ISSN 1392-3196
Zemdirbyste-Agriculture, vol. 97, No. 2 (2010), p. 73–82
UDK 631.442.4:631.5.01:631.582:631.51:633.358

Weed infestation and changes in field pea (*Pisum sativum* L.) yield as affected by reduced tillage of a clay loam soil

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Abstract

Experiments were carried out during 2007–2009 at the Joniškėlis Experimental Station of the Lithuanian Institute of Agriculture on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). The study was designed to assess the effects of shallow ploughing and ploughless tillage as well as its combinations with other agronomic practices – incorporation of lime sludge, cover crops (mixture of white mustard and oilseed radish) for green manure and mulch, improving soil condition and environment protection on the spread of weeds in a field pea crop and field pea productivity. It was found that when the post-sowing period was dry, reduced tillage of clay loam soil resulted in a higher weed incidence as well as a reduction in field pea yield, especially when leaving a cover crop for mulch during winter without tillage in autumn, as compared to deep ploughing. Under such conditions and due to reduced tillage, the spread of *Galium aparine* L. and *Chenopodium album* L. was wider, and in the cases of low field pea crop density as well as poor competition abilities, the mass of weeds increased. When the moisture was sufficient for field pea to emerge during post-sowing period, the spread of annual weeds was lower due to reduced tillage. Incorporation of lime sludge together with ploughless tillage helped to prevent the spread of weeds and reduction of field pea yield and was more favourable compared to ploughing.

Key words: clay loam, ploughing, ploughless tillage, lime sludge, cover crops, weeds, field pea.

Introduction

One of the main positions in soil management aids is given to appropriate tillage system. Tillage influences formation of soil water and nutrition regimes, level and course of microbiological processes as well as weed control systems, insects and diseases, i.e. the majority of plants' growth factors, determining the yield and production quality. Heavy soil tillage with application of conventional mouldboard ploughing requires high energy and time inputs as well as financial investments. Therefore, a lot of factors influence the contemporary search for possibilities to reduce soil tillage: necessity of accumulation and conservation of organic matter in the soil, new environment protection requirements, changes in farm specializations, unstable prices and demand for agricultural produce, increasing price of fuel as well as other energy sources, fertilizers and other inputs necessary for cultivation of crops, wide supply of new mechanisms and other factors (Holland, 2004; Deike et al., 2008; Tausojamoji žemdirbystė…, 2008).

Studies, performed in various countries, indicate that success of reduced tillage is dependent upon soil and climate conditions, species of cultivated crops and other factors (Bostrom, Fogelfors, 1999; Semb Torresen et al., 2003; Deike et al., 2008). Research carried out in Lithuania shows that reduced tillage, including ploughless tillage can be applied, considering conditions of the country, though various problems occur in our soils, usually weed infested and containing less organic matter and nutrients (Boguzas et al., 2006; Marcinkevičienė, Bogužas, 2006; Seibutis, Feiza, 2008).

An increase in weed incidence in crops is one of the main obstacles for successful application of reduced tillage. It is known, that after application of reduced tillage, perennial as well as grass annual weeds spread more and dominate (Hakansson, 2003). Fertile clay loam soils, if not infested with perennial weeds, as indicated by research performed in Lithuania and Latvia, do not always require deep annual ploughing (Velykis, Satkus, 2006; Ausmane, Melngalvis, 2007; Tausojamoji žemdirbystė..., 2008).

Studies, performed in Norway, indicate that after application of reduced tillage the amount of perennial and overwintering weeds as well as volunteer crops is growing; greater seed content accumulates in upper topsoil layer. However, if weeds are under appropriate control, their seedbank is not significantly increasing due to the application of reduced tillage. It is stressed, that weed control in crops of various biological groups and fertility of plants in the systems of reduced tillage can be attained by application of combinations of gliphosate and post-emergence herbicides. Therefore, the reduced tillage determines higher level of weed control dependence upon herbicides and this increases the danger of development of weeds, resistant to herbicides. Weather conditions influence the yield-reducing effect, due to uneven spread of weeds in various tillage systems (Semb Torresen et al., 2003).

The effect of tillage, as a method of mechanical destruction, on different biological groups of weeds is not equal. The tillage objective for annual weeds is to prevent seed production and deplete seed reserves in the soil. The main tillage objective for perennials is to destroy the underground parts as well as to prevent seed production and reduce reserves of seeds (Chicouence, 2006). Tillage study conducted in Sweden shows, that it is possible to maintain acceptable weed population levels for most of crops by utilizing appropriate tillage strategies (Bostrom, Fogelfors, 1999).

Various crops compete with weeds in different ways. Under the conditions of intensive cropping with the aim of reducing energy consumption and global warming of climate as well as environment pollution, greater crop diversification is applied by introducing grain legumes, the cultivation of which requires less amount of components, ha-zardous for the environment, into the crop rotation (Nemecek et al., 2008). Under the conditions of a cooler climate, the most appropriate species from legumes is field pea. However, spring sown pea, especially of commonly cultivated semi-leafless varieties, are comparatively disadvantaged relative to weeds. Field pea competes with weeds poorly during the first month after sowing. Their early-season growth is comparatively slow, the ground remains without complete cover by the crop canopy and perennial as well as annual weeds, emerging early, are very competitive with field pea. The range of herbicides for weed control in field pea crops is not wide and their efficacy is often insufficient. Therefore, cultivation of field pea requires appropriate selection of tillage and sowing for weeds not to compete with crops at their emergence and to minimize yield losses (Harker et al., 2001; Avola et al., 2008; Sepp et al., 2009).

Cultivation of cover crops is important for increase of plant diversity as well as improvement of environment protection state in cereal-dominated rotations. Cover crops, rapidly emerging and densely covering soil, efficiently compete with weeds. Fast-growing cover crops compete with weeds for space, light, nutrients, moisture and rooting zone. Vigorous cover crops can fully compete with seed-emerging annual weeds. Perennial weeds that propagate by roots, rhizomes or tubers and have bigger nutritional reserves are difficult to suppress, but aggressive cover crops can significantly reduce their growth. Incorporation of cover crops as green manure stops the effect of weed suppression. When cover crops are killed by frost in winter, residues, remaining in soil surface as mulch can prolong weed suppression for some period of time. Brassica cover crops suppress growth of weeds, especially small seeded, for several weeks after they were incorporated or were winter killed, due to allelopathic substances which appear within decomposition of residues. In autumn, weeds are well suppressed by mustard species, cultivated as cover crops (Hakansson, 2003; Grimmer, Masiunas, 2004; Haramoto, Gallandt, 2004; Kinderienė, 2005; Maikštėnienė et al., 2009).

The objective of the study was to assess the effect of conventional ploughing and ploughless tillage as well as its combinations with supplementary practices, improving soil condition and environment protection, on the spread of weeds in a field pea crop and field pea productivity.

Materials and methods

Soil and site description. Research was carried out at the Joniškėlis Experimental Station of the Lithuanian Institute of Agriculture situated on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*) of the northern part of Central Lithuania's lowland (56º21′ N, 24º10′ E) during the period 2007–2009. Topsoil characteristics were as follows: 27% clay, 50% silt, 23% sand, 2.2% humus and pH – 6.6. During the last 40 years, the annual means of temperature and total amount of rainfall were 6.1ºC and 547.4 mm.

Experimental design and parameters. The effects of conventional ploughing and ploughless soil tillage as well the combinations of ploughless soil tillage with practices for soil improvement and sustaining of environment on weed population and field pea crop productivity were investigated following the experimental design: 1) deep (20–23 cm) mouldboard ploughing (DP), 2) shallow (15–17 cm) mouldboard ploughing (SP), 3) ploughless tillage at 10–12 cm depth (PT), 4) ploughless tillage at 10–12 cm depth with lime sludge incorporation (PT + LS), 5) ploughless tillage at 10–12 cm depth with cover crop for green manure (PT + GM), 6) cover crop for mulch without autumn tillage (NT + WM). Research was conducted in a crop rotation spread over space and time: 1) field pea, 2) winter wheat, 3) spring oilseed rape, 4) spring barley. The field experiment was arranged as a randomized single row design in four replicates. Each tilled sub-plot was 16.0 m long and 5.0 m wide of which 13.0 by 2.30 m was harvested.

General conditions of the experiment. The whole field trial included spring barley (pre-crop) straw chopping during harvesting and incorporating into the soil at 6–8 cm depth during stubble loosening by using a combined stubble breaker, equipped with sweeps, discs and rollers. Cover crops were a mixture of white mustard (*Sinapis alba* L.) cv. 'Braco' (10 kg seed ha^{-1}) and oilseed radish (*Raphanus sativus* L.) cv. 'Rufus' (13 kg seed ha^{-1}). They were sown after stubble loosening and application of pre-sowing tillage. Deep (treatment 1) and shallow (treatment 2) ploughing was performed with a mouldboard plough. Ploughless soil tillage (treatments 3 and 4) was performed by a combined stubble breaker. Lime sludge (7.0 t ha^{-1}) was incorporated into the soil during ploughless tillage operation (treatment 4). Cover crop for green manure (treatment 5) was chopped and incorporated into the soil by a disk harrow into the depth of 8–10 cm late in autumn. Cover crop for mulch in winter (treatment 6) was left without tillage in autumn and was frost killed prior to the spring and its residues covered the soil. After application of analyzed practices, field pea (*Pisum sativum* L. (Partim)) cv. 'Tinker' was grown, sowing 1.2 million seed ha^{-1}. The herbicides with selective mode of action were applied against dicotyledonous weeds in field pea crop: Stomp 330 EC 1.5 l ha^{-1} (pendimetalin 330 g a.i. l^{-1}) + Basagran 480 1.0 l ha^{-1} (bentazon 480g a.i. l^{-1}).

Meteorological conditions. The autumn in 2006 was rainy, warm and long; therefore sown cover crops emerged and grew well. The highest precipitation rate was in October; it was 23.3 mm higher than the annual mean. The spring in 2007 started early and was dryer than usual. Precipitation rate in May and June varied less from the annual mean, though in July it was higher by 37.8 mm than the annual mean. Conditions for early emergence of crops and weeds were favourable. Post harvest period varied less from the annual mean by precipitation rate and air temperature. In 2008, meteorological conditions were characterized by warmer winter, wet spring and very dry first half of summer, but wet end. The influence of drought on spring crop emergence was adverse. In November 2008–April 2009, the period was warmer by 1.8°C than usual, though wet. High precipitation was observed in December and March (respectively 63.1 and 51.7 mm). Extremely dry April and May influenced poor emergence and development of spring crops. However, June and July were wet and affected the new flush of weed emergence (Figure).

Experimental methods and assessments. Weed incidence in the field pea crop was determined by a quantitative-weighing method twice during the growing period: number of weeds and species in the beginning of stem elongation stage (BBCH 30–32) before application of herbicides, and at pod formation stage (BBCH 73–75) of field pea before harvesting, while the biomass of dry material – only at pod formation stage. Field pea seedlings were counted after final germination. Number of weeds and field pea seedlings, also mass of weeds were determined in 0.25 m^2 fixed plots, in four places per each plot with a frame of 50 x 50 cm. The data of the number and mass of weeds for the evaluation of statistically significant differences were transformed according to the formula: $\sqrt{x+1}$. The data of field pea grain yield was adjusted to 15.0% moisture. The experimental data were processed by *Anova* and *Stat Eng*.

Results and discussion

Weed infestation after emergence of field pea. After emergence, *Galium aparine* L., *Fallopia convolvulus* L., Löve *Thlaspi arvense* L., *Chenopodium album* L. and other annual weeds dominated in field pea crops. Out of perennial weeds, whose content was not high in the field pea crop (from 0 to 3 weed m^{-2}), more common were *Cirsium arvense* L. Scop and *Elytrigia repens* (L.) Nevski. Reduced tillage or its combinations with supplementary practices for improvement of soil condition as well as environment protection (lime sludge, cover crops of mixed white mustard and oilseed radish for green manure as well as mulch) in separate experimental years increased the incidence of *G. aparine* and *C. album* in the field pea crop as compared to conventional deep ploughing (Table 1).

Year average

Temperature °C	−5.8	−5.6	−1.1	6.2	12.3	15.6	17.2	17.1	12.0	6.3	1.4	−3.0
Rainfall mm	30.9	24.6	27.3	37.4	45.6	59.4	69.2	67.9	57.9	45.5	42.7	69.0

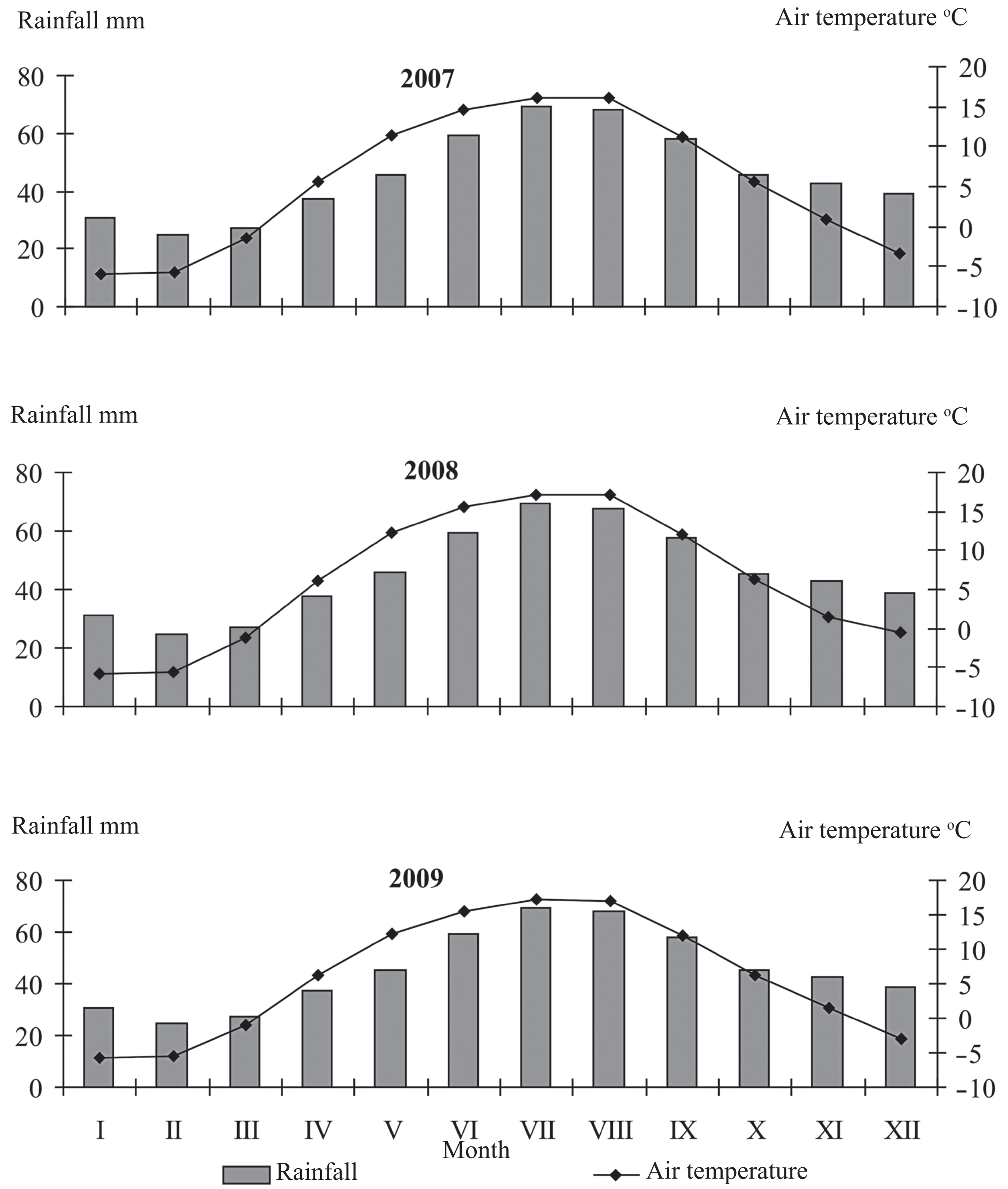

Figure. Meteorological conditions during the experimental period
Joniškėlis Experimental Station, 2007–2008

Table 1. The incidence of weeds in the field pea crop in spring before herbicide application
Joniškėlis Experimental Station

Weeds	Tillage					
	DP	SP	PT	PT + LS	PT + GM	NT + WM
			2007			
Galium aparine	0	0	1.0*	0	1.0*	0
Fallopia convolvulus	3.5	1.5	0.5*	0.5	1.0*	1.0
Thlaspi arvense	5.5	5.5	7.0	7.0	7.0	5.0
Chenopodium album	1.0	0	0	0	0	0
Other annual	14.5	27.0	19.5	18.0	25.5	25.0
All annual m^{-2}	24.5	34.0	28.0	25.5	34.5	31.0
All perennial m^{-2}	0	0.5	1.0	3.0	0	1.0
All weeds m^{-2}	24.5	34.5	29.0	28.5	34.5	32.0
			2008			
Galium aparine	1.8	2.8	3.5	4.3	9.8*	7.8*
Fallopia convolvulus	3.8	2.0	2.0	2.8*	1.0*	1.8*
Thlaspi arvense	8.3	4.5	4.8	2.3	1.5	2.0
Chenopodium album	5.3	5.5	3.3	4.5	4.3	6.0
Other annual	32.1	22.5	26.2	17.6	29.2	32.9
All annual m^{-2}	51.3	37.3	39.8	31.5*	45.8	50.5
All perennial m^{-2}	0	0	0.8	0.3	1.3*	2.8*
All weeds m^{-2}	51.3	37.3	40.6	31.8*	47.1	53.3
			2009			
Galium aparine	0.8	3.0	5.3*	2.8	7.0*	8.3*
Fallopia convolvulus	15.0	14.8	13.8	13.0	21.5	18.3
Thlaspi arvense	2.5	2.5	5.8	3.8	1.0	0.8
Chenopodium album	10.3	19.0	33.0*	35.8*	31.8*	58.8*
Other annual	67.7	64.2	98.4	67.6	93.5	70.8
All annual m^{-2}	96.3	103.5	156.3*	123.0	154.8*	157.0*
All perennial m^{-2}	1.3	1.5	0.3	1.5	1.5	3.0
All weeds m^{-2}	97.6	105.0	156.6*	124.5	156.3*	160.0*

Note. * – at $P < 0.05$.

Many studies indicate that the timing of weed emergence flushes is mostly related to the timing and rate of seed germination, which depend on soil water potential and temperature as well as tillage systems and crop sowing date (Gill, Arshard, 1995; Hakansson, 2003; Boguzas et al., 2006; Tausojamoji žemdirbystė..., 2008; Gardarin et al., 2010). Assessment of the effect of meteorological conditions of all experimental years on the spread of weeds in the field pea crop revealed that in the case of sufficiently wet post-sowing period (2007) and the best emergence of field pea as well as immediate adequate suppression of weeds, the weed content in the crop was significantly lower than that during the dry years of 2008 and 2009 (Table 1). As a result, reduced tillage and its combinations with other practices during the year, favourable for field pea growing, did not have any substantial effect on the spread of weeds in the crop.

During the dry year 2008, the initial stage of field pea growing period revealed higher rate of spread of perennial weeds, occurring in connection with combining reduced tillage with a cover crop for the green manure as well as cover crop without tillage in autumn for mulch, as compared to the deep ploughing (Table 1). This could be influenced by favourable autumn conditions for the development of perennial weeds, because if cover crop is left for mulch during the winter without tillage in autumn or with shallow incorporation of the green manure in autumn, there is no effect of mechanical suppression of tillage by cutting their roots or other impacts on these weeds or the effect is relatively low. However, ploughless tillage with incorporation of lime sludge in the year 2008 determined better emergence of field pea and significantly lower (by 38.6%) emergence of annual weeds as compared to the deep ploughing.

For very poor emergence of field pea (only 33–49 plants m^{-2}) during the extremely dry post-sowing period in 2009, ploughless tillage and its combination with a cover crop for the green manure as well as a cover crop for mulch without tillage in autumn, determined an increase in the content of annual weeds as well as content of all weeds (Table 1). Only in the cases of incorporation of lime sludge together with ploughless tillage, increase in weed content was not significant as compared to conventional tillage. Shallow ploughing, as compared to deep ploughing, did not determine the weed incidence during initial stages of field pea vegetation significantly in any year of the study.

Boguzas et al. (2006) found that reduced autumn tillage had no significant effect on the spread of weeds in spring cereals compared to deep ploughing. However, with no-tillage in autumn in loam soil, weed content in crops increased by 1.3–10.3 times. Perennial and annual weeds spread more with no-tillage in autumn. Moreover, favourable conditions for the spread of perennial weeds occurred.

Weed incidence prior to field pea harvesting. During the normally wet year, favourable for field pea growing (2007), annual weed content prior to harvesting with application of deep soil ploughing remained relatively similar to that in the initial stages of growth. Application of all methods of reduced tillage as well as combinations with supplementary practices reduced annual weed content as compared to that at the beginning of field pea growth. Moreover, reduction of tillage in all cases determined a significant decrease by 33.3–56.9% in annual weed content, as compared to deep ploughing (Table 2). During the dry year (2008), annual weed content increased prior to field pea harvesting, because emergence of weeds continued in later stages. However, under these conditions the ploughless tillage only as well as its combination with lime sludge, reduced annual weed content by 40.1 and 43.6%, respectively, compared to deep ploughing (Table 2).

Table 2. The incidence of weeds in the field pea crop before harvesting
Joniškėlis Experimental Station

Weeds	Tillage					
	DP	SP	PT	PT + LS	PT + GM	NT + WM
			2007			
All annual m^{-2}	25.5	16.5*	11.5*	17.0*	14.5*	11.0*
All perennial m^{-2}	4.0	5.5	16.5	10.5	9.0	12.0
All weeds m^{-2}	29.5	22.0	28.0	27.5	23.5	23.0
DM♦ mass of annuals g m^{-2}	15.97	13.39	7.50	12.35	9.70	10.70
DM♦ mass of perennials g m^{-2}	0.84	1.51	0.04	0.81	1.28	1.17
Total weed DM♦ mass g m^{-2}	16.81	14.90	7.54	13.16	10.98	11.87
			2008			
All annual m^{-2}	86.0	72.0	51.5*	48.5*	77.5	73.5
All perennial m^{-2}	3.5	3.0	3.5	2.5	3.0	3.5
All weeds m^{-2}	89.5	75.0	55.0	51.0	80.5	77.0
DM♦ mass of annuals g m^{-2}	74.52	91.18	77.07	62.05	111.59	114.10
DM♦ mass of perennials g m^{-2}	3.60	0.63	3.10	0.34	1.37	0.30
Total weed DM♦ mass g m^{-2}	78.12	91.81	80.17	62.39	112.96	114.40
			2009			
All annual m^{-2}	59.8	73.3	70.0	67.8	76.5*	88.5*
All perennial m^{-2}	10.3	15.0	17.3	15.8	10.3	14.5
All weeds m^{-2}	70.10	88.30	87.30	83.60	86.80	103.00
DM♦ mass of annuals g m^{-2}	66.22	108.84	106.54	87.32	105.62	92.12
DM♦ mass of perennials g m^{-2}	3.31	6.27	16.40	15.18	3.16	24.43
Total weed DM♦ mass g m^{-2}	69.53	115.11*	122.94*	102.50	108.78	116.55*

Notes. ♦DM – dry matter. * – at $P < 0.05$.

Only during the year, extremely unfavourable for field pea growing (2009) due to the lack of moisture during the post-sowing period, when rain started after application of herbicides and gave a new flush of weed emergence, annual weed content increased by 27.9 and 48.0%, respectively due to ploughless tillage combination with a cover crop for green manure and cover crop for mulch without tillage in autumn, that determined poor emergence of field pea, as compared to deep ploughing (Table 2). It is possible to state, that under favourable conditions for emergence of field pea and weed at the beginning of crop growth, after efficient destruction of weeds by herbicides of a selective action, with their further emergence suppressed by dense crop, reduction of tillage can even reduce the spread of annual weed.

Perennial weed content from the beginning of field pea growth until harvesting increased and was from 2.5 to 17.3 weeds m^{-2}. In most cases, their content increased most markedly in the plots, where ploughless tillage had been applied (Table 2).

The practices applied determined the total weed mass more significantly only in 2009, when weeds were spread the most. Total weed mass was respectively by 65.6, 76.8 and 67.6% higher due to shallow ploughing, ploughless tillage without any supplementary practices and cover crop, left for mulch in winter without tillage in autumn, compared to deep ploughing (Table 2).

As pointed out by Marcinkevičienė and Bogužas (2006), brassica cover crops for feed and green manure are equal to stubble breaking or crops' spray with herbicides, according to their effect on weed content in cereal crops, when the primary tillage method is conventional ploughing. However, if cover crops are left for winter and are incorporated into soil in spring, the mass of weeds in spring cereals is higher if compared to cover crops' ploughing down in autumn.

Productivity of field pea crop. In the cases when field pea was sufficiently supplied with moisture (2007) crop emerged rather evenly under application of all analyzed practices (Table 3). Due to the dry post-sowing period in 2008, field pea density was on average twice as low as that in 2007. Under such conditions, field pea in 2008 emerged best with application of ploughless tillage together with incorporation of lime sludge and their density was 40.0% higher compared to deep ploughing. During the year, the least favourable for field pea growth (2009) crop density was 33.0–48.8 plants m^{-2}, i.e. 3 times lower than that in 2007.

Table 3. The indicators of field pea crop productivity

Joniškėlis Experimental Station

Tillage	Field pea density plants m^{-2}	DM♦ mass per weed g	DM♦ mass per field pea plant g
		2007	
DP	118.0	0.50	8.88
SP	116.0	0.74	10.32
PT	113.0	0.67	11.43*
PT + LS	119.5	0.55	8.69
PT + GM	122.5	0.56	8.60
NT + WM	106.0	0.95*	9.18
LSD_{05}	22.21	0.660	1.582
		2008	
DP	70.0	1.12	18.23
SP	47.0	1.25	17.66
PT	79.0	1.78	18.48
PT + LS	98.0	1.03	18.14
PT+ GM	57.0	1.46	16.85
NT+ WM	66.0	1.58	12.21*
LSD_{05}	23.05	0.684	3.159
		2009	
DP	45.8	0.98	15.64
SP	40.8	1.35	15.68
PT	41.5	1.40	14.22
PT + LS	48.8	1.22	15.40
PT + GM	33.0	1.25	12.40*
NT + WM	38.5	1.19	12.77*
LSD_{05}	12.93	0.509	2.526

Note. ♦DM – dry matter. * – at $P < 0.05$.

There were significant negative linear correlations between the content of annual weeds ($r = -0.61$), content of all weeds before herbicide application ($r = -0.60$), as well as total weed air-dry mass prior to harvesting ($r = -0.58$) and field pea density after emergence in unfavourable for field pea year 2008, also such correlations between the total weed air-dry mass ($r = -0.61$), as well as single weed air-dry mass ($r = -0.54$) and field pea density in extremely unfavourable year 2009 (Table 5). Consequently, dense spring crops with strong competitive ability decrease the weed emergence and increase death of emerged weeds in the crop (Romaneckienė et al., 2008).

Mean mass per field pea plant indicates conditions for growth of field pea, related to wider spread of weeds, crop density as well as physical soil properties and other changes. In the cases with poor emergence of field pea and the highest incidence of weeds (2008 and 2009), combination of ploughless tillage with a cover crop for green manure and cover crop for mulch without tillage in autumn, determined a significant reduction in field pea mass per plant compared with deep ploughing (Table 3). Within higher density of field pea crop, mean mass per plant was lower than in a thin crop.

Field pea yield. If cover crop is left for mulch during winter without tillage in autumn, a significant reduction in field pea yield occurs in all periods of study: in 2007 – 10.6%, in 2008 – 56.0%, in 2009 – 31.6%, as compared to deep ploughing (Table 4). During the period, extremely unfavourable for field pea in 2009, with a long dry post-sowing period, field pea yield also significantly reduced because of ploughless tillage with no supplementary practices, performed in autumn as well as such tillage with cultivation of cover crop together incorporating its biomass for green manure, respectively by 19.4 and 19.9%, as compared to deep ploughing. Incorporation of lime sludge together with ploughless tillage prevented field pea yield reduction due to reduced tillage and in 2008 determined higher field pea yield by 42.0% as compared to deep ploughing.

Table 4. Grain yield of field pea

Joniškėlis Experimental Station

Tillage	Year 2007	Year 2008	Year 2009
	grain yield t ha^{-1}		
DP	3.79	1.93	2.06
SP	4.09	1.80	2.03
PT	3.82	2.22	1.66
PT + LS	3.79	2.74	2.10
PT + GM	3.53	1.74	1.65
NT + WM	3.39	0.85	1.41
LSD_{05}	0.359	0.404	0.335

Table 5. The relationship between indicators of field pea grain yield, crop productivity and weed incidence

Joniškėlis Experimental Station

Trait *y* denomination	Trait *x* denomination	Regression equation	r	r^2	F_{Fisher}
2008 m.					
Field pea yield t ha^{-1}	Field pea seedlings m^{-2}	y = 35.90 + 17.70x	0.55**	0.30	9.36
Annual weeds m^{-2} after field pea emergence	Field pea seedlings m^{-2}	y = 111.94 – 1.00x	0.61**	0.37	12.84
All weeds m^{-2} after field pea emergence	Field pea seedlings m^{-2}	y = 69.56 – 0.38x	0.60**	0.36	12.16
Total weed air-dry mass g m^{-2}	Field pea seedlings m^{-2}	y = 172.41 – 1.19x	0.58**	0.33	11.03
2009 m.					
Field pea yield t ha^{-1}	Annual weeds m^{-2} after field pea emergence	y = 230.98 – 54.55x	0.59**	0.35	11.61
Field pea yield t ha^{-1}	All weeds m^{-2} after field pea emergence	y = 233.06 – 54.87x	0.59**	0.35	11.67
Total weed air-dry mass g m^{-2}	Field pea seedlings m^{-2}	y = 165.53 – 1.44x	0.61**	0.37	12.89
Air-dry mass of single weed g	Field pea seedlings m^{-2}	y = 1.75 – 0.01x	0,54**	0.29	8.91

Harker et al. (2001) have reported that if weeds compete with crops throughout the whole season, field pea yield losses may range from 40 to 70%. A critical weed competition period starts 1–2 weeks after field pea emergence, and weed removal in later periods reduces optimal yield of field pea.

A medium strong direct linear correlation was established between field pea grain yield and crop density in unfavourable for crop emergence year 2008 (r = 0.55). In extremely unfavourable for field pea emergence year 2009 a medium strong negative linear correlation was established between crop yield and content of annual (r = −0.59) as well as content of all weeds (r = −0.59), counted before herbicide application (Table 5).

Conclusions

1. Ploughless tillage in autumn and its combination with cover crop, incorporated for green manure late in autumn as well as cover crop, left for mulch during winter without tillage in autumn, determined the spread of annual weeds during the year, unfavourable to field pea emergence due to the lack of moisture. During normally wet and favourable for field pea emergence year, annual weed content prior to harvesting was significantly (by 33.3–56.9%) lower due to shallow ploughing, ploughless tillage and its combinations with incorporation of lime sludge, cover crops for green manure and for mulch, as compared to deep ploughing.

2. Ploughless tillage affected wider spread of annual weeds *Galium aparine* L. and *Chenopodium album* L. in the cases of dry post-sowing periods and poor emergence of field pea.

3. Within the application of ploughless tillage, suppressing perennial weeds less or leaving cover crop for mulch during winter without tillage in autumn, perennial weed content significantly increased from the initial stages of field pea growth until harvesting, as compared to deep ploughing.

4. Reduced tillage during the year, unfavourable for field pea growing due to the lack of moisture, in most cases increased the weed dry matter mass.

5. If cover crop was left for mulch without tillage in autumn, field pea grain yield significantly declined by 10.6, 56.0 and 31.6% in all years of study and if cover crop biomass was shallowly incorporated late in autumn by ploughless tillage, as well as because of ploughless tillage with no supplementary practices – respectively by 19.4 and 19.9% only in the year, extremely unfavourable for emergence and growth of field pea, as compared to deep ploughing. Incorporation of lime sludge by ploughless tillage improved emergence of field pea, helped to prevent the spread of weeds as well as yield reduction or even reduced weed incidence in the crop and increased field pea yield.

Received 01 03 2010
Accepted 27 04 2010

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ISSN 1392-3196
Žemdirbystė-Agriculture, t. 97, Nr. 2 (2010), p. 73–82
UDK 631.442.4:631.5.01:631.582:631.51:633.358

Piktžolių išplitimas ir sėjamojo žirnio (*Pisum sativum* L.) derliaus pokyčiai taikant supaprastintą sunkaus priemolio dirvų dirbimą

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Santrauka

Lietuvos žemdirbystės instituto Joniškėlio bandymų stotyje 2007–2009 m. giliau karbonatingame giliau glėjiškame sunkaus priemolio rudžemyje (RDg4-k2), *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*) atlikti tyrimai, siekiant įvertinti seklaus arimo ir bearimio žemės dirbimo bei jo derinių su dirvožemio savybes ir aplinkos tausojimą gerinančiomis priemonėmis – kalkių purvo įterpimu, tarpiniais pasėliais (baltųjų garstyčių ir aliejinių ridikų mišiniu) žaliajai trąšai ir mulčiui – įtaką piktžolių plitimui žirnių pasėlyje ir žirnių produktyvumui. Nustatyta, kad, posėjiniam laikotarpiui esant sausringam, sunkaus priemolio dirvų dirbimo supaprastinimas lėmė didesnį piktžolių išplitimą ir žirnių derliaus sumažėjimą, ypač tarpinius pasėlius palikus mulčiui per žiemą visai be žemės dirbimo rudenį, palyginti su giliu arimu. Tokiomis sąlygomis dėl supaprastinto žemės dirbimo žirnių pasėlyje labiau išplito *Galium aparine* L. bei *Chenopodium album* L. ir, esant mažam žirnių pasėlio tankumui bei menkai stelbiamajai gebai, piktžolių masė padidėjo. Kai posėjiniu laikotarpiu žirniams gerai sudygti užteko drėgmės, taikant supaprastintą žemės dirbimą trumpaamžių piktžolių išplito mažiau. Kalkių purvo įterpimas ir kartu bearimis žemės dirbimas padėjo išvengti piktžolių išplitimo ir žirnių derliaus sumažėjimo ar net buvo tinkamesnis, palyginti su arimu.

Reikšminiai žodžiai: sunkus priemolis, arimas, bearimis dirbimas, kalkių purvas, tarpiniai pasėliai, piktžolės, žirniai.