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FEASIBILITY OF PLOUGHLESS SOIL TILLAGE APPLICATION ON A SANDY LIGHT LOAMY SOIL

Danutė ŠIMANSKAITĖ

Lithuanian Institute of Agriculture
Akademija, Dotnuva, Kėdainiai district
E-mail: dana@lzi.lt

Abstract

Experiments, conducted during the period 2000-2005 at the Lithuanian Institute of Agriculture, were designed to evaluate the effects of plough and ploughless soil tillage and methods of sowing on an *Endocalcari-Endohypogleyic Cambisol* and to estimate their effects on soil physical properties ad cereal yield. Experiment I was established in 2000 after harvesting of vetch and oats mixture, experiment II was set up in 2001 after peas harvesting. Our experimental evidence suggests that different soil tillage and sowing methods had a significant effect on soil structure, soil bulk density, total and air-filled porosity, soil moisture and yield. In experiment I winter wheat yield in the first year of growing when direct drilled into stubble was almost the same (4.42 t ha^{-1}) as that obtained in the conventional soil tillage treatment (4.36 t ha^{-1}). When winter wheat had been continuously grown for two, three and four years and direct drilled, the yield declined by 27.2 %, 18.3 % and 10.2 %. In experiment II when winter wheat was grown in the cereal crop rotation, the best yields were obtained when sown after peas by a direct drill into tilled soil. The yield of spring barley declined by 14.7 % when sown by a direct drill into minimally tilled soil, compared with conventional tillage; when oats were direct drilled a non-significant yield reduction trend was observed, and when sown into minimally tilled soil the yield was similar (5.77 t ha^{-1}) to that produced in the conventional soil tillage treatment (5.84 t ha^{-1}). When peas were grown, both these simplified tillage methods significantly declined the yield, when peas were direct drilled, the yield declined by 44.0 % and by 21.7 % when drilled into minimally tilled soil by a direct drill.

Key words: conventional and ploughless soil tillage, zero tillage, soil physical properties, yield.

Introduction

Research into reduced autumn soil tillage has been done in many European countries and in the USA. Soil chemical ad physical properties are important factors determining potential soil fertility and crop productivity. While estimating the effects of conventional and minimal soil tillage on soil physical and chemical properties, controversial findings are obtained. This is determined by specific conditions: soil amelioration level, soil texture, weather conditions and crop species grown. Mouldboardless implements exert a negative effect on limnoglacial clay soil properties and on the productivity of agrocenoses /Maikštėnienė, 1997/, whereas on well tamed moraine light loam soils prevailing in Central Lithuania's Lowland replacement of deep soil tillage by shallow tillage or rototilling does not result in a yield reduction and deterioration of soil properties /Šimanskaitė, 1996/. Research findings indicate that simplification of soil tillage, application of direct drilling, caused changes in soil physical properties: increased soil bulk density /Douglass et al., 1980; Pedgeen, 1981/, especially in the first three years of the experiment /Ellis et al., 1982/, and soil hardness /Pollard et al., 1981; Ellis et al., 1982; Hill, Cruse, 1985/. Soil hardness tests conducted on silty loam showed that when soil had been ploughed for ten years, its hardness in the 10 cm depth was 0.5 MPa, and in unploughed soil it was 1.4 MPa /Cannell, 1985/. Research done on a wide range of west European soil types suggests that when reduced (minimal) soil tillage had been used for several successive years the soil aggregate stability in the topsoil was improved more than in ploughed soils /Douglass et al., 1980; Pollard et al., 1981; Boone et al., 1984/. The trials of Stancevičius et al. (2003) conducted during 1997-1999 revealed that in light loam lying on sandy loam, covered by moraine clay Endo-hypogleyi-Eutric Planosol having replaced deep ploughing (23-25 cm) by shallow ploughing (12-14 cm) or by deep or shallow ploughless soil tillage, soil bulk density and moisture did not change significantly at different barley crop growth stages. Our experiments conducted during the period 1975-1981 in Dotnuva on a loamy soil showed that rototilling at the 10-12cm depth reduced moisture content in the 10-20cm soil depth, but the reduction was lower than when applying shallow ploughing at the 10-12cm depth, and in the 0-10cm depth a trend of soil moisture content increasing was observed, which can be explained by an in crease in humus in this layer /Šimanskaitė, 1985/. Minimization of soil tillage promoted humus buildup in the topsoil layer as well as an increase in the content of humic acids in the soil.

The yields of agricultural crops produced using reduced soil tillage are rather controversial. In Poland on light-textured soils during 1978-1980 it was determined that when maize had been sown into an unploughed soil the yield declined by 9 % /Dzienia, Sosnowski, 1989/. In Latvia on heavy loam soils during the period 2001-2002 the application of direct drilling reduced the yield of spring barley and spring barley undersown with red clover and timothy by 27.1 % and 8.3 %, respectively /Ausmane et al., 2004/. In England, the data averaged over eight years suggest that the use of zero tillage – direct drilling resulted in 15 % lower spring barley yield compared with that produced in a ploughed soil /Pedgeen, 1981/. Some literature sources indicate that the use of direct drilling gave the same winter wheat and maize yield as ploughing at a normal depth /Hipps, Hodgson, 1987; Konstantinovich, 1998/. In the USA Hill R. L. (1990) reported that on light-textured soils maize yield was significantly higher in direct drilled treatments. In Lithuania testing of direct drilling into untilled soil was started several years ago on well tamed, fertile light loam soils with a low weed incidence in Dotnuva /Šimanskaitė, 2002; Cesevičius et al., 2005/, Raudondvaris /Germanas, Bakasėnas, 2004; Germanas, 2006; Lukošiūnas, 2004, 2005; Lukošiūnas et al., 2005/ and the Lithuanian University of Agriculture /Šarauskis, Romaneckas, 2002/. The objective of our tests was to study the feasibility of replacement of the conventional (autumn) soil tillage system (stubble breaking and deep ploughing) by up-to-date, more economical, less labour-intensive and less time-consuming soil tillage systems; to evaluate the effects of plough and ploughless soil tillage and methods of sowing and to estimate their effects on soil physical properties and cereal yield.

Experimental materials and methods

Experiments were conducted at the Lithuania Institute of Agriculture (LIA) in Dotnuva during 2000-2005. The soil of the experimental site is sandy light loamy Endocalcari-Endohypogleyic Cambisol, with the following agrochemical characteristics: during the experimental period the soil was medium-rich in phosphorus and potassium (available P_2O_5 and K_2O 141 amounted to 178 and 113-137 mg kg^{-1} soil), pH_{KCl} 6.8-7.3. Experiment I was established in 2000 after harvesting of vetch and oats mixture, experiment II was set up in 2001 after harvesting of peas. The experimental design of experiment I was as follows: treatment 1 (control treatment) – stubble breaking by a plough at the 10-12 cm depth, ploughing by a plough with a ploughlayer's densifier at the 22-25 cm, sowing by a disc drill; treatment 2 – ploughing by a plough with a ploughlayer's densifier at the 20-22 cm depth, sowing by a disc drill; treatment 3 – stubble breaking by a combined stubble breaker SL-4 at the 10-12 cm depth, ploughing by a plough with a ploughlayer's densifier at the 22-25 cm depth, sowing by a disc drill; treatment 4 – stubble breaking by a combined stubble breaker SL-4 at the 10-12 cm depth, ploughing by a plough with a ploughlayer's densifier at the 22-25 cm depth, sowing by a direct drill (stubble drill); treatment 5 – Roundup application on an untilled soil, sowing by a direct drill. Experiment II was conducted observing the following design: 1. Stubble breaking at the 10-12 cm depth, ploughing by a plough with a ploughlayer's densifier at the 22-25 cm, sowing by a disk drill (control treatment). 2. Ploughing shortly before sowing at the 20- 22 cm depth by a plough with a ploughlayer's densifier, sowing by a disk drill. 3. Stubble breaking by a combined stubble breaker at the 10-12 cm depth, ploughing by a plough with a ploughlayer's densifier at the 22-25 cm depth, sowing by a disk drill. 4. Stubble breaking by a combined stubble breaker at the 10-12 cm depth, ploughing by a plough with ploughlayer's densifier at the 22-25 cm depth, sowing by a direct drill. 5. Stubble breaking by a combined stubble breaker at the 10-12 cm depth, sowing by a direct drill. 6. Roundup application on an untilled soil, sowing by a direct drill. In experiments I and II treatments 1, 2, 3 in 2000-2005 were sown by a 3m-wide sowing machine "Saxonia", treatments 4,5,6 were sown by a combined disk Swedish 4m-wide direct drill "Super Rapid Väderstad". In the fifth treatment (experiment I) and in the sixth treatment (experiment II) after preceding crops harvesting stubble was left and the soil was not tilled until sowing, three weeks before sowing the stubble was sprayed with the herbicide Roundup 4 l ha^{-1}. In the third and fourth treatments the stubble was broken by a versatile combined stubble breaker SL-4 at the 10-12 cm depth. The combined stubble breaker was fitted with three types of working parts: in the front wide arrow coulters, behind them a disk row of disk harrow and in the rear rollers. In experiment I the soil of the first, second, third and fourth treatments and in experiment II the soil of the first, second, third, fourth, and fifth treatments was ploughed by a mouldboard plough with semi helical mouldboards with a ploughlayer's densifier hitched with a John Deere tractor (130AE). Prior to soil tillage phosphorus and potassium fertilisers ($P_{90}K_{90}$) were applied. Nitrogen fertilisers N_{30+60} were applied in spring. Before sowing the soil of the plots of the other experimental treatments was cultivated by a Germinator at the 6-8 cm depth. Crop management was performed following the technological requirements set for the crops grown. In experiment I in 2000-2004 winter wheat 'Širvinta' was grown, in 2001-2002 the straw was raked up and removed from the plots, in 2003-2004 the straw was chopped and spread on all experimental plots; in experiment II the tests were done in a cereal crop rotation with the following crop sequence: winter wheat 'Širvinta', spring barley 'Luokė', oats 'Jaugila', peas 'Profi'. In experiment II the straw was chopped and spread on the plots. The field experiments were set up in four replications, the plots were arranged randomly. Crop yield was determined for each experimental plot. Grain yield was adjusted to 15 % moisture content.

Soil and plant analyses were done following the standard methods approved in the LIA's system. Soil samples for physical analyses were collected before the primary (main) soil tillage, after soil tillage, in spring after resumption of vegetation (tillering stage) and after crop harvesting. To estimate the changes in soil physical properties the samples were taken from the ploughlayer's 0-10 cm and 10-20 cm depth before soil tillage, at tillering stage and upon completion of vegetation. To assess the changes in soil structure as affected by soil tillage the samples were taken from the ploughlayer's 0-10 cm and 10-20 cm depth, and soil bulk density was determined every 5 cm. Physical analyses of the soil samples were done using the following methods: structure and its stability in water by Savinov; bulk density by Kachinski 100 cm^3 by cylindrical drill; total and air-filled porosity by calculation method from bulk density, solid phase density and moisture /Vadiunina, Korčagina, 1986/; soil moisture by weight method by drying at a constant +105 ^{o}C temperature. The data of soil physical analyses, weed incidence in the crop stand and yield were processed by the analysis of variance method /Dospechov, 1985/, using computer software /Tarakanovas, Raudonius, 2003/.

Experimental results and discussion

Soil structure and its stability in water. The experimental data suggest that in well-tamed *Endocalcari-Endohypogleyic Cambisol* macrostructure changed due to the soil tillage (Table 1). At the beginning of the rotation (07 08 2001) in experiment I the greatest amount of valuable soil structural aggregates 0.25-5.0 mm in size was found in the direct drilled unploughed soil: 27.4 % in the 0-10 cm layer and 32.8% in the 10-20 cm layer, compared with the conventional soil tillage, their amount was by 2.7 % and 5.6 % higher. The amount of water stable aggregates in various soil tillage systems did not differ significantly, only in unploughed direct drilled soil it tended to increase. In the last year of the crop rotation (Table 2) the content of clods declined in all experimental plots, compared with the first year of the rotation; the amount of valuable aggregates in the direct drilled treatments increased from 27.4 % to 40.6 % in the 0-10cm layer and from 32.8 % to 33.4 % in the 10-20 cm layer. In experiment II (Table 3) in the last year of the crop rotation in the differently tilled treatments the amount of valuable soil aggregates of 0.25-5.00 mm increased, their greatest amount was identified in the treatments ploughed before sowing: 43.5 % in the 0-10 cm layer and 37.1 % in the 10-20 cm layer. The lowest amount of valuable soil aggregates was found in the direct drilled unploughed treatments. The amount of water stable aggregates larger than 0.25 mm in the minimally tilled soil by plougless implements and sown by a direct drill as well as in the soil sown without tillage, significantly increased in the 0-10 cm layer by 13.5 % and 12.0 %, and in the 10-20 cm layer their amount was by 9.6 % and 9.8 % higher compared with conventional soil tillage. In all treatments the amount of aggregates larger than 1 mm was higher compared with conventional soil tillage. These aggregates are very valuable from the agronomic point of view since they maintain soil friability and improve water regime.

Table 1. The effect of different soil tillage and sowing methods on soil structure at the beginning of the crop rotation

1 lentelė. *Įvairių žemės dirbimo ir sėjos būdų įtaka dirvožemio struktūrai rotacijos pradžioje*

Dotnuva, experiment I, 07 08 2001 / *I bandymas*

Treatment *Variantas*	Depth cm *Gylis cm*	Soil structural aggregates % *Dirvožemio struktūriniai agregatai %*			Water stable aggregates % *Vandenyje patvarūs agregatai %*	
		> 5 mm	5.0-0.25 mm	< 0.25 mm	> 0.25mm	> 1 mm
Stubble breaking, ploughing, sowing by a disk drill *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10 10-20	73.4 71.5	25.7 27.2	0.82 1.25	43.7 45.8	6.64 5.90
Ploughing just before sowing, sowing by a disk drill / *Arta prieš pat sėją, sėta diskine sėjamąja*	0-10 10-20	67.0 78.6	32.0 20.1	1.00 1.30	45.7 47.6	6.34 5.64
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku , arta, sėta diskine sėjamąja*	0-10 10-20	67.0 78.4	32.0 19.9	1.00 1.63	45.9 48.8	6.56 6.12
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku , arta, sėta ražienine sėjamąja*	0-10 10-20	66.1 77.5	32.7 20.7	1.12 1.70	45.9 49.3	6.14 6.72
Roundup application on untilled soil, direct drilling *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10 10-20	71.5 66.3	27.4 32.8	1.07 0.90	45.3 48.2	8.32 9.50
LSD_{05} / R_{05}	0-10 10-20				3.70 3.02	2.82 1.61

Table 2. The effect of different soil tillage and sowing methods on soil structure on the end of crop rotation

2 lentelė. *Įvairių žemės dirbimo ir sėjos būdų įtaka dirvožemio struktūrai rotacijos pabaigoje*

Dotnuva, experiment I, 12 08 2004 / *I bandymas*

Treatment *Variantas*	Depth cm *Gylis cm*	Structural aggregates % *Dirvožemio struktūriniai agregatai %*				Water stable aggregates % *Vandenyje patvarūs agregatai %*	
		> 5 mm, incl.	> 10 mm	0.25-5 mm	< 0.25 mm	> 0.25 mm	> 1 mm
Stubble breaking, ploughing, sowing by a disk drill / *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10 10-20	51.3 51.0	28.3 28.4	45.4 41.8	3.18 7.13	41.9 40.3	7.39 6.69
Ploughing just before sowing, sowing by a disk drill */ Arta prieš pat sėją, sėta diskine sėjamąja*	0-10 10-20	45.4 45.7	23.6 22.6	49.1 46.5	5.51 7.69	41.9 48.5	7.58 8.60
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku, arta, sėta diskine sėjamąja*	0-10 10-20	48.7 45.6	27.4 21.6	46.9 46.7	4.32 7.61	42.8 46.0	6.88 8.51
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku, arta, sėta ražienine sėjamąja*	0-10 10-20	48.2 48.7	28.9 26.8	48.0 46.6	3.78 4.67	41.6 44.8	6.74 7.11
Roundup application on untilled soil, direct drilling *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10 10-20	56.0 62.8	29.4 36.7	40.6 33.4	3.25 3.69	46.7 44.1	10.16 10.26
LSD_{05} / R_{05}	0-10 10-20	2.20 8.08	10.00 10.56	9.02 8.85	3.895 2.706	4.46 5.94	3.035 4.330

Table 3. The effect of different soil tillage and sowing methods on soil structure on the end of crop rotation

3 lentelė. *Įvairių žemės dirbimo ir sėjos būdų įtaka dirvožemio struktūrai rotacijos pabaigoje*

Dotnuva, experiment II, 18 08 2005 / *Dotnuva, II bandymas, 2005 08 18*

Treatment *Variantas*	Depth cm *Gylis cm*	Structural aggregates % *Struktūriniai agregtatai %*				Water stable aggregates % *Vandenyje patvarūs agregatai %*	
		> 5 mm, incl.	> 10 mm	0.25-5 mm	< 0.25 mm	> 0.25 mm	> 1 mm
Stubble breaking, ploughing, sowing by a disk drill / *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10	55.3	33.3	41.5	3.18	43.5	6.98
	10-20	65.9	40.3	32.4	1.67	48.7	7.27
Ploughing just before sowing, sowing by a disk drill / *Arta prieš pat sėją, sėta diskine sėjamąja*	0-10	53.8	28.6	43.5	2.64	53.0	10.65
	10-20	61.1	33.0	37.1	1.73	55.2	13.09
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku, arta, sėta diskine sėjamąja*	0-10	60.3	34.9	36.6	3.03	52.3	9.85
	10-20	70.9	42.2	27.6	1.51	53.4	9.09
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku, arta, sėta ražienine sėjamąja*	0-10	56.6	30.7	39.7	3.63	51.7	8.88
	10-20	73.2	46.5	25.2	1.60	52.8	8.97
Stubble breaking by a combined stubble breaker, direct drilling *Skusta kombinuotu skutiku, sėta ražienine sėja*	0-10	68.0	39.9	29.7	2.10	56.0	14.47
	10-20	72.3	45.9	26.3	1.35	58.3	17.16
Roundup application on untilled soil, direct drilling / *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10	59.0	30.2	38.5	2.50	55.8	14.97
	10-20	71.6	42.7	26.6	1.65	58.5	16.34
LSD_{05} / R_{05}	0-10	14.02	16.00	13.49	1.068	7.40	4.331
	10-20	9.78	12.64	9.79	0.722	4.34	5.084

Soil bulk density is one of the values that changes most under natural and anthropogenic effects. During 2001-2004 winter wheat was grown in experiment I. The best conditions for winter wheat growing are those when soil bulk density amounts to 1.33 Mg m^{-3} /Rassadin, Kačnova, 1989/. Our experimental evidence suggests that when conventional autumn soil tillage had been replaced by zero soil tillage (direct drilling) the soil bulk density in experiment I at the beginning of the rotation in the year 2001 was 1.49 Mgm^{-3} in the 0-10 cm layer and in the 10-20 cm layer it was 1.48 Mg m^{-3} (Table 4). In 2002 it exceeded the optimal value for winter wheat by 0.08 Mg m^{-3} in the 0-10 cm layer and by 0.06 Mg m^{-3} in the 10-20 cm layer, in the control treatment it was 1.38 and

1.45 Mg m^{-3}, respectively. In 2002 this had a great impact on the yield. In the last year of the crop rotation (12 08 2004) the soil bulk density tended to decline in all soil tillage systems tested, except for direct drilling where in the 0-10 cm layer it increased by 0.08 Mg m^{-3}, and in the 10-20 cm layer by 0.17 Mg m^{-3} (or 13 %), compared with the conventional autumn tillage (treatment 1) (Table 5). The soil became denser in the last year of the rotation in the 10-20 cm layer by 0.05 Mg m^{-3} or by 3.4 % compared with the first year of the crop rotation. In experiment II in the direct drilling treatments the soil bulk density increased in spring only in the 0-10 cm layer by 0.08 Mg m^{-3} (LSD_{05} = 0.08), in the autumn in the topsoil it increased by 0.11 Mg m^{-3} (LSD_{05} = 0.106), and in the 10-20 cm depth showed a trend of increasing by 0.04 Mg m^{-3} (LSD_{05} = 0.087) (Table 6).

Table 4. The effect of different soil tillage systems and sowing methods on soil physical properties
4 lentelė. *Skirtingų žemės dirbimo sistemų ir sėjos būdų įtaka dirvožemio fizikinėms savybėms*

Dotnuva, experiment I, 07 08 2001 / *Dotnuva, I bandymas, 2001 08 07*

Treatment *Variantas*	Depth cm *Gylis cm*	Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg m^{-3}*	Soil moisture % *Dirvožemio drėgnis %*	Soil porosity % *Dirvožemio poringumas %*	
				Total *Bendrasis*	Air-filled *Aeracinis*
Stubble breaking, ploughing, sowing by a disk drill / *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10 10-20	1.42 1.49	17.7 16.9	46.0 43.2	20.7 18.1
Ploughing just before sowing, sowing by a disk drill */ Arta prieš pat sėją, sėta diskine sėjamąja*	0-10 10-20	1.47 1.49	17.4 17.0	44.2 43.5	18.7 18.2
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku, arta, sėta diskine sėjamąja*	0-10 10-20	1.51 1.53	17.4 17.1	42.7 42.0	16.5 16.0
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku, arta, sėta ražienine sėjamąja*	0-10 10-20	1.49 1.49	17.5 17.0	43.2 43.2	17.2 18.0
Roundup application on untilled soil, direct drilling / *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10 10-20	1.49 1.48	16.8 15.7	43.4 43.6	18.4 20.4
LSD_{05} / R_{05}	0-10 10-20	0.060 0.068	0.59 0.62	2.29 2.58	3.24 3.62

Soil total and air-filled porosity is an important soil characteristic on which water and air regime and plant growth conditions are dependent. Experimental findings show that when the soil had been tilled using various methods, the conditions of total soil porosity were good, in experiment II in the 0-10 cm layer it ranged from 46 to 49 % (Table 6), it was slightly lower (42-47 %) in the bottom 10-20 cm layer, in experiment I the total air porosity ranged from 42.2 to 45.9 % and from 41.7 % to 48.5 %. The best aeration is when air makes up 20-25 % of the porosity /Vadiunina, Korčagina, 1986/. The data averaged over four years indicate that in experiment II when using various soil tillage systems there was sufficient content of air-filled pores (22.0-31.8 %), compared with conventional soil tillage (control treatment); when zero tillage – direct drilling was applied a reduction trend was observed. In experiment I air-filled porosity ranged from 16.0 % to 20.7 % in the autumn of 2001 (Table 4) and from 20.9 % to 31.2 % in the autumn of 2004; when drilled into minimally tilled soil by a direct drill and into untilled soil a reduction trend was observed.

Table 5. The effect of different soil tillage systems and sowing methods on soil physical properties

5 lentelė. *Skirtingų žemės dirbimo sistemų ir sėjos būdų įtaka dirvožemio fizikinėms savybėms*

Dotnuva, experiment I, 12 08 2004 / *Dotnuva, I bandymas, 2004 08 12*

Treatment *Variantas*	Depth cm *Gylis cm*	Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg m^{-3}*	Soil moisture % *Dirvožemio drėgnis %*	Soil porosity % *Dirvožemio poringumas %*	
				Total *Bendrasis*	Air-filled *Aeracinis*
Stubble breaking, ploughing, sowing by a disk drill / *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10 10-20	1.41 1.36	14.6 13.1	46.6 48.3	26.1 30.6
Ploughing just before sowing, sowing by a disk drill / *Arta prieš pat sėją, sėta diskine sėjamąja*	0-10 10-20	1.39 1.38	15.3 14.4	47.1 47.7	25.8 27.8
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku, arta, sėta diskine sėjamąja*	0-10 10-20	1.40 1.33	14.5 13.6	47.0 49.3	26.7 31.2
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku , arta, sėta ražienine sėjamąja*	0-10 10-20	1.36 1.34	15.6 15.4	48.5 49.2	27.4 28.6
Roundup application on untilled soil, direct drilling / *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10 10-20	1.49 1.53	14.6 13.6	43.2 41.7	21.5 20.9
LSD_{05} / R_{05}	0-10 10-20	0.072 0.084	1.51 1.48	2.74 3.20	3.99 4.15

Table 6. The effect of different soil tillage systems and sowing methods on soil physical properties, on the end of crop rotation
6 lentelė. *Įvairių žemės dirbimo ir sėjos būdų įtaka dirvožemio fizikinėms savybėms rotacijos pabaigoje*

Dotnuva, experiment II, 18 08 2005 / *Dotnuva, II bandymas, 2005 08 18*

Treatment *Variantas*	Depth cm *Gylis cm*	Soil bulk density $Mg\ m^{-3}$ Dirvožemio tankis $Mg\ m^{-3}$	Soil moisture % *Dirvožemio drėgnis %*	Soil porosity % *Dirvožemio poringumas %*	
				Total *Bendrasis*	Air-filled *Aeracinis*
Stubble breaking, ploughing, sowing by a disk drill / *Skusta plūgu, arta, sėta diskine sėjamąja*	0-10	1.32	15.7	49.8	29.0
	10-20	1.42	17.5	46.2	21.4
Ploughing just before sowing, sowing by a disk drill / *Arta prieš pat sėją, sėta diskine sėjamąja*	0-10	1.26	16.0	52.2	32.0
	10-20	1.35	18.3	48.7	24.0
Stubble breaking by a combined stubble breaker, ploughing, sowing by a disk drill / *Skusta kombinuotu skutiku, arta, sėta diskine sėjamąja*	0-10	1.33	16.0	49.5	28.3
	10-20	1.41	17.8	46.4	21.4
Stubble breaking by a combined stubble breaker, ploughing, sowing by a direct drill / *Skusta kombinuotu skutiku, arta, sėta ražienine sėjamąja*	0-10	1.31	14.9	50.0	30.3
	10-20	1.40	17.2	46.8	22.7
Stubble breaking by a combined stubble breaker, direct drilling / *Skusta kombinuotu skutiku, sėta ražienine sėja*	0-10	1.34	16.1	49.0	27.4
	10-20	1.46	17.2	44.5	19.5
Roundup application on untilled soil, direct drilling / *Neįdirbta dirva purkšta raundapu, sėta ražienine sėjamąja*	0-10	1.43	15.2	45.8	24.1
	10-20	1.46	17.1	44.6	19.9
LSD_{05} / R_{05}	0-10	0.106	1.19	4.02	5.99
	10-20	0.101	0.63	3.85	5.11

Soil moisture varied in relation to the various tillage methods: in the case of direct drilling (treatment 5) soil moisture declined throughout the whole ploughlayer in the autumn of 2001 (Table 4), this was affected by increasing soil bulk density, compared with conventional tillage (control treatment), in 2004 in treatment 5 there were no changes in soil moisture (Table 5), in experiment II soil moisture in the last year of the crop rotation (2005) did not change significantly throughout the whole ploughlayer (Table 6).

Cereal yield. Winter wheat was grown for four years in succession after vetch and oats mixture. The experimental findings suggest that in 2001 the grain yield of winter wheat grown after cropped fallow was similar in all soil tillage systems tested, however, it was significantly higher (5.20 $t ha^{-1}$) in treatment 4. In 2002 when sown into untilled soil the grain yield declined by 27.2 %, compared with the conventional soil tillage (stubble breaking + ploughing) – 3.83 t ha^{-1} (Table 7). The highest grain yield (4.02 t ha^{-1}) was obtained in the treatments including stubble breaking by a combined stubble breaker SL-4 at the 10-12 cm depth, followed by ploughing at the 22-25 cm depth and direct drilling, these treatments had the lowest weed incidence and accumulated higher nutrient contents in the soil and the yield had a trend to increase by 5.0 % (LSD_{05} = 6.88), compared with the control treatment. In 2003 the yield declined in all treatments, an especially marked reduction (25.1 % and 18.3 %) occurred in the direct drilled treatment 4. In 2004 grain yield declined by 0.59 t ha^{-1} (10.8 %) in the direct drilled soil treatment, with prior Roundup spraying at a dose rate of 4 l ha^{-1}. The lowest number of seedlings formed in untilled soil sprayed with Roundup 4 l ha^{-1}, in winter wheat crop stand the number of seedlings was by 15 % lower compared with conventional tillage; productive tillering coefficient of winter wheat in 2001-2002 ranged from 1.6 to 1.8; in the winter wheat stand in untilled soil (zero tillage) the number of productive stems was significantly (by 21.8 %) lower than in the conventional tillage treatment, there were by 4.3 % fewer grains per spike and they were by 12.4 % smaller compared with the conventional soil tillage. Moisture regime in the second half of the growing season is especially relevant for grain size. Drought stress that occurred after flowering accelerated an increase in grain dry matter but shortened grain filling period, which had a negative effect on grain size and yield /Samarah, 2005/. Fewer grains per ear formed and they were smaller (treatment 5), which affected the yield.

Table 7. The effect of different soil tillage systems and sowing methods on winter wheat grain yield
7 ***lentelė.*** *Skirtingų žemės dirbimo sistemų ir sėjos būdų įtaka žieminių kviečių derliui*
Dotnuva, 2001-2004, experiment I / *Dotnuva, 2001-2004 m., I bandymas*

Treatment *Variantas*	Winter wheat grain yield t ha^{-1} / *Žieminių kviečių derlius t ha^{-1}*							
	2001		2002		2003		2004	
	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
1	4.36	100.0	3.83	100.0	3.51	100.0	5.48	100.0
2	4.46	102.3	3.87	101.0	3.21	91.5	5.26	66.5
3	4.37	100.2	3.79	99.0	3.29	93.8	5.45	101.7
4	5.20	119.3	4.02	105.0	2.63	74.9	5.37	95.6
5	4.42	101.4	2.79	72.8	2.87	81.7	4.89	79.3
LSD_{05} / R_{05}	0.400		0.263		0.325		0.532	

In experiment II (Table 8) in 2002, when winter wheat was grown in the cereal crop rotation, the best yields 5.86 t ha^{-1} (treatment 5) and 5,84 t ha^{-1} (treatment 4) were obtained when sown after peas by a direct drill into tilled soil. Spring barley requires conventional soil tillage. The best yields in 2003 were obtained in treatments 3 and 4, in the direct drilling treatments (treatment 6) a reduction trend was observed (7.9 %), and in the drilling into minimally tilled soil by a direct drill (treatment 5) the lowest yield was obtained, by 14.7 % lower compared with the conventional soil tillage.

Table 8. The effect of primary soil tillage simplification and sowing methods on cereal yield

8 lentelė. *Pagrindinio žemės dirbimo supaprastinimo ir sėjos būdų įtaka javų derliui*

Dotnuva, 2002-2005, experiment II / *Dotnuva, 2002-2005 m., II bandymas*

Treatment *Variantas*	Grain yield t ha^{-1} / *Grūdų derlius t ha^{-1}*							
	Winter wheat *Žieminiai kviečiai*		Spring barley *Vasariniai miežiai*		Oats *Avižos*		Peas *Žirniai*	
	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
1	5.34	100.0	4.43	100.0	5.84	100.0	3.43	100.0
2	5.53	103.6	3.92	88.5	4.62	79.1	2.28	66.5
3	5.61	105.1	4.86	109.7	5.83	99.8	3.49	101.7
4	5.84	109.4	4.82	108.8	5.74	98.3	3.28	95.6
5	5.86	109.7	3.78	85.3	5.77	98.8	2.72	79.3
6	5.66	106.0	4.08	92.1	5.53	94.7	1.92	56.0
LSD_{05} / R_{05}	0.458		0.546		0.631		0.479	

When oats were grown in 2004 the highest yield was produced in the conventionally tilled treatment 1. When oats were direct drilled a yield reduction trend was observed, and when oats were drilled into the minimally tilled soil, the yield was the same as in the conventionally tilled soil – 5.84 t ha^{-1} and 5.77 t ha^{-1}, respectively. When legume crops are grown in a cereal crop rotation, direct drilling and drilling into minimally tilled soil are completely unsuitable, since the yield of peas declined by 44.0 % and 20.7 %, respectively compared with the conventional autumn soil tillage. Ploughing just before sowing by mouldboard ploughs fitted with a ploughlayer's densifier (treatment 2) is suitable when winter wheat is grown in a cereal crop rotation after peas. For spring barley, oats and peas this soil tillage method is unsuitable since the yield declined by 11.5 %, 20.9 % and 33.5 %, respectively compared with conventional tillage.

Conclusions

1. The structure of a well-tamed sandy light loam soil changed in relation to the different soil tillage systems and sowing methods used. When winter wheat was grown as a monocrop and directly drilled (experiment I), the content of clods declined in the last year of the rotation; in the 0-10 cm soil layer the content of valuable structural aggregates 0.25-5.0 mm in size increased by 23.2 %, and in the 10-20 cm soil layer only an inappreciable increasing trend was observed compared with the first year of the rotation. In the cereal crop rotation (experiment II) the content of structural aggregates of 0.25-5.0 mm diameter when direct drilled and drilled into minimally tilled soil by a direct drill tended to decline. In experiment I different soil tillage systems did not have any significant effect on the stability of aggregates larger than 0.25 mm. In the cereal crop rotation when direct drilled into the soil loosened by mouldboardless implements, as well as when drilled into stubble their content increased in the 0-10 cm layer by 13.5 % and 12.0 %, respectively and in the 10-20 cm layer the content of these

aggregates was by 9.6 % and 9.8 % higher, compared with the conventional soil tillage. The content of structural aggregates larger than 1mm in all soil tillage systems tested was higher than in the conventional tillage system (stubble breaking + ploughing).

2. Soil bulk density in the treatments where winter wheat was grown for four years in succession and where direct drilling into stubble was applied in the first year of growing increased by 0.07 Mg m^{-3} only in the 0-10 cm layer, in the fourth year of growing it increased in the whole ploughlayer: in the 0-10 cm layer by 0.08 Mg m^{-3}, in the 10-20 cm layer by 0.07 Mg m^{-3}, compared with the conventional tillage. In the cereal crop rotation in the untilled soil at the beginning of the rotation the soil bulk density was higher only in the topsoil layer (in the 0-10 cm layer it increased by 0.08 Mg m^{-3}), at the end of the rotation in this layer it increased by 0.11 Mg m^{-3}, and in the 10-20 cm layer only a trend of increasing was observed, compared with the conventional autumn tillage; when sown by a direct drill into minimally tilled soil the soil bulk density changed inappreciably and only in the 0-10 cm layer.

3. In the direct drilling treatments total soil porosity declined significantly in experiments I and II only in the 0-10 cm soil layer. Air-filled porosity in both experiments significantly declined by 4.4 % in the 0-10 cm layer at the beginning of the rotation (experiment I), and at he end by 4.9 % (experiment II), in the 10-20 cm layer a trend of reduction was observed.

4. Different soil tillage systems and sowing methods applied in the treatments where winter wheat had been continuously grown for four years affected soil moisture: when direct drilled it declined significantly by 0.96 percentage units in the first year of growing throughout the whole ploughlayer in the 0-10 cm layer and by 1.16 percentage units in the 10-20 cm layer, compared with the conventional tillage; in the fourth year of growing soil moisture was similar in the different soil tillage systems applied. In the cereal crop rotation soil moisture declined by 1.2 percentage units in the 10-20 cm layer, in the 0-10 cm layer there were no changes in soil moisture; in the last year of rotation soil moisture did not change significantly in the whole ploughlayer, compared with the conventional soil tillage.

5. Different soil tillage systems and sowing methods exerted a significant effect on winter wheat yield: when winter wheat was grown for four years in succession, when direct drilled, in the first year the yield was similar to that obtained in the conventional soil tillage system, in the second year when drilled into untilled soil sprayed with Roundup 4 l ha^{-1} the yield declined by 27.2 %, in the third year by 18.3 % and in the last year of growing by 10.7 %. When winter wheat was grown in the cereal crop rotation, the best yields were obtained when sown after peas by a direct drill into tilled soil. The yield of spring barley declined by 14.7 % when sown by a direct drill into minimally tilled soil, compared with conventional tillage; when oats were direct drilled, a trend of yield reduction was observed, and when sown by a direct drill into minimally tilled soil the yield was similar (5.77 t ha^{-1}) to that obtained in conventionally tilled soil (5.84 t ha^{-1}). When peas were grown, both of these reduced soil tillage methods significantly reduced the yield, when peas were direct drilled, the yield declined by 21.7 % and 44.0 % when sown by a direct drill into minimally tilled soil.

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BEARIMIO ŽEMĖS DIRBIMO TAIKYMO GALIMYBĖS LENGVO PRIEMOLIO DIRVOSE

D. Šimanskaitė

Santrauka

2000-2005 metais Lietuvos žemdirbystės institute Dotnuvoje giliau karbonatingame giliau glėjiškame lengvo priemolio rudžemyje buvo tirta verstuvinio ir beverstuvio purenimo ir skirtingų sėjos būdų įtaką dirvožemio fizikinėms savybėms ir javų derliui. I bandymas įrengtas 2000 metais nuėmus vikių ir avižų mišinį, II bandymas – 2001 m. nuėmus žirnius. Tyrimais nustatyta, kad skirtingi žemės dirbimo ir sėjos būdai turėjo esminės įtakos dirvožemio struktūrai, dirvos tankiui, bendrajam ir aeraciniam poringumui, dirvožemio drėgmei ir derliui. I bandyme žieminių kviečių derlius pirmaisiais auginimo metais, sėjant į neįdirbtą dirvą (į ražieną), gautas toks pat – 4,42 t ha^{-1} kaip ir taikant įprastą žemės dirbimą – 4,36 t ha^{-1}. Atsėliuojant žieminius kviečius dvejus, trejus ir ketverius metus ir sėjant juos į neįdirbtą ražieną, derlius mažėjo atitinkamai 27,2 %, 18,3 % ir 10,2 %. II bandyme auginant žieminius kviečius javų sėjomainoje po žirnių, geriausias derlius gautas sėjant juos į įdirbtą ražieną; sėjant į neįdirbtą ražieną, derlius turėjo tendenciją didėti. Vasarinių miežių derlius gautas iš esmės mažesnis (14,7 %), sėjant į minimaliai įdirbtą dirvą, palyginus su įprastu dirbimu; sėjant avižas į neįdirbtą dirvą (į ražieną), derlius turėjo tendenciją šiek tiek mažėti, o sėjant į minimaliai įdirbtą dirvą, derlius panašus 5,77 t ha^{-1} kaip ir įprastai dirbant dirvą – 5,84 t ha^{-1}. Auginant žirnius, abu šie supaprastinto žemės dirbimo būdai patikimai mažino derlių – sėjant žirnius į neįdirbtą dirvą (į ražieną), derlius mažėjo 44,0 % ir 21,7 % sėjant ražienine sėjamąja į minimaliai beverstuviu purentuvu įdirbtą dirvą.

Reikšminiai žodžiai: įprastas ir bearimis žemės dirbimas, nulinis žemės dirbimas, fizikinės dirvožemio savybės, derlius.