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THE IMPACT OF SOIL TILLAGE MINIMIZATION ON SANDY LOAM SOIL

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Abstract

The influence of different soil preparation and sowing technologies on soil physical properties and grain yield of winter wheat, spring barley and spring wheat was studied in the stationary field experiments conducted at the Lithuanian Institute of Agriculture during 2003-2006. The *Endocalcari-Endohypogleyic Cambisol* sandy loam soil was prepared for winter and spring cereals in different ways: 1) stubble cultivation to 10-12 cm depth, mouldboard ploughing to 21-23 cm depth and tillage with a precision seedbed cultivator to 3-4 cm; 2) stubble cultivation to 10-12 cm and tillage with a precision seedbed cultivator to 3-4 cm; 3) stubble cultivation to 10-12 cm; treatments 4 and 5 no tillage before drilling. In treatments 1 and 2 cereals were sown by a disc drill 'Saxonia', in treatments 3 and 4 by a sowing unit DS-3, and a sowing unit 'Amazone' in treatment 5. Soil moisture was found to be lower at 0-5 cm depth in the treatment, where ploughing and tillage by a precision seedbed cultivator had been done. Soil bulk density increased and air-filled porosity decreased at 0-5 cm depth, when cereals had been sown by a direct, disc-coulter drill DS-3 without pres-sowing tillage. Soil total and air-filled porosity varied from 45.7 to 56.4 and from 21.1 to 42.5 %, respectively. Different soil tillage and sowing methods did not have any significant effect on soil bulk density, total and air-filled porosity at 10-20 cm depth soil layer. The most stable cereal grain yield was obtained in the treatment where stubble cultivation and ploughing had been applied.

Key words: soil tillage, direct drilling, soil physical properties, crop yield.

Introduction

Crop establishment largely depends on the methods used for seedbed preparation and drilling. Under reduced tillage and no-till (direct drilling into stubble) changes of soil physical properties occur, and soil bulk density and penetration resistance increase /Hill, Cruse, 1985/. In Lithuania some research was done on reduced primary and pre-sowing seedbed preparation / Maikštėnienė, 1980; Arlauskas, 1999; Feiza et al., 2005/. Various implements and intensities for seedbed preparation have been compared in sandy loam and clay loam soils. In dry springs a very important factor for uniform emergence of cereals is a good seed-soil contact /Satkus, 2001/. In the first year after the shift from mouldboard ploughing to reduced and no-till system, no significant differences in soil physical properties and winter wheat yield were found /Šimanskaitė, 2002/. It was assumed that the seeds should be placed directly on a firm and moist seedbed base and covered by a layer of fine aggregates /Heinonen, 1985/. In different trials it was found that the finer the aggregate size of the ploughed layer, the better the cereals emergence /Brown et al., 1996; Hakkanson et al., 2002/. The new precision seedbed cultivators have been very often used in recent years, one of which is Kongskilde Germinator – a precision seedbed cultivator designed to create a perfect seedbed, in many cases, in just one pass. An important indicator of soil properties is bulk density. The optimal bulk density for plant growth is different for each soil. In general, less than optimal bulk density leads to poor water relations, and high bulk density reduces aeration and increases penetration resistance, limiting root growth. The effect of soil tillage on bulk density is temporary, and after tillage the soil rapidly settles, recovering its former bulk density /Campbell, Henshall, 1991; Franzen et al., 1994/. The objective of the present study was to investigate the effects of different soil tillage and sowing systems on soil physical properties and cereal yield.

Materials and methods

Stationary field experiments were conducted during 2003-2006 on a sandy loam soil, at the Lithuanian Institute of Agriculture in Dotnuva. The soil was prepared according to the following design:

1. Stubble cultivation to 10-12 cm depth; mouldboard ploughing to 22-23 cm depth; tillage by a precision seedbed cultivator before sowing, sowing by a disc-coulter drill "Saxonia";
2. Stubble cultivation to 10-12 cm depth; tillage by a precision seedbed cultivator before sowing, sowing by a disc-coulter drill "Saxonia";
3. Stubble cultivation to 10-12 cm depth; sowing by a disc sowing unit DS-3;
4. No tillage; sowing by a disc sowing unit DS-3;
5. No tillage; direct sowing by a sowing unit "Amazone" with a rotary cultivator.

The field experiment was arranged as a complete randomized block design in four replicates. Gross plot size was 10 x 20 m and net harvested plot size 2.3 x 10 m. The soil of the experimental site is *Endocalcari-Endohypogleyic Cambisol*, sandy loam. The crop sequence in the trial was as follows: field pea, winter wheat, spring wheat, and spring barley. Each year, 3 weeks after harvesting of previous crop, non-selective herbicide (a.i. glyphosate at a dose of 1.44 l ha^{-1}) was sprayed in treatments 2-5 to control weeds and volunteer plants. To control weeds in winter wheat at tillering stage the herbicides Monitor 25 g ha^{-1} (a.i. sulfosulfuron 750 g kg^{-1}) and Arat 150 g ha^{-1} (a.i. tritosulfuron 250 + dicamba 500 g kg^{-1}) with adjuvant Dash 0.5 l ha^{-1} in spring wheat and spring barley were used.

The winter wheat variety 'Širvinta' was sown on September 17 in 2003, at 450 seeds per m^2. The spring wheat variety 'Zebra' was sown on May 5 in 2005, at 500 seeds per m^2. The spring barley 'Luokė' was sown on May 5 in 2006, at 450 seeds per m^2. The soil samples to determine soil bulk density, moisture, and porosity were taken at the beginning of the growing season in spring and after harvesting of cereals. Two cylinders (100 cm^2) for each plot were used to take undisturbed soil samples. The samples to determine soil bulk density were taken from the depths of 0-5, 5-10, 10-15 and 15-20 cm. The yield of cereals was adjusted to 85% dry matter content. Analysis of variance (ANOVA) was conducted on soil physical and yield data /Dospechov, 1985; Tarakanovas, 1996/.

Results and discussion

Soil bulk density in spring at the beginning of the growing season was close to optimum and similar in different soil tillage treatments. The highest bulk density at 0-5 cm depth was in the treatment where cereals had been sown by a sowing unit DS-3 in no tilled soil (Table 1). The findings of the soil moisture showed that in the upper soil layer of 0-5 cm in spring moisture content was lower after mouldboard ploughing compared to stubble cultivation and no tillage treatments. When ploughed without any trash on the surface, the soil in dry springs lost more water compared to reduced tillage and no tillage plots. In deeper soil layers no moisture and bulk density differences were found between soil tillage and sowing treatments. Higher bulk density and moisture contents were measured in "no till" treatment in a long term experiment in Germany /Ulrich et al., 2006/.

Table 1. The effect of soil tillage and sowing on soil bulk density and moisture at the beginning of cereal growing season in spring
1 lentelė. *Dirvos dirbimo ir sėjos įtaka dirvožemio tankiui ir drėgniui javų vegetacijos pradžioje pavasarį*

Dotnuva 2004-2006

Treatment *Variantas*	Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg m^{-3}*				Soil moisture % *Dirvožemio drėgnis %*			
	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*
1	2	3	4	5	6	7	8	9
Stubble cultivation, mouldboard ploughing, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, arta, dirbta kombinuotu priešsėjiniu agregatu sėta sėjamąja „Saksonija"su diskiniais noragėliais*	1.19	1.30	1.35	1.34	10.5	15.2	16.3	17.6
Stubble cultivation, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija"su diskiniais noragėliais*	1.20	1.30	1.29	1.29	14.7	16.4	17.4	18.0

Table 1 continued
1 lentelės tęsinys

1	2	3	4	5	6	7	8	9
Stubble cultivation, sowing by a direct drill DS-3 / *Skusta beverstuviu skutikliu, sėta tiesioginės sėjos agregatu DS-3*	1.15	1.32	1.36	1.34	12.8	16.1	16.3	17.2
No tillage, sowing by a direct drill / *Nedirbta, sėta tiesioginės sėjos agregatu DS-3*	1.26	1.32	1.35	1.32	15.1	16.5	17.3	17.9
No tillage, sowing by a direct drill "Amazone" *Nedirbta, sėta tiesioginės sėjos agregatu „Amazonė"*	1.15	1.34	1.33	1.31	15.4	16.0	16.9	17.6
LSD_{05} / R_{05}	0.059	0.065	0.053	0.062	1.89	0.88	0.63	0.70

After the growing season, some increase in bulk density compared to spring data was observed. The highest bulk density at 0-5 cm depth after harvesting of cereals was in the treatment, where cereals had been sown by a direct, disc-type drill, without soil tillage. In the treatment where cereals had been sown by a direct drill mounted with a rotary cultivator, the bulk density was higher at 5-10 cm depth compared to the other treatments' results (Table 2). A vibrant rotary cultivator in this case caused some increase in bulk density below the tillage zone. The same tendency of soil moisture content between the treatments as in spring was observed after harvesting. Soil moisture was lower after mouldboard ploughing and higher after stubble cultivation and in the direct- drilled treatments in 0-5 cm soil layer (Table 2). Higher moisture content in no tillage compared to reduced tillage in spring was found in other field experiments /Feiza et al., 2006/.

In spring the total soil porosity ranged from 48.3 to 56.4 %, and about 60 % of pores were air -filled. Conditions were close to optimal. The lowest air-filled soil porosity at 0-5 cm depth was in the direct drilling treatment (Table 3), and an opposite tendency of higher total soil porosity in 0-5 cm depth was recorded after sowing by an 'Amazone' direct drill with a rotary cultivator. In 5-20 cm soil layers there were no significant differences in the total and air-filled porosity between tillage and sowing treatments.

Table 2. The effect of soil tillage and sowing on soil bulk density and moisture after harvesting of cereals

2 lentelė. *Dirvos dirbimo ir sėjos įtaka dirvožemio tankiui ir drėgniui po javų derliaus nuėmimo*

Dotnuva 2004-2006

Treatment *Variantas*	Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg m^{-3}*				Soil moisture % *Dirvožemio drėgnis %*			
	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*
Stubble cultivation, mouldboard ploughing, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, arta, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	1.23	1.30	1.37	1.35	16.2	17.1	17.3	16.4
Stubble cultivation, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	1.17	1.30	1.37	1.40	17.5	17.6	17.1	15.1
Stubble cultivation sowing by a direct drill DS-3 *Skusta beverstuviu skutikliu, sėta tiesioginės sėjos agregatu DS-3*	1.17	1.39	1.42	1.42	19.9	18.0	17.1	16.1
No tillage, sowing by a direct drill / *Nedirbta, sėta tiesioginės sėjos agregatu DS-3*	1.31	1.39	1.44	1.40	18.5	17.2	16.7	16.1
No tillage, sowing by a direct drill "Amazone" *Nedirbta, sėta tiesioginės sėjos agregatu „Amazonė"*	1.24	1.45	1.41	1.42	18.4	17.1	17.0	16.0
LSD_{05} / R_{05}	0.064	0.073	0.046	0.048	1.15	0.61	0.53	1.14

Table 3. The effect of soil tillage and sowing on soil porosity in spring
3 lentelė. *Žemės dirbimo ir sėjos įtaka dirvožemio poringumui pavasarį*
Dotnuva 2004-2006

Treatment *Variantas*	Soil total porosity % *Bendras dirvožemio poringumas %*				Soil air-filled porosity % *Dirvožemio aeracinis poringumas %*			
	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*
Stubble cultivation, mouldboard ploughing, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, arta, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	54.8	50.6	48.5	49.2	42.2	30.8	26.5	25.7
Stubble cultivation, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	54.3	50.4	51.1	51.0	36.8	29.0	28.8	27.8
Stubble cultivation, sowing by a direct drill DS-3 *Skusta beverstuviu skutikliu, sėta tiesioginės sėjos agregatu DS-3*	56.1	49.8	48.3	49.0	42.5	29.4	26.7	26.6
No tillage, sowing by a direct drill / *Nedirbta, sėta tiesioginės sėjos agregatu DS-3*	51.9	49.8	48.8	49.9	33.4	28.2	25.8	26.5
No tillage, sowing by a direct drill "Amazone" *Nedirbta, sėta tiesioginės sėjos agregatu „Amazonė"*	56.4	49.2	49.5	50.1	38.8	28.0	27.2	27.3
LSD_{05} / R_{05}	2.24	2.47	2.03	2.34	5.45	4.06	2.67	2.86

During the growing season the total and air-filled soil porosity changes were not substantial. The highest total and air-filled soil porosity at 0-10 cm soil layer was identified in the plots where stubble cultivation had been done. When the soil had not been tilled before sowing and cereals were sown by a direct drill DS-3, the soil total and air-filled porosity at the same soil layer was the lowest (Table 4).

Table 4. The effect of soil tillage and sowing on soil porosity after harvesting
4 lentelė. *Įvairaus žemės dirbimo ir sėjos įtaka dirvožemio poringumui po derliaus nuėmimo*

Dotnuva 2004-2006

Treatment *Variantas*	Soil total porosity % *Dirvos bendras poringumas %*				Soil air-filled porosity % *Dirvožemio aeracinis poringumas %*			
	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*	0-5 cm depth *gylis*	5-10 cm depth *gylis*	10-15 cm depth *gylis*	15-20 cm depth *gylis*
Stubble cultivation, mouldboard ploughing, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, arta, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	52.4	49.4	47.1	47.4	31.6	26.5	23.2	24.5
Stubble cultivation, tillage by a precision soil preparation unit, sowing by a disc drill "Saxonia" *Skusta beverstuviu skutikliu, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija" su diskiniais noragėliais*	55.4	50.8	48.0	47.1	34.8	27.9	24.4	26.0
Stubble cultivation, sowing by a direct drill DS-3 *Skusta beverstuviu skutikliu, sėta tiesioginės sėjos agregatu DS-3*	55.3	50.2	48.1	46.6	32.7	26.4	24.5	23.9
No tillage, sowing by a direct drill / *Nedirbta, sėta tiesioginės sėjos agregatu DS-3*	51.2	46.6	45.7	46.4	26.9	21.7	21.1	23.2
No tillage, sowing by a direct drill "Amazone" *Nedirbta, sėta tiesioginės sėjos agregatu „Amazonė"*	53.6	46.4	46.7	46.8	31.0	22.4	22.9	24.0
LSD_{05} / R_{05}	1.63	2.08	1.47	1.45	2.88	2.83	2.11	2.51

The most stable grain yield of cereals over the trial period 2004-2006 compared to the other treatments was recorded in the plots where stubble cultivation after harvesting of preceding crop, and mouldboard ploughing to 22-23 cm depth had been performed (Table 5). In 2004 the highest winter wheat grain yield was produced in the no-tilled before sowing plots, and direct-drilled by a sowing unit DS-4. In the plots where only stubble cultivation to 10-12 cm depth had been done, due to the higher weed infestation compared to the other treatments, grain yield was lower by on average 0.93 t ha^{-1}. Different soil preparation and sowing means exerted a very similar effect on spring wheat grain yield in the year 2005. In the dry growing season in 2006 higher grain yield of spring barley was obtained in the plots, sown by a direct disc drill DS-4 (Table 5).

Table 5. The influence of soil tillage and sowing on cereal grain yield t ha^{-1}
5 lentelė. *Dirvos dirbimo ir sėjos įtaka javų derliui t* ha^{-1}
Dotnuva, 2004-2006 m.

Treatment *Variantas*	Winter wheat *Žieminiai kviečiai* 2004	Spring wheat *Vasariniai kviečiai* 2005	Spring barley *Vasariniai miežiai* 2006
Stubble cultivation, mouldboard ploughing, tillage by a precision soil preparation unit, sowing by a disc drill “Saxonia” / *Skusta beverstuviu skutikliu, arta, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija” su diskiniais noragėliais*	5.43	5.57	3.27
Stubble cultivation, tillage by a precision soil preparation unit, sowing by a disc drill “Saxonia”/ *Skusta beverstuviu skutikliu, dirbta kombinuotu priešsėjiniu agregatu, sėta sėjamąja „Saksonija” su diskiniais noragėliais*	5.10	5.48	2.73
Stubble cultivation, sowing by a direct drill DS-3 / *Skusta beverstuviu skutikliu, sėta tiesioginės sėjos agregatu DS-3*	4.49	5.67	3.35
No tillage, sowing by a direct drill *Nedirbta, sėta tiesioginės sėjos agregatu DS-3*	6.12	5.40	3.59
No tillage, sowing by a direct drill “Amazone”/ *Nedirbta, sėta tiesioginės sėjos agregatu „Amazonė”*	5.97	5.37	3.15
LSD_{05} / R_{05}	0.434	0.308	0.301

Conclusions

1. The highest bulk density at 0-5 cm depth in spring and after harvesting was recorded in the treatment where the soil had not been tilled before cereal sowing by a direct drill DS-3.

2. Soil moisture in the upper soil layer of 0-5 cm in spring was lower after mouldboard ploughing compared to stubble cultivation and no tillage treatments.

3. Different soil tillage and sowing methods did not exert any significant effect on soil bulk density, moisture content, total and air-filled porosity at the 10-20 cm depth soil layer.

4. The most stable grain yield of cereals was obtained in the plots where stubble cultivation after harvesting of preceding crop and mouldboard ploughing to 22-23 cm depth had been performed.

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ŽEMĖS DIRBIMO MAŽINIMO ĮTAKA LENGVO PRIEMOLIO DIRVAI

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Santrauka

Stacionariame lauko bandyme Dotnuvoje 2003-2006 m. buvo tirta giliau karbonatingo sekliau glėjiško lengvo priemolio dirvos dirbimo mažinimo ir sėjos įvairiomis sėjamosiomis įtaka dirvožemio fizikinėms savybėms ir žieminių kviečių, vasarinių miežių ir vasarinių kviečių grūdų derliui. Žemės dirbimo schema: 1. Skusta strėliniais skutikliais 10-12 cm gyliu, arta 21-23 cm gyliu, prieš sėją dirbta tikslaus dirbimo kombinuotu kultivatoriumi 3-4 cm gyliu. 2. Skusta strėliniais skutikliais 10-12 cm gyliu, prieš sėją dirbta tikslaus dirbimo kombinuotu kultivatoriumi 3-4 cm gyliu. 3. Skusta strėliniais skutikliais 10-12 cm gyliu. 4 ir 5 variantuose dirva iki sėjos nedirbta. Javai pasėti eiline diskine sėjamąja „Saksonija" 1 ir 2 variantuose, sėjos agregatu DS-3, sudarytu iš strėlinių dirvos dirbimo noragėlių sėjamosios priekyje ir diskinių sėklų įterpimo noragėlių 3 ir 4 variantuose ir sėjos agregatu „Amazonė" su rotoriniu dirvos įdirbimu ir diskiniais sėjos noragėliais 5 variante.

Nustatyta, kad skutant ir ariant viršutiniame dirvos 0-5 cm sluoksnyje, dirvožemis buvo mažiau drėgnas nei kitų variantų laukeliuose. Didžiausias dirvožemio tankis viršutiniame 0-5 cm sluoksnyje 1,26-1,31 Mg m^{-3}, o mažiausias bendrasis ir aeracinis poringumai buvo sėjant į nedirbtą dirvą sėjos agregatu DS-3. Dirvožemio bendrasis ir aeracinis poringumai, tiek giliai ariant, tiek sekliai dirbant, svyravo nuo 45,7 iki 56,4 % ir nuo 21,1 iki 42,5 procento. Dirvožemio fizikinės savybės 10-20 cm gylyje dėl dirbimo gylio ir intensyvumo iš esmės nesiskyrė. Mažiausi javų grūdų derliaus svyravimai buvo dirvą skutant ir giliai ariant.

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