) M. Lainz.	–	–	–	1.2	3.8
<i>Poaceae</i>	<i>Poa annua</i> L.	–	–	1.4	–	–
<i>Fabaceae</i>	<i>Trifolium pratense</i> L.	2.2	–	1.4	–	–
<i>Plantaginaceae</i>	<i>Plantago major</i> L.	–	–	–	–	1.9
<i>Violaceae</i>	<i>Viola arvensis</i> Murray	19.8	21.6	29.0	5.0	13.2
<i>Lamiaceae</i>	<i>Stachys palustris</i> L.	–	–	–	1.2	–
<i>Chenopodiaceae</i>	<i>Chenopodium album</i> L.	36.3	27.0	27.6	23.8	39.6
<i>Euphorbiaceae</i>	<i>Euforbia helioscopia</i> L.	–	–	–	1.2	–
Shallow ploughless tillage						
<i>Brassicaceae</i>	<i>Erysimum cheiranthoides</i> L.	3.9	1.6	3.1	1.5	4.4
	<i>Capsella bursa-pastoris</i> L.	4.9	12.2	24.3	33.3	20.3
	<i>Sinapsis arvensis</i> L.	–	–	0.5	–	–
<i>Polygonaceae</i>	<i>Persicaria lapathifolia</i> L.	15.7	12.2	12.9	10.6	13.0
	<i>Fallopia convolvulus</i> L.	12.7	11.4	8.2	9.1	15.9
	<i>Rumex acetosella</i> L.	–	–	0.5	–	–
	<i>Rumex crispus</i> L.	2.0	–	–	–	–
<i>Caryophyllaceae</i>	<i>Spergula arvensis</i> L.	13.7	22.8	6.2	4.5	3.6
<i>Asteraceae</i>	<i>Tripleurospermum perforatum</i> (Merat.) M. Lainz.	–	–	1.5	3.8	–
	<i>Sonchus arvensis</i> L.	–	–	0.5	0.8	–
<i>Violaceae</i>	<i>Viola arvensis</i> Murray	6.9	6.5	7.2	4.5	5.1
<i>Lamiaceae</i>	<i>Galeopsis tetrahit</i> L.	–	–	–	0.8	–
<i>Chenopodiaceae</i>	<i>Chenopodium album</i> L.	40.2	33.3	35.1	31.1	37.7

R – plant residues, R + S – plant residues + straw, GI + S – green manure 1st cut + straw, GII + S – green manure 2nd cut + straw, M + S farmyard manure 40 t ha⁻¹ + straw

The data of the statistical analysis of relative abundance of weed seed species suggest that a significant influence on the spread of seeds of *Fallopia convolvulus* L., *Viola arvensis* Murray, *Persicaria lapathifolia* L. was exerted by the soil tillage ($F_{act.} = 13.8 > F_{tabl.0.1} = 5.01$,

$F_{act.} = 10.98 > F_{tabl.0.1} = 5.01$, $F_{act.} = 4.26 > F_{tabl.0.1} = 5.01$, respectively) (Table 5). The seeds of *F. convolvulus* L. accounted for the significantly highest percentage of the total weed seed bank in the conventional soil tillage (deep ploughing) treatment.

Table 5. The variance of the distribution of the weed seed species in the ploughlayer
Vežaičiai, 2011

Variance	<i>Chenopodium album</i>	<i>Fallopia convolvulus</i>	<i>Viola arvensis</i>	<i>Persicaria lapathifolia</i>
	F _{act.}	F _{act.}	F _{act.}	F _{act.}
Treatments	1.85	3.46**	3.72**	2.26*
Primary soil tillage (factor A)	1.85	13.8**	10.98**	4.26*
Soil fertility improvement measures (factor B)	3.22*	1.25	1.59	1.69
Interaction of factors A and B	1.17	1.98	2.97**	2.05

* – significant at $P < 0.05$, and ** – significant at $P < 0.01$

The differences among other soil tillage methods were smaller than the least significant difference ($LSD_{0.05}$). The seeds of *Viola arvensis* Murray were found in the shallow ploughing treatment; however, significant differences were found while comparing deep ploughing and shallow ploughing with shallow ploughless tillage. Because of the interaction of soil tillage and soil fertility improvement measures the highest counts of *V. arvensis* Murray seeds in the ploughlayer were found in the shallow ploughing and green manure 1st cut + straw treatment. Shallow ploughless tillage had a more marked influence on the distribution *Persicaria lapathifolia* L. seeds.

Soil fertility improvement measures ($F_{act.} = 3.22 > F_{tabl.0.05} = 2.54$) impacted on the distribution of *Chenopodium album* L. seeds. The significantly highest percentage of this species seeds from the total weed seed bank was identified in the treatment involving stubble ploughing. The weed seed bank's species composition differed from that of red clover sward, which was the last course of the rotation. Only 27–40% of the soil weed seed bank species were the same as in the red clover sward. These were annual archeophytes *Ch. album* L., *F. convolvulus* L., *P. lapathifolia* L. ir *Capsella bursa-pastoris* L.

Conclusions

1. The primary soil tillage had a significant influence on the weed incidence and soil weed seed bank in the crops of the second rotation. The greatest amount of weeds, in numbers as well as dry mass, was found in the crops of winter triticale and spring rape in the shallow ploughless tillage treatment, in the crops of spring barley in the shallow ploughing treatment, and in the sward of red clover in the deep and shallow ploughing treatments. The soil fertility improvement measures and their interaction with soil tillage methods did not have any significant influence on the amount of weeds and their dry matter mass in the rotation crops.

2. In the deep ploughing treatment, the soil weed seed bank was significantly less abundant (15643 seeds m^{-2}) than in the shallow ploughing or shallow ploughless tillage treatments. The influence of primary soil tillage methods manifested itself not only directly, but also through their interaction with soil fertility improvement measures. In the shallow ploughless tillage treatment, all the soil fertility improvement measures significantly increased the soil weed seed bank, compared with the conventional soil tillage treatment.

3. The shallow ploughing and shallow ploughless tillage treatments contained 25.5% and 41.5% more weed seed species in the soil, compared with the conventional soil tillage (deep ploughing) treatment. The amount of weed seed species was increased by ploughed in residues + straw and/or straw together with 40 t ha^{-1} of farmyard manure. This treatment contained by on average 21.7% and 23.3% more weed seed species, compared with that with ploughed in residues only).

4. *Polygonaceae* Juss, *Chenopodiaceae* Vent. and *Violaceae* L. were most numerous in the ploughlayer's weed seed bank. The seeds of *Persicaria lapathifolia* L., *Fallopia convolvulus* L., *Chenopodium album* L. and *Viola arvensis* Murray were identified in all experimental treatments.

5. Only soil tillage had a significant effect on the distribution of *F. convolvulus* L. and *P. lapathifolia* L. seeds. The distribution of *V. arvensis* Murray seeds was significantly impacted by the soil tillage and its interaction with soil fertility improvement measures, while that of *Ch. album* L. seeds was significantly influenced by only soil fertility improvement measures.

6. The weed seed bank's species composition differed from that of red clover sward, which was the last course of the rotation. Only 27–40% of the soil weed seed bank species were the same as in the red clover sward. These were annual archeophytes *Ch. album* L., *F. convolvulus* L., *P. lapathifolia* L. and *Capsella bursa-pastoris* L.

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Pagrindinio žemės dirbimo įtaka dirvožemio sėklų bankui ir piktžolėtumui javų bei žolių sėjomainoje

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Santrauka

Lietuvos agrarinių ir miškų mokslų centro Vėžaičių filiale 2008–2011 m. vykdytas lauko bandymas, siekiant nustatyti įvairių žemės dirbimo būdų (gilus arimas, sekclus arimas, sekclus neariminis dirbimas) ir dirvožemio derlingumą gerinančių priemonių (augalų liekanos, augalų liekanos + šiaudai, I pjūties žalioji trąša + šiaudai, II pjūties žalioji trąša + šiaudai, mėšlas 40 t ha⁻¹ + šiaudai) įtaką dirvožemio užterštumui piktžolių sėklomis bei sėjomainos piktžolėtumui. Bandymo dirvožemis – nepsoptintasis sekliai glėjiškasis balkšvasžemis (Jlg8-n), granulimetrinė sudėtis – smėlingas priemolis.

Visais tyrimų metais sėjomainos pasėlių piktžolėtumui ir dirvožemio užterštumui piktžolių sėklomis esminę įtaką turėjo rudeninis žemės dirbimas. Žieminių kvietrugių ir vasarinių rapsų pasėliuose didžiausias piktžolių kiekis bei jų sausųjų medžiagų masė nustatyta taikant sekclus neariminį dirbimo būdą, vasarinių miežių pasėlyje – sekclus arimą, o raudonųjų dobilų žolyne – gilų ir sekclus arimą. Skirtingos dirvožemio derlingumą palaikančios priemonės ir jų sąveika su žemės dirbimo būdais esminės įtakos sėjomainos pasėlių piktžolėtumui neturėjo. Piktžolių sėklų kiekis dirvožemyje taikant sekclus arimą ir sekclus neariminį dirbimą nustatytas 1,5 ir 2,2 karto didesnis nei dirbant tradiciniu būdu (giliai ariant). Žemės dirbimo būdų įtaka pasireiškė ne tik tiesiogiai, bet ir per sąveiką su dirvos derlingumą palaikančiomis priemonėmis. Nepriklausomai nuo pasirinktos dirvos derlingumą palaikančios priemonės, taikant sekclus neariminį dirbimą visais atvejais piktžolių sėklų kiekis dirvožemyje nustatytas iš esmės didesnis, lyginat su tradiciniu žemės dirbimo būdu.

Taikant sekclus arimą ir sekclus neariminį dirbimą, dirvožemyje įvairių rūšių piktžolių sėklų nustatyta 25,5 ir 41,5 % daugiau nei dirbant tradiciniu būdu (giliai ariant). Visuose variantuose rasta *Chenopodium album* L., *Persicaria lapathifolia* L., *Fallopia convolvulus* L. ir *Viola arvensis* Murray sėklų. *F. convolvulus* L. ir *P. lapathifolia* L. sėklų paplitimui esminės įtakos turėjo tik žemės dirbimas, *V. arvensis* Murray – žemės dirbimas ir jo sąveika su dirvos derlingumą palaikančiomis priemonėmis, o *Ch. album* L. sėklų paplitimą lėmė tik dirvos derlingumą palaikančios priemonės (organinės trąšos).

Reikšminiai žodžiai: dirvos derlingumą palaikančios priemonės, piktžolių kiekis ir jų masė, sėjomaina, sėklų bankas, žemės dirbimas rudenį.