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Response of field pea (*Pisum sativum* L.) growth to reduced tillage of clayey soil

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Abstract

Research was done at the Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). The objective of this study was to determine the effects of reduced (shallow ploughing and ploughless tillage) tillage as well as its combinations with supplementary agronomic practices, improving soil conditions – incorporation of lime sludge, cover crop (mixture of white mustard and oilseed radish) for green manure and mulch on the emergence, growth and development of field pea (*Pisum sativum* L.) crop. Data revealed that shallow ploughing caused the worst field pea emergence in 2008. Ploughless tillage in combination with lime sludge incorporation resulted in a significantly higher soil water content in seedbed layer (0–5 cm) directly after field pea sowing in 2009, better field pea germination within the prolonged droughty post-sowing periods (18 and 20 days respectively in 2008 and 2009) and higher grain yield in 2008 as compared to deep ploughing. Due to the ploughless tillage together with incorporation of the cover crop biomass for the green manure late in autumn, significantly higher soil water content was registered in the seedbed directly after sowing in 2010 and at 5–15 cm depth according to the average data of 2008–2010; however the emergence and growth of field pea under droughty conditions were worse, and yield decreased in 2009 and 2010. Application of ploughless tillage with no supplementary practices resulted in significantly higher soil water content in seedbed directly after field pea sowing in 2010; however, in field pea yield decreased in 2009. Cover crop winter mulch without tillage in autumn led to a significantly higher soil water content in the seedbed directly after sowing in 2010, while the soil water content after field pea emergence at 5–15 cm depth in 2008 and at 15–25 cm depth according to the average data of 2008–2010 was lower, seedbed structure was mostly worse, field pea growth and development were poor and crop yield was lower in all years of study as compared to deep ploughing. Rapid capillary water movement, characteristic of clay loam with predominant silty fractions, could lead to a higher drying of soil layers unloosened in the autumn. Field pea yield was influenced by the amount of rainfall during one month after sowing in a droughty year 2008 and by the soil structure in a seedbed in 2009.

Key words: clay loam, reduced tillage, seedbed, soil water content, *Pisum sativum*.

Introduction

Climate change has been one of the greatest economic, social and environmental threats. It is predicted that the agriculture shall join economic sectors facing the biggest harmful effects (Bukantis, Rimkus, 2005; Peltonen-Sainio et al., 2009; Reidsma et al., 2010).

North European bio geographical region, to which Lithuania belongs, can suffer a lot due to extreme situations – frequenting droughts and floods – appearing with the changing climate (The European environment…, 2010). Typical climate changes have been observed in this European region. Here, early summer droughts become more frequent or there is insufficient rainfall to ensure the rapid, undisturbed early crop growth especially during stages, affecting the yield. Frequent and abundant rainfall during plant growth increases the incidence of diseases, causes crop lodging, degrades yield quality and does a lot of damage to the crop during harvesting. Such uneven spread of precipitation during the period of the crop growth is unfavourable for the yield as well as for the formation of its quality (Peltonen-Sainio et al., 2009). While adapting to the changing climate, it is necessary to select appropriate species and varieties of crops, sowing methods and time as well as tillage methods and tools.

Lithuanian climatologists note that dry and hot weather is more often observed in Northern and Western Lithuania, even though the hottest and driest weather has always been observed in Southern as well as South-eastern Lithuania. Lithuania assumes the continental climate features; anomalies of the weather temperature, irrigation become more frequent and the climate changes indicate tendencies of dryness (Bukantis, Rimkus, 2005).

Due to the global warming, transpiration as well as water consumption need for crops can significantly increase, therefore crop cultivation technologies should increase the water – use efficiency, which is indicated by the total yield produced per unit of water used (Richter et al., 2007). It is sated that within the context of the changing climate and reducing resources of energy as well as growing need to diminish the harm for environment, it is considered appropriate to expand the cultivation of legume grain crops in Europe. One of the most appropriate legume crops in regions with the cooler climate is the field pea (Nemecek et al., 2008).

Field pea is a widely adaptable legume crop for soils of various types: from sandy to clayey ones. Field pea is less productive on soils with a hard setting surface or with a clayey, poorly drained subsoil. Canadian scientists state that good field pea yield can be obtained with less water if compared to wheat with a deep root system. Field pea has a great yield potential in semiarid regions with lower precipitation level. Direct drilling is suitable for field pea here (Miller et al., 1996). Literature often indicates that when growing field pea in droughty regions, the yield is significantly determined by the precipitation rate during the period of vegetation as well as the water availability in soil, especially during flowering, pod and seed formation (Nielsen, 2001).

Field pea is heat-stress sensitive during flowering. Such stress can affect the pod and seed formation. Therefore it is recommended to sow earlier for peas to flower while the weather is cooler. Indeterminate species are better adapted to growth under conditions of hot, dry weather in droughty regions, while determinate semi-leaved species of field pea are better adapted to regions with more moisture. Field pea has a relatively shallow root system and high water use efficiency; therefore peas are treated as a good rotational crop in the regions where water conservation is problematic. The field pea need for moisture is similar to that of cereals; however peas tolerate the water-logged soil less (Miller et al., 1996; Nielsen, 2001; Nemecek et al., 2008).

Soil tillage significantly affects the growth of crops as well as their yield within the changing soil structure and moisture during the period of vegetation. During the droughty seasons the greatest effect is exerted by the soil moisture. Soil properties and environment have an influence on the rate of water movement in gaseous and liquid forms into soil and out of soil. It is often stressed that the sustainable soil tillage increases the availability of water for crops. However, it does not always determine better emergence of crops as well as early emergence. Due to the reduced tillage and the increased soil compaction as well as hardness, crops can form more shallow roots and take less water supplies in total soil profile as well as suffer from recurrent droughts under the conditions of the changing climate (Hakansson et al., 2002; Holland, 2004; Atkinson et al., 2007; Tausojamoji žemdirbystė..., 2008).

Changes of the soil properties, depending on tillage, are determined by the soil type, implements for tillage, tillage depth, and soil state, especially moisture during tillage, and climate conditions. The variability of tillage effect on crop emergence, growth and yield is greatly determined by the moisture reserves and their distribution in soil as well as the temperature. Application of the ploughless tillage can lessen the moisture evaporation rate, because the roughness of soil surface is reduced if compared to the conventional ploughing (Holland, 2004; Tausojamoji žemdirbystė..., 2008; Romaneckas et al., 2009; Feiza et al., 2010).

The moisture evaporation rate also lessens with the plant residues left in soil; the water filtration is improved. The soil bulk density and other properties can significantly affect the growth of crops' roots as well as possibilities for using the moisture reserves. Together with the search and development of the rational reduced tillage systems, the soil state, appropriate for the growth of crops and environment protection is to be attained by applying minimal amount of energy, time and investments. Sustainable tillage in droughty world regions is primarily applied as the aid for the soil protection from erosion and compaction, to maintain the moisture and to reduce production costs. Together with increasing number of extreme floods and droughts in Europe, linked with the changing climate, the search for sustainable soil tillage is connected with strive to reduce the harm of the extreme climate changes (Holland, 2004; Kovač et al., 2005).

Seedbed preparation, especially in clayey soils is an important factor for the good emergence of crops as well as for their growing and development. Spring crops emerge poorly in clay and clay loam during dry springs, because the prepared seedbed is coarse and dries out rapidly (Hakansson et al., 2002; Atkinson et al., 2007; Nugis et al., 2009).

Appropriate seedbed must have the protective layer for the moisture evaporation and it must also ensure good emergence of crops under drought conditions (Hakansson et al., 2011 b). Large seeds require more time for emergence, because they need more water to initiate germination. Small seeds emerge more rapidly if planted shallowly, while large – deeply (Hakansson et al., 2011 a). During the cultivation of field pea, it is recommended to avoid the intensive soil tillage in spring in order to protect the seedbed from drying out, because seeds of peas require higher moisture level than those of cereal grains. Emergence of field pea normally takes 10–14 days and the blossoming starts in 40–50 days from sowing (Miller et al., 1996; Nielsen, 2001).

Crops, cultivated under extreme conditions, require the constant source of nutrients; the soil should be as little as possible contaminated with plant pathogens. Solution for this and many other problems can be found by cultivating cover crops for green manure (Cherr et al., 2006).

Reduced clayey soil tillage systems for field pea growing have not been sufficiently investigated in Lithuania. The objective of this study was to determine the effects of reduced tillage as well as its combinations with supplementary agronomic practices – incorporation of lime sludge, introducing cover crop for green manure and mulch on improving soil physical conditions, emergence, growth and development of field pea (*Pisum sativum* L.) crop. Our research hypothesis was based on the concept, that determinate semi-leaved field pea is a crop sensitive to the reduction of tillage intensity on clay loam soil under drought conditions in North Lithuania and requires appropriate selection of tillage methods to improve crop emergence and minimize yield losses.

Materials and methods

Soil and site description. During the period 2008–2010, research was carried out at the Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry 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). Topsoil characteristics were as follows: 27% clay, 50% silt, 23% sand, organic C – 1.28% and pH_{KCL} – 6.6. During the last 40 years, the annual means of temperature and total amount of precipitation were 6.1ºC and 547.4 mm.

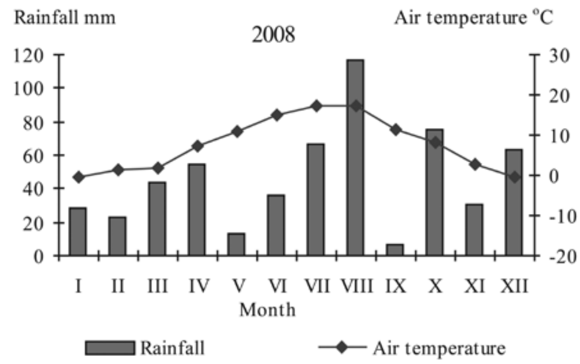
Experimental design and parameters. The effects of conventional ploughing and reduced ploughless tillage as well the combinations of ploughless tillage with practices for soil improvement on field pea emergence, development and yield were investigated following the experimental design: 1) deep (20–23 cm) mouldboard ploughing, 2) shallow (15–17 cm) mouldboard ploughing, 3) ploughless tillage at 10–12 cm depth, 4) ploughless tillage at 10–12 cm depth with lime sludge incorporation 5) ploughless tillage at 10–12 cm depth with cover crop for green manure, 6) cover crop for mulch without autumn soil tillage. 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 2.3 m was harvested and field pea yield was estimated.

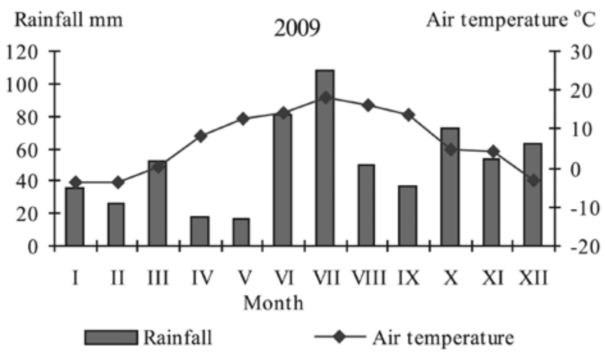
General conditions of the experiment. The pre-crop (spring barley) straw was chopped during harvesting and incorporated into the soil at 6–8 cm depth during stubble cultivation by using a combined stubble cultivator, equipped with sweeps, discs and roller. Cover crop was the mixture of white mustard (*Sinapis alba* L.) cv. 'Braco' (10 kg seed ha^{-1}) and oilseed radish (*Raphanus sativus* L.) cv. 'Rufus' (13 kg seed ha^{-1}). Cover crop was sown after stubble cultivation and application of pre-sowing tillage. Deep (20–23 cm, treatment 1) and shallow (15–17 cm, treatment 2) ploughing was performed with a mouldboard plough, ploughless tillage (treatments 3 and 4) by a combined stubble cultivator. Lime sludge (7.0 t ha^{-1}) was incorporated into the soil at 10–12 cm depth during ploughless tillage operation in autumn (treatment 4). Cover crop for green manure (treatment 5) was chopped by a chopper and incorporated into the soil by a disk harrow into the depth of 8–10 cm late in autumn. Cover crop for winter mulch (treatment 6) was left without any tillage in autumn and its residues covered the soil. Determinate semi-leaved field pea (*Pisum sativum* L. (Partim)) cv. 'Tinker' was grown, sowing 1.2 million seed ha^{-1} by a wedge-shaped coulter drill. Crop fertilization – $N_{30}P_{90}K_{60}$. The herbicides with selective mode of action were applied in the 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 480 g a.i. l^{-1}).

Meteorological conditions. Post-harvest period in 2007 did not differ from the long-term average according to precipitation rate and air temperature (Table 1). In 2008, meteorological conditions were characterised by the warmer winter, wet spring and very dry first half and end of summer (Fig. 1). Drought negatively affected emergence of field pea. The period of November 2008 – April 2009 was 1.8°C degrees warmer than usual, but it was wet. High precipitation was observed in December and March (63.1 and 51.7 mm, respectively). Extremely dry April and May in 2009 determined poor emergence and development of field pea; however June and July were very wet. The period after harvesting was favourable for cover crop, but the drought period started in September. In April 2010, the precipitation was lower than annual average. High precipitation in May improved growing conditions for field pea. The summer in 2010 was wet and extremely hot. Duration of droughty post-sowing period: in 2008 – 18 days, in 2009 – 20 days, in 2010 – 10 days.

Table 1. The amount of rainfall and mean air temperature during long-term (30 years) period (data from Joniškėlis Experimental Station's meteorological site)

Parameters	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Temperature ºC	−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





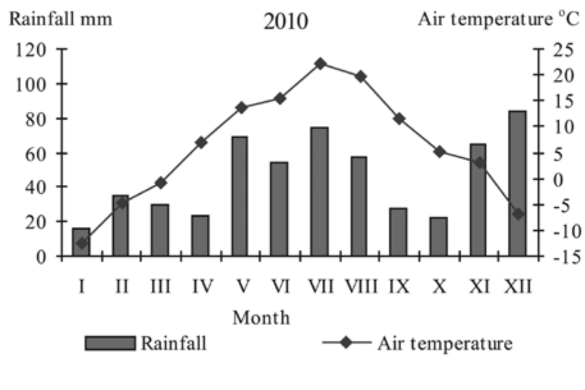


Figure 1. The amount of precipitation and mean air temperature during the study period (data from Joniškėlis Experimental Station's meteorological site)

Experimental methods and assessments. The following assessments were made every year: 1) soil water content (weighing method) directly after sowing of field pea and after crop emergence (BBCH 13–15) at 0–5, 5–15 and 15–25 cm depths; 2) indicators of seedbed (0–5 cm) structure (fractions of soil aggregates) directly after sowing according to the method, described by Hakansson et al. (2002). Seedbed structural coefficient (C_{st}) for estimation of integrated importance of all fractions on seedbed quality was calculated in the following way: $C_{st} = A_2/(A_1 + A_3)$, where A_1 – amount of structural aggregates <2 mm, % (v/v); A_2 – amount of structural aggregates 2–5 mm, % (v/v); A_3 – amount of structural aggregates >5 mm, % (v/v). Field pea seedlings were counted periodically every three days after the beginning of emergence until the full emergence; pea plants were also counted before harvesting. Measurements were done at randomly selected 4 registration sites of 0.25 m^2 of each plot. Germination rate coefficient (C_{ge}) for estimation of seed germination rate was calculated in the following way: $C_{ge} = (D_{S1}/l_1 + D_{S2}/l_2 + \ldots + D_{Sn}/l_n)/N$, where $D_{S1,} D_{S2} \ldots D_{Sn}$ – number of seedlings, $l_1, l_2, \ldots l_n$ – period of days from the date of field pea sowing till the final counting of seedlings, N – number of seedling counts. The data of field pea grain yield was adjusted to 15.0% (w/w) standard moisture. The experimental data were processed by the analysis of variance and correlation-regression analysis methods using the software *ANOVA* and *STAT-ENG*. The symbols used in the article * and ** denote statistically significant at 95% and 99% probability level.

Results and discussion

Large seeds of field pea need more water for emergence than those of cereal grains. In spite of the deeper sowing depth (approximately 5.0 cm) required for field pea than the one required for spring cereals, it is important to preserve the moisture of the upper seedbed layer after the pre-sowing soil tillage. The tilled upper seedbed layer in clayey soils loses the water rapidly and the seedbed has a water content below the plant wilting point, when dry weather occurs after spring sowing. The plant wilting water content in the clay loam soil of research site is to be considered 10.0% (w/w) (Tausojamoji žemdirbystė..., 2008) In our study, the soil water content depended on tillage systems used, year conditions and depth of soil layer. Soil water content in seedbed layer (0–5 cm) directly after the sowing of field pea ranged from 7% to 11% (w/w) during all 3-year study period (Table 2). Therefore the seedbed had water content below the wilting point more frequently and critical conditions for the emergence of crop were formed. This agrees with what was reported by Hakansson et al. (2011 b) that soils, containing more than 25% of clay, dry rapidly after the pre-sowing tillage in the depth of 3 cm below the plant wilting point; however in light soils the moisture content, available for crops usually remains up to the soil surface. In the treatment combining ploughless tillage with lime sludge, the soil water content in seedbed layer (0–5 cm) after sowing of field pea was by 3.46 fold significantly higher in 2009 and by 1.4–3.4 fold higher in 2010 in all treatments of the ploughless tillage and winter mulch without tillage compared to deep ploughing.

The soil water in soil layers under the seedbed is the main reserve of moisture for the good emergence of crops during dry post-sowing periods. Swedish researchers suggest that good emergence of crops requires the moisture content in soil under the seeds, which is 5% (w/w) higher than the moisture of plant wilting (Hakansson et al., 2011 b). Unloosened dense soil under the seedbed layer ensures capillary rise of water up to the seed and results in good seed germination in the absence of rainfall. However, not all seeds fall on the unloosened and moist soil layer during sowing. Individual year conditions during the study had no significant effect on soil water content in deeper (5–15 and 15–25 cm) soil layers directly after field pea sowing (Table 2). According to the average data of 2008–2010, we defined significantly by 1.89 fold highest soil water content at 5–15 cm depth in ploughless tillage system with cover crop for green manure compared to deep ploughing. Tillage intensity had no significant influence on soil water content at 15–25 cm depth directly after field pea sowing. Both soil layers (5–15 and 15–25 cm) below the seedbed retained more moisture than the seedbed (0–5 cm) layer directly after field pea sowing in all tillage systems investigated.

Table 2. Soil water content % (w/w) directly after field pea sowing under different tillage in 2008–2010

Tillage	Depth cm	Year			
		2008	2009	2010	average
Deep ploughing	0–5	8.05	7.91	7.62	7.86
	5–15	18.40	16.42	15.88	16.90
	15–25	19.73	18.35	18.05	18.71
Shallow ploughing	0–5	10.94	9.97	8.60	9.84
	5–15	19.44	17.31	17.22	17.99
	15–25	20.80	18.10	17.97	18.96
Ploughless tillage	0–5	7.64	9.24	9.50	8.79
	5–15	18.28	17.11	16.65	17.35
	15–25	18.06	17.56	17.34	17.65
Ploughless tillage + lime sludge	0–5	8.09	11.37	9.03	9.50
	5–15	18.36	16.64	16.34	17.11
	15–25	19.55	17.34	17.14	18.01
Ploughless tillage + green manure	0–5	7.13	8.86	9.57	8.52
	5–15	18.63	16.97	16.84	18.79
	15–25	18.54	18.64	17.31	18.16
Winter mulch without tillage	0–5	7.18	9.11	11.00	9.10
	5–15	18.32	16.78	16.93	17.34
	15–25	19.61	17.43	17.03	18.02
LSD_{05}	0–5	3.477	2.118	1.320	2.471
	5–15	1.379	1.099	0.875	1.137
	15–25	2.304	0.913	0.674	1.483
Interaction of treatment and year F-act.: 0–5 cm – 2.53*, 5–15 cm – 0.41, 15–25 cm – 1.37					

* – $P < 0.05$ level of probability

Seedbed layer (0–5 cm) after field pea emergence was very dry in droughty year 2008 and 2009 (post-sowing periods without rainfall, 18 and 20 days, respectively) and had a water content below the wilting point, while in year the 2010 with duration of post-sowing period without rainfall for only 10 days, soil water content was favourable for field pea growing (Table 3). Individual year conditions of our study affected soil water content after the emergence of field pea only at 5–15 cm depth. Due to the mulch, left over the winter without tillage in autumn, the soil water content at 5–15 cm depth in droughty year 2008 was by 1.59 fold significantly lower compared to deep ploughing. According to the average data of 2008–2010, application of winter mulch without tillage in autumn significantly decreased the soil water content after field pea emergence by 0.87 fold at 15–25 cm depth compared to deep ploughing.

Table 3. Soil water content % (w/w) after field pea emergence under different tillage in 2008–2010

Tillage	Depth cm	Year			
		2008	2009	2010	average
Deep ploughing	0–5	5.36	7.47	16.35	9.73
	5–15	16.52	15.84	16.44	16.27
	15–25	17.73	17.69	16.19	17.20
Shallow ploughing	0–5	5.09	6.79	16.88	9.59
	5–15	15.90	15.91	16.85	16.22
	15–25	16.95	17.61	16.33	16.96
Ploughless tillage	0–5	5.74	7.80	18.10	10.55
	5–15	15.73	15.22	16.24	15.73
	15–25	16.83	16.78	16.28	16.63
Ploughless tillage + lime sludge	0–5	5.69	8.14	17.16	10.33
	5–15	15.33	15.52	16.11	15.65
	15–25	16.46	16.90	16.42	16.59
Ploughless tillage + green manure	0–5	6.17	7.25	17.79	10.40
	5–15	15.90	16.27	16.94	16.37
	15–25	16.82	17.26	16.63	16.90
Winter mulch without tillage	0–5	6.10	7.16	17.40	10.22
	5–15	14.93	15.50	15.72	15.38
	15–25	16.34	16.80	15.86	16.33
LSD_{05}	0–5	1.189	1.360	0.650	1.108
	5–15	1.269	0.824	0.787	0.985
	15–25	0.820	0.748	0.649	0.742
Interaction of treatment and year F-act.: 0–5 cm – 1.85, 5–15 cm – 2.29*, 15–25 cm – 1.20					

* – $P < 0.05$ level of probability

Our data partly corresponds to the findings published by other researchers concerning the influence of reduced and no-tillage on soil moisture changes. According to the results of the trials, carried out in Central Lithuania on sandy loam and loam soils, no-tillage and direct drilling caused greater soil water content after crop sowing in the upper 0–5 and 5–10 cm layers, while this index in deeper layers was essentially lower as compared to both conventional and reduced tillage (Feiziene et al., 2008). Romaneckas et al. (2009) reported that reduction of autumn tillage intensity on a silty loam increased the soil water content before pre-sowing tillage in spring and after sowing in the soil upper layer (0–10 cm), while tillage intensity had no significant influence on soil water content in deeper (10–20 cm) layer. Research, performed in West Lithuania's sandy loam soils shows that shallow ploughless tillage conserves soil moisture and can lead to better crop germination in droughty spring (Čiuberkis et al., 2010). Due to the application of the sustainable tillage, part of soil surface remains covered with plant residues, therefore the runoff of water is reduced and the infiltration rate to the soil is increased; moreover, the evaporation is reduced as well (Stenberg et al., 2000; Holland, 2004; Richter et al., 2007). Researches, carried out in Slovakia in medium textured soil indicated that more moisture was preserved after the conventional ploughing, compared to ploughless tillage or sowing without tillage (Kovač et al., 2005). On the contrary, studies performed in sandy loam soils in Poland indicate that application of the reduced tillage and direct drilling led to the higher moisture content preserved than in the ploughed soil (Malecka et al., 2009).

In generally, soil moisture changes due to tillage are related to several things, including soil type, type of tillage equipment, tillage depth, soil conditions at the time of tillage and climatic conditions (Holland, 2004; Kovač et al., 2005; Atkinson et al., 2007; Feiza et al., 2010). The site specific soil properties can lead to significant changes of soil water movement and its stories. In clayey soils with predominant silty fraction capillary water rises quickly and goes up pretty high (Tausojamoji žemdirbystė…, 2008). Silt fraction is the dominant in soil of our research site and accounts for 50%, while clay and sand fractions for 27% and 23%, respectively. Consequently, deeper silty clay loam soil layers unloosened in autumn may dry out more quickly and more than loosened ones. While the higher moisture preservation capacity remains in loosened layers of clayey soil with disturbed capillaries.

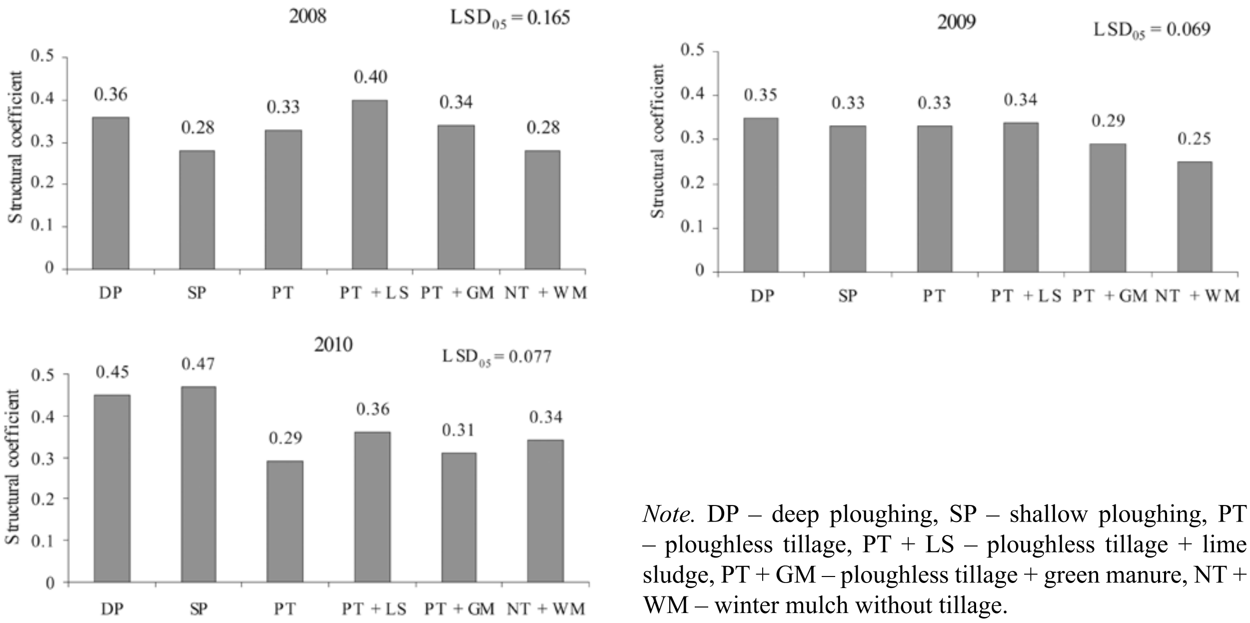
The seedbed structure is important for achieving good soil-seed contact as well as using the moisture reserves for the emergence of crops, especially when the seeds were not incorporated or could not be incorporated into the deeper unloosened soil layers. According to Swedish researchers, soil aggregates of 2–5 mm are considered to be the most appropriate in the seedbed (Hakansson et al., 2002). Individual year conditions of our study affected the seedbed structure (Table 4). The portion of 2–5 mm soil aggregate fraction was significantly lower compared to deep ploughing: in 2008 – under shallow ploughing, ploughless tillage and winter mulch without tillage; in 2009 – under winter mulch without tillage; in 2010 – under ploughless tillage, ploughless tillage + lime sludge, ploughless tillage + green manure and winter mulch without tillage systems.

The portion of soil aggregates >5 mm, which predetermines seedbed cloddiness, was significantly higher: in 2008 – in shallow ploughing and mulch without tillage systems; in 2009 — in ploughless tillage + green manure and winter mulch without tillage; in 2010 – in ploughless tillage and ploughless tillage + green manure. The content of dusty fraction (<2 mm) was significantly lower: in 2008 – under winter mulch without tillage; in 2009 – in ploughless tillage + green manure and winter mulch without tillage, however in 2009 this index was significantly higher under application of ploughless tillage + lime sludge compared to deep ploughing. Assessing the effect of tillage on the structure of seedbed, prepared for field pea according to the structural coefficient, as the integrated indicator of the importance of all fractions, it is possible to state that the seedbed structure was significantly worse under winter mulch without tillage compared to deep ploughing in 2009 and 2010, under ploughless tillage, ploughless tillage in combination with lime sludge and ploughless tillage with green manure – in 2010 (Fig. 2).

Table 4. Fractions of soil aggregates in field pea seedbed (0–5 cm layer) under different tillage in 2008–2010

Tillage	Soil aggregates % (v/v)		
	>5 mm	2–5 mm	<2 mm
	2008		
Deep ploughing	40.5	30.0	29.5
Shallow ploughing	51.4	22.0	26.6
Ploughless tillage	48.8	24.0	27.3
Ploughless tillage + lime sludge	43.4	29.3	27.4
Ploughless tillage + green manure	48.3	25.6	26.1
Winter mulch without tillage	58.2	21.9	19.9
LSD_{05}	8.79	5.46	4.70
	2009		
Deep ploughing	51.6	26.1	22.3
Shallow ploughing	52.5	24.8	22.7
Ploughless tillage	55.1	24.7	20.2
Ploughless tillage + lime sludge	47.7	25.4	26.9
Ploughless tillage + green manure	63.0	22.5	14.5
Winter mulch without tillage	67.0	19.8	13.2
LSD_{05}	5.67	3.98	3.39
	2010		
Deep ploughing	46.7	31.2	22.1
Shallow ploughing	45.6	31.8	22.5
Ploughless tillage	56.0	22.4	21.6
Ploughless tillage + lime sludge	50.2	26.5	23.3
Ploughless tillage + green manure	56.9	23.6	19.5
Winter mulch without tillage	52.8	25.5	21.8
LSD_{05}	7.22	3.77	4.76
Interaction of treatment and year F-act.: >5 mm – 2.33*, 2–5 mm – 2.96*, <2 mm – 4.65**			

* – $P < 0.05$ level of probability, ** – $P < 0.01$ level of probability

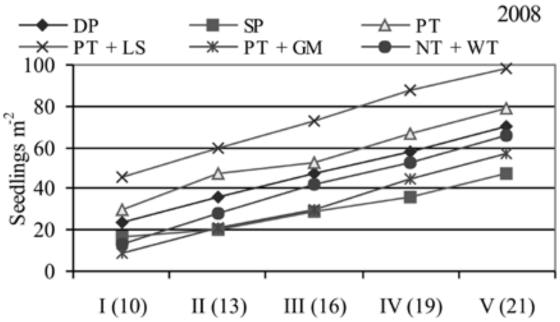


Note. DP – deep ploughing, SP – shallow ploughing, PT – ploughless tillage, PT + LS – ploughless tillage + lime sludge, PT + GM – ploughless tillage + green manure, NT + WM – winter mulch without tillage.

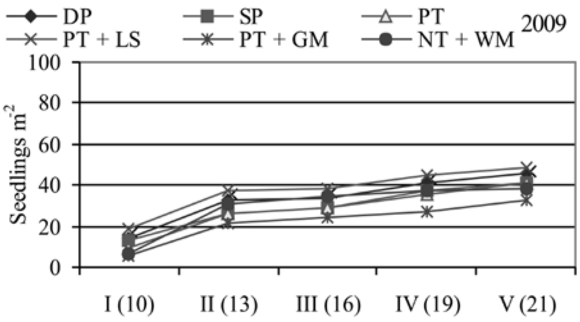
Figure 2. Structural coefficient of field pea seedbed (0–5 cm layer) under different tillage in 2008–2010

During the soil tillage, when there is an appropriate moisture level in it, the most favourable structure of the tilled layer is formed, i.e. with many small aggregates and minority of clod; the specific surface area of aggregates is the highest. Our data confirms the concept, that only such structure ensures good contact between seeds and soil as well as appropriate conditions to use soil water for the emergence of crops (Dexter, Birkas, 2004). It is important that during droughty period seeds in seedbeds are covered with aggregates, 50% of which are smaller than 5 mm (Hakansson et al., 2011 b).

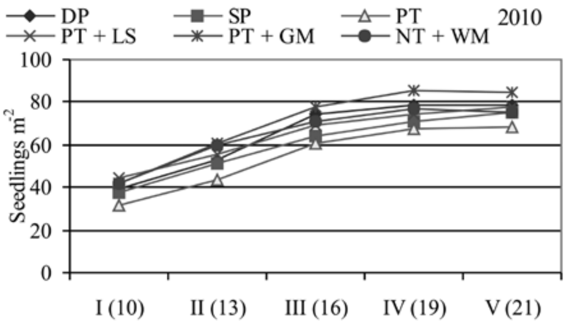
With the lasting droughty post-sowing periods in 2008 and 2009, field pea demonstrated the best emergence in our study after the ploughless tillage with the incorporation of the lime sludge (Fig. 3). The worst emergence of peas was observed during droughty years as was indicated by dynamics of their emergence (Fig. 3) and by the calculated coefficient of germination intensity (Table 5) under the shallow ploughing in 2008 and under the ploughless tillage with incorporation of the green manure in 2009. With the lasting droughty period (in 2009) the field pea crop density after the emergence was only 33–49 seedlings m^{-2} and when the droughty period after sowing was short (in 2010), field pea emergence and its rate were not significantly dependent upon the tillage.



LSD$_{05}$: I = 8.53, II = 10.38, III = 10.43, IV = 15.71, V = 23.05



LSD$_{05}$: I = 6.63, II = 13.02, III = 12.44, IV = 13.62, V = 12.93



LSD$_{05}$: I = 10.97, II = 10.30, III = 13.55, IV = 12.16, V = 13.51

Notes. I (10) … V (21) – measurements (days from sowing); DP – deep ploughing, SP – shallow ploughing, PT – ploughless tillage, PT + LS – ploughless tillage + lime sludge, PT + GM – ploughless tillage + green manure, NT + WM – winter mulch without tillage.

Figure 3. Changes in field pea crop density during emergence period under different tillage in 2008–2010

Table 5. Intensity of field pea germination under different tillage in 2008–2010

Tillage	Year		
	2008	2009	2010
	Coefficient of germination intensity		
Deep ploughing	2.85	2.07	4.07
Shallow ploughing	1.80	1.80	3.78
Ploughless tillage	3.40	1.70	3.39
Ploughless tillage + lime sludge	4.56	2.34	4.09
Ploughless tillage + green manure	1.85	1.33	4.42
Winter mulch without tillage	2.36	1.98	4.13
LSD$_{05}$	0.647	0.715	0.706

In droughty year 2008, strong direct linear correlation was established between the field pea germination intensity and the amount of rainfall during one month after sowing ($r = 0.75$, $y = 1.94 + 0.03x$, $P < 0.01$), also medium strong correlation was determined between the field pea crop density after emergence and amount of rainfall during one month after sowing ($r = 0.57$, $y = 50.04 + 0.44x$, $P < 0.05$).

Soil physical state, formed by the tillage and affected by the environmental factors, determines the emergence of crops and their further growth, development and finally – the yield. Such effect was mostly significant during the droughty years of our investigations. In the treatment combining ploughless tillage with incorporation of the lime sludge, the field pea crop density in 2008, before harvesting was 45.0% higher compared to the deep ploughing treatment (Table 6).

Droughty periods in 2009 determined that the field pea crop before harvesting was very thin – 42–49 plants m^{-2}. During the wetter year 2010, denser field pea crop (61–75 plants m^{-2}) was observed until harvesting, regardless of the tillage method applied.

Table 6. Field pea crop density before harvesting under different tillage in 2008–2010

Tillage	Year		
	2008	2009	2010
	Number of plants m^{-2}		
Deep ploughing	55.5	48.5	66.3
Shallow ploughing	43.0	46.5	71.5
Ploughless tillage	66.5	43.8	61.3
Ploughless tillage + lime sludge	80.5	43.5	75.3
Ploughless tillage + green manure	52.0	42.3	71.3
Winter mulch without tillage	48.0	43.5	67.5
LSD_{05}	17.08	9.97	11.27
Interaction of treatment and year F-act. 3.68**			

** – $P < 0.01$ level of probability

In thinner crop (in 2008 and 2009), biomass per field pea plant was higher if compared to the denser crop (2010) (Table 7). Individual year conditions during the study period had no significant effect on field pea above ground biomass before harvesting. According to the average data of 2008–2010, we observed significantly lower (by 24.0%) field pea above ground biomass under winter mulch without tillage than in deep ploughed soil. Decrease of field pea above ground biomass due to the most reduced tillage of clay loam, i.e. without applying tillage in autumn but leaving the cover crop for mulch in winter, indicates that conditions for the development of field pea in droughty as well as in moist years were the least favourable if compared to any other applied tillage system. The spread of weed was observed together with lasting droughty periods in thin field pea crop (Velykis, Satkus, 2010), the competition of which also had an effect on the development of peas.

Table 7. Field pea above ground biomass before harvesting under different tillage in 2008–2010

Tillage	Year			
	2008	2009	2010	average
	Dry mass per plant g			
Deep ploughing	18.23	15.64	12.21	15.36
Shallow ploughing	17.66	15.68	11.30	14.88
Ploughless tillage	18.48	14.22	11.76	14.82
Ploughless tillage + lime sludge	16.67	15.40	11.86	14.64
Ploughless tillage + green manure	16.85	12.40	10.79	13.35
Winter mulch without tillage	12.21	12.77	10.02	11.67
LSD_{05}	3.639	2.526	1.625	2.724
Interaction of treatment and year F-act. 1.20				

In Poland, researches in sandy loam indicated that biomass of field pea in early growing stages (BBCH 32–33) after the conventional tillage was higher than the reduced tillage or the direct drilling were applied; though later stages before harvesting did not exhibit such effect (Malecka et al., 2009).

Individual year conditions of our research affected on field pea crop yield. Contrasting growth conditions determined that application of the ploughless tillage together with incorporation of lime sludge led to 42.0% higher field pea grain yield in 2008 than in deep ploughed soil (Table 8). However, if mulch was left for winter without tillage in autumn, field pea grain yield in 2008 was 56.0% lower as compared to the deep ploughing. Under the conditions, mostly unfavourable for the emergence and growth of field pea, in 2009, when mulch was left without autumn tillage, the ploughless tillage with incorporation of green manure, as well as such tillage without any supplementary agronomic practices was applied; the grain yield was lower by 31.6%, 19.9% and 19.4%, respectively as compared to deep ploughed plots. Even during 2010, favourable for field pea growing, within the left cover crop mulch without applied tillage for winter as well as the ploughless tillage with incorporated green manure the field pea yield was lower by 24.0% and 12.9%, respectively than in deep ploughing treatment. Ploughless tillage with incorporation of green manure was applied at the end of October, i.e. later than in other research plots with the aim of producing more biomass of the cover crop for the manure.

A strong direct linear correlation was established between field pea grain yield and amount of rainfall during one month after sowing in 2008 ($r = 0.91$, $y = 1.40 + 0.039x$, $P < 0.01$), as well as a medium strong correlation was determined between the field pea grain yield and crop density after emergence ($r = 0.55$, $y = 35.90 +$

Table 8. Grain yield of field pea t ha^{-1} under different tillage in 2008–2010

Tillage	Year		
	2008	2009	2010
Deep ploughing	1.93	2.06	4.12
Shallow ploughing	1.80	2.03	4.05
Ploughless tillage	2.22	1.66	3.89
Ploughless tillage + lime sludge	2.74	2.10	4.12
Ploughless tillage + green manure	1.74	1.65	3.59
Winter mulch without tillage	0.85	1.41	3.13
LSD_{05}	0.404	0.335	0.343
Interaction of treatment and year F-act. 3.11**			

** – $P < 0.01$ level of probability

17.70x, $P < 0.01$). In 2009, the year unfavourable for field pea emergence and growth a strong direct linear correlation was established between field pea grain yield and structural coefficient of seedbed ($r = 0.88$, y = 0.10 + 0.12x, $P < 0.05$).

A similar observation about worse field pea growth under reduced and no-tillage was made in Central Lithuania on sandy loam soils by Baigys et al. (2006), who indicated that field pea grain yield amounted to 3.38 t ha^{-1} under the deep ploughing and was by 34.7% higher compared to shallow ploughing, and by 11.9% higher than in direct-drilled treatment (Baigys et al., 2006). No-tillage in Central Lithuania's soils caused lower crop productivity by 7–12% during a 6-year application as compared to conventional deep ploughing (Feiziene et al., 2008). Čiuberkis et al. (2010) reported that under West Lithuania's climatic conditions conventional deep ploughing on sandy loam soil was more favourable for growing spring crops compared to shallow ploughless tillage. Our data are also in line with research, carried out in Sweden and shows that combination of the shallow tillage with incorporation of lime materials into the silty clay loam soil of a poor structure led to the increased yield of crops (Stenberg et al., 2000). According to investigations, carried out in Norway, the crop yield after the ploughless tillage in clay loam soil was more dependent upon the summer precipitation rate as compared to conventional ploughing (Riley et al., 2009). Deibert and Utter (2004) have reported that in the USA, in clayey soil, the tillage methods did not always affect the field pea yield, though the reduced tillage with application of chisel and disc type implements was often more favourable than conventional ploughing as well as cultivation without tillage. Conversely, Estonian researchers found that the yield of field pea, cultivated in the organic crop rotation was lower due to the reduced ploughless tillage as compared to the conventional ploughing (Sepp et al., 2009). Consequently, cultivation of field pea in clayey soils under drought conditions requires appropriate selection of tillage methods and supplementary agronomic practices to improve crop emergence and minimize yield losses.

Conclusions

1. Soil water content depended on the tillage systems used, year conditions and soil depth. Ploughless tillage in combination with lime sludge incorporation significantly increased the soil water content in seedbed layer (0–5 cm) directly after field pea sowing in 2009 as compared to deep ploughing. All ploughless tillage systems (ploughless tillage, ploughless tillage with lime sludge incorporation, ploughless tillage with cover crop incorporation for green manure) and cover crop winter mulch without tillage in autumn had such an effect in 2010. Application of ploughless tillage with green manure incorporation significantly increased the soil water content directly after field pea sowing at 5–15 cm depth compared to deep ploughing.

Seedbed remained very dry with soil water content below the wilting point till field pea emergence in droughty years 2008 and 2009. Application of winter mulch without tillage in autumn significantly reduced the soil water content at 5–15 cm depth after field pea emergence in 2008 and at 15–25 cm depth in all the years of study compared to deeply ploughed soil. Consequently, unloosened in the autumn clay loam soil layers with predominant silty fractions and rapid capillary water movement may dry out more quickly in spring than loosened ones.

2. The reduction of tillage intensity had negative influence on seedbed structure. Application of winter mulch without tillage in autumn mostly causes deterioration of soil structure (decrease of 2–5 mm soil aggregates and increase of >5 mm soil aggregates, predetermining cloddiness) in the seedbed layer.

3. Within the prolonged droughty post-sowing periods (18 and 20 days, respectively in 2008 and 2009), field pea demonstrated the best emergence after the ploughless tillage had been applied together with incorporation of lime sludge. The lowest field pea germination rate under droughty conditions was registered due to shallow ploughing in 2008 and ploughless tillage with green manure incorporation in 2009. In droughty year 2008, field pea germination intensity ($r = 0.75$, $P < 0.01$) and crop density ($r = 0.57$, $P < 0.01$) were influenced by the amount of rainfall during one month after sowing.

4. Application of ploughless tillage in combination with lime sludge incorporation significantly increased the field pea grain yield by 42.0% in 2008 as compared to deep ploughing. Winter mulch without tillage in autumn resulted in significantly lower field pea yield by 56.0%, 31.6%, and 24.0%, respectively in 2008, 2009 and 2010; ploughless tillage with green manure incorporation by 19.9% and 12.9%, respectively in 2009 and 2010; ploughless tillage with no supplementary practices by 19.4% in 2009 as compared to deep ploughing. In droughty year 2008, field pea grain yield was influenced by the amount of rainfall during one month after sowing ($r = 0.91$, $P < 0.01$) and by the crop density after emergence ($r = 0.55$, $P < 0.01$). Soil structure (structural coefficient) in the seedbed strongly influenced the grain yield ($r = 0.88$, $P < 0.05$) in the year 2009, which was unfavourable for field pea emergence.

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References

Atkinson B. S., Sparkes D. L., Mooney S. J. Using selected soil physical properties of seedbeds to predict crop establishment // Soil and Tillage Research. – 2007, vol. 97, iss. 2, p. 218–228

Baigys G., Feiza V., Kutra G., Feizienė D. Physical soil properties and moisture impact on productivity of spring barely and peas after application of different tillage // Vandens ūkio inžinerija. – 2006, No. 3 (6), p. 23–31

Bukantis A., Rimkus E. Climate variability and change in Lithuania // Acta Zoologica. – 2005, vol. 15, No. 2, p. 100–104

Cherr C. M., Scholberg J. M. S., McSorley R. Green manure approaches to crop production: a synthesis // Agronomy Journal. – 2006, vol. 98, iss. 2, p. 302–319

Čiuberkis S., Karčauskienė D., Bernotas S. Climate variations and reduced soil tillage in Western Lithuania (summary) // Vagos. – 2010, vol. 88 (41), p. 14–21 (in Lithuanian)

Deibert E. J., Utter R. A. Field pea growth and nutrient uptake: response to tillage systems and nitrogen fertilizer applications // Communications in Soil Science and Plant Analysis. – 2004, vol. 35, iss. 7–8, p. 1141–1165

Dexter A. R., Birkas M. Prediction of soil structures produced by tillage // Soil Tillage Research. – 2004, vol. 79, p. 233–238

Feiza V., Feizienė D., Auškalnis A., Kadžienė G. Sustainable tillage: results from long-term field experiments on *Cambisol* // Žemdirbystė=Agriculture. – 2010, vol. 97, No. 2, p. 3–14

Feiziene D., Feiza V., Lazauskas S., Kadziene G. Simanskaite D., Deveikyte I. Long-term tillage and fertilization influence on a *Cambisol* in Lithuania // Dazzi C., Costantini E. (eds). The soils of tomorrow: soils changing in a changing world. Advances in GeoEcology 39. – Reiskirchen, Germany, 2008, p. 605–620

Hakansson I., Arvidsson J., Keller T., Rydberg T. Effects of seedbed properties on crop emergence: 1. Temporal effects of tempera-

ture and sowing depth in seedbeds with favourable properties // Acta Agriculturae Scandinavica, Section B: Soil and Plant Science. – 2011 (a), vol. 61, iss. 5, p. 458–468
Hakansson I., Arvidsson J., Rydberg T. Effects of seedbed properties on crop emergence: 2. Effects of aggregate size, sowing depth and initial water content under dry weather conditions // Acta Agriculturae Scandinavica, Section B: Soil and Plant Science. – 2011 (b), vol. 61, iss. 5, p. 469–479
Hakansson I., Myrbeck A., Etana A. A review of research on seedbed preparation for small grains in Sweden // Soil and Tillage Research. – 2002, vol. 64, iss. 1–2, p. 23–40
Holland J. M. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence // Agriculture, Ecosystems and Environment. – 2004, vol. 103, iss. 1, p. 1–25
Kovač K., Macak M., Švančarkova M. The effect of soil conservation tillage on soil moisture dynamics under single cropping and crop rotation // Plant Soil Environment. – 2005, vol. 51, iss. 3, p. 124–130
Malecka I., Blecharczyk A., Dobrzeniecki T. The productivity and environmental consequences of long-term ploughless tillage systems in field pea // Fragmenta Agronomica. – 2009, vol. 26, No. 3, p. 118–127
Miller P., Brandt S., Campbell C., Zentner R. Alternative crops in wheat country: yield response to available water / Soils and Crops Extension Division. – Saskatoon, Canada, 1996, p. 375–383
Nemecek T., von Richthofen J. S., Dubois G., Casta P., Charles R., Pahl H. Environmental impacts of introducing grain legumes into European crop rotations // European Journal of Agronomy. – 2008, vol. 28, iss. 3, p. 380–393
Nielsen D. C. Production functions for chickpea, field pea and lentil in Central Great Plains // Agronomy Journal. – 2001, vol. 93, p. 563–569
Nugis E., Kuht J., Etana A., Hakansson I. Effects of seedbed characteristics and surface layer hardening on crop emergence and early plant growth // Agronomy Research. – 2009, vol. 7, iss. 2, p. 847–854
Peltonen-Sainio P., Jauhiainen L., Hakala K. Are there indications of climate change induced increases in variability of major field crops in the northernmost European conditions? // Agricultural and Food Science. – 2009, vol. 18, iss. 3–4, p. 206–222
Reidsma P., Ewert F., Lansink A. O., Leemans R. Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses // European Journal of Agronomy. – 2010, vol. 32, p. 91–102
Richter G. M., Lawlor D. W., Latiri K., Acutis M., Qureshi K. Field scale water-use efficiency inherent variability and options for crop selection and management / Rana G. et al. (eds). WEMWD Workshop: how to advance the knowledge on water use efficiency in the Mediterranean region? – Bari, Italy, 2007, p. 93–100
Riley H., Borresen T., Lindemark P. O. Recent yield results and trends over time with conservation tillage on clay loam and silt loam soils in southeast Norway // Acta Agriculturae Scandinavica, Section B: Plant Soil Science. – 2009, vol. 59, iss. 4, p. 362–372
Romaneckas K., Romaneckienė R., Šarauskis E., Pilipavičius V., Sakalauskas A. The effect of conservation primary and zero tillage on soil bulk density, water content, sugar beet growth and weed infestation // Agronomy Research. – 2009, vol. 7, special iss. 1, p. 73–86
Sepp K., Kanger J., Sarekanno M. Influence of soil tillage methods on the weediness and yields of spring wheat, spring barley and field pea in organic crop rotation // Agronomy Research. – 2009, vol. 7, special iss. 1, p. 477–484
Stenberg M., Stenberg B., Rydberg T. Effects of reduced tillage and liming on microbial activity and soil properties in a weakly-structured soil // Agriculture, Ecosystems and Environment. Applied Soil Ecology. – 2000, vol. 14, iss. 2, p. 135–145
Tausojamoji žemdirbystė našiuose dirvožemiuose: monografija / sudaryt. S. Maikštėnienė [Sustainable agriculture on productive soils (summary)]. – Akademija, Kėdainių r., 2008, 328 p. (in Lithuanian)
The European environment – state and outlook 2010: Synthesis. Chapter 2: climate change // European Environment Agency. <http://www.eea.europa.eu/soer/synthesis/synthesis/chapter2.xhtml> [accessed 07 10 2011]
Velykis A., Satkus A. Weed infestation and changes in field pea (*Pisum sativum* L.) yield as affected by reduced tillage of a clay loam soil // Žemdirbystė=Agriculture. – 2010, vol. 97, No. 2, p. 73–82

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Molingų dirvų supaprastinto dirbimo įtaka sėjamajam žirniui (*Pisum sativum* L.)

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Lietuvos agrarinių ir miškų mokslų centro Joniškėlio bandymų stotis

Santrauka

Tyrimai atlikti 2008–2010 m. Lietuvos agrarinių ir miškų mokslų centro Joniškėlio bandymų stotyje. Dirvožemis – giliau karbonatingas giliau glėjiškas sunkaus priemolio rudžemis (RDg4-k2). Tyrimų tikslas – įvertinti supaprastinto (seklaus arimo ir bearimio) žemės dirbimo ir jo derinių su papildomomis dirvožemio gerinimo priemonėmis – kalkių purvo įterpimu, tarpiniais pasėliais (baltųjų garstyčių ir aliejinių ridikų mišiniu) žaliajai trąšai ir mulčiui – įtaką sėjamojo žirnio (*Pisum sativum* L.) dygimui, augimui ir vystymuisi. Tyrimai parodė, kad taikant seklų arimą žirnių dygimas buvo prasčiausias 2008 m. Bearimis žemės dirbimas, kartu įterpiant kalkių purvą, lėmė iš esmės didesnį dirvožemio drėgnį sėklų guoliavietėje (0–5 cm) tuoj po žirnių sėjos 2009 m., geresnį žirnių dygimą ilgiau užtrukus sausringiems posėjiniams laikotarpiams (18 ir 20 dienų 2008 bei 2009 m.) ir didesnį jų grūdų derlių 2008 m., palyginti su giliu arimu. Taikant bearimį žemės dirbimą ir kartu vėlų rudenį įterpiant tarpinių pasėlių biomasę žaliajai trąšai, iš esmės daugiau drėgmės išliko sėklų guoliavietėje tuoj po sėjos 2010 m. ir 5–15 cm gylyje vidutiniškai per visus tyrimų metus. Tačiau sausringais 2009 ir 2010 m. žirniai dygo ir augo prasčiau, o jų derlius buvo mažesnis. Taikant bearimį žemės dirbimą be papildomų priemonių, nustatytas iš esmės didesnis drėgmės kiekis sėklų guoliavietėje tuoj po sėjos 2010 m., tačiau sumažėjo žirnių derlius 2009 m. Paliekant tarpinių pasėlių mulčią žiemai be žemės dirbimo rudenį, sėklų guoliavietė tuoj po sėjos buvo iš esmės drėgnesnė 2010 m. Tačiau po žirnių sudygimo mažiau drėgmės išliko 5–15 cm gylyje 2008 m. ir 15–25 cm gylyje vidutiniškai per visus tyrimų metus, dažnai prastėjo sėklų guoliavietės struktūra, žirniai silpnai augo ir jų derlius visais tyrimų metais buvo mažesnis, palyginti su giliu arimu. Rudenį nepurentų armens sluoksnių didesnį išdžiūvimą galėjo lemti dulkiškiems sunkiems priemoliams būdingas greitas kapiliarinės drėgmės judėjimas. Sausringais 2008 m. žirnių derlių lėmė kritulių kiekis per mėnesį po sėjos, o 2009 m. – sėklų guoliavietės struktūra.

Reikšminiai žodžiai: sunkus priemolis, supaprastintas žemės dirbimas, sėklų guoliavietė, dirvožemio drėgnis, *Pisum sativum*.