Chapter 2. PLANT NUTRITION AND SOIL MICROBIOLOGY

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THE EFFECT OF DIFFERENT TILLAGE METHODS AND ORGANIC FERTILIZERS ON SOIL PHYSICAL STATE AND CROP YIELD

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Abstract

The present paper summarises the data of field and laboratory trials conducted in Lithuania (Vėžaičiai Branch of the Lithuanian Institute of Agriculture) during the period 2003-2006. The effects of primary soil tillage: 1) deep (22-25 cm) ploughing; 2) shallow (10-12 cm) ploughing; 3) shallow (8-10 cm) tillage with a disc harrow as well as the effects of different organic fertilizers (farmyard manure, green manure and straw) on the main physical indicators of moraine loam soil (structure, bulk density, moisture) and on the yield of crop rotation crops were investigated in the 4th field crop rotation. It was revealed that soil tillage methods had no significant effect on soil bulk density. A significant increase in water stable aggregates in the topsoil under the effect of shallow tillage was observed. All organic fertilizers, especially farmyard manure, and straw incorporated in the following year were found to be effective for the improvement of moraine loam soil physical state. The highest crop yield in the first crop rotation was produced in the deeply ploughed plots. In the shallow tillage plots a significant crop yield reduction ($p > 0.01$) was recorded. Under the effect of organic fertilizers (farmyard manure + straw or green manure + straw) a significant increase ($p > 0.01$) in the yield of the crop rotation crops occurred.

Key words: soil tillage, organic fertilizers, physical properties, crop yield.

Introduction

Soil physical state is influenced by different forms of land use and cultivation. The conventional agriculture, mainly characterised by intensive tillage and mineral fertilizing, had a negative effect on soil quality. Therefore with conservation agriculture the soil is protected from rainfall erosion and water runoff, and the soil aggregates, organic matter and fertility level naturally increase /Arlauskas et al., 1996; Conyers et al., 2003; Kinderiene; 2005; Riley, 2005/. The conservation tillage applied seems to be highly effective in enhancing water recharge and water conservation, particularly in years with much lower than average precipitation /Moreno et al., 1995; Erkki, 1999/. Reduced tillage has been suggested as one of the possibilities to improve soil physical state without negative effects on crop yield /Ekeberg, Riley, 1997; Šimanskaitė, 2002/.

There exists another opinion about the effect of reduced soil tillage on crop yield. Research done in Lithuania and abroad indicates that intensive deep ploughing is the main factor for achievement of maximum crop yield /Feiza, Cesevičius, 2005/ as well as the cereal crop yield will be maintained under reduced tillage regimes at roughly the same levels as with annual ploughing, even when crop residues are retained /Riley, 2005/. The positive effect of crop residues, farmyard manure and green manure on soil physical state and crop yield was obtained after incorporation into the soil /Ožeraitienė, Jovaiša, 2004/. The efficiency of ploughless tillage depends on soil cultivation degree, soil texture and climate /Arlauskas et al., 1996/. Although ploughing is still the most common tillage, conservation and minimum tillage systems have been increasing in importance in European farming systems in recent years.

The aim of this investigation is to evaluate the changes in topsoil physical properties and crop rotation yield under different intensity tillage and organic fertilization influence in the humid region of West Lithuania.

Materials and methods

The experiments were carried out in West Lithuania, on the eastern part of sea-coast lowland with moderately warm, humid climate and mean annual precipitation rate over 800 mm. The soil is moderately cultivated *Dystric-Epihypogleyic Albeluvisol* (texture – morain loam, clay 13-15 %) with medium content of organic carbon, pH-5.1-5.3, medium amount of phosphorus and potassium. Soil structure is lumpy silt. To evaluate the effect of different soil tillage means with incorporation of different organic fertilizers on the physical properties of topsoil and crop rotation yield the following trial design was used: soil tillage in autumn – factor A 1) deep (22-25 cm) ploughing; 2) shallow (10-12 cm) ploughing; 3) shallow (8-10 cm) tillage with a disc harrow and organic fertilizers – factor B: 1) plant residues; 2) straw (straw triticale 5.5 t ha^{-1} DM) +N10/t straw +straw rape (2.8 t ha^{-1}) DM; 3) green manure - biomass (3.2 t ha^{-1}) of red clover 1stcut year + straw triticale (2.8 t ha^{-1}) DM +N10/t straw; 4) green manure – biomass (1.5 t ha^{-1}) of red clover 2nd cut year + triticale straw (5.5 t ha^{-1}) +N10/t straw + straw rape (2.8 t ha^{-1}) DM; 5) manure 40 t ha^{-1} + triticale straw (5.5 t ha^{-1}) +N10/t straw + straw rape (2.8 t ha^{-1}) DM; (Table 1).

Investigations were done in a 4-field rotation with mineral fertilizing: 1) red clover ($P_{90}K_{90}$); 2) winter triticale ($N_{90}P_{60}K_{90}$); 3) spring rape ($N_{150}P_{90}K_{150}$); 4) barley with under crop ($N_{60}P_{60}K_{90}$). The experiment was arranged as a complete randomised bloc design with four replicates. Every year after harvesting the trial was limed with 300 kg $CaCO_3$ per plot. Pre-sowing soil preparation was performed by a cultivator PS-3000.

The soil samples for physical analyses were taken from the topsoil after harvesting. Samples for soil structure analyses were taken in topsoil layer at 0-20cm depth, bulk density was estimated every 5.0 cm. To estimate the effect of organic fertilizers on soil bulk density and moisture the samples were taken twice during spring rape vegetation period: after sowing and at flowering stage. Physical analyses of soil samples were done using the following methods: Savinov for soil structure and its water stability, cylinder-auger of Kachinski for soil bulk density. Analysis of variance (ANOVA) was conducted on soil physical and crop yield data for each year /Tarakanovas, Raudonius, 2003/.

Table 1. Trial design
1 lentelė. *Bandymo schema*

Soil tillage in autum (factor A) / *Žemės dirbimas rudenį (A veiksnys)*			
Deep (22-25cm) ploughing / *Gilus (22-25cm) arimas*			
Shallow(10-12cm) ploughing / *Seklus (10-12cm) arimas*			
Shallow (8-10cm) tillage / *Seklus (8-10cm) dirbimas*			
Crop rotation, year and organic fertilizers (factor B) ***Rotacijos augalai, metai ir organinės trąšos (B veiksnys)***			
Red clover *Raudonieji dobilai* 2003	Winter triticale *Žieminiai kvietrugiai* 2004	Spring rape *Vasariniai rapsai* 2005	Spring barley *Miežiai* 2006
Plant residues *Augalų liekanos*	Plant residues *Augalų liekanos*	Plant residues *Augalų liekanos*	-
Plant residues *Augalų liekanos*	Straw triticale *Kvietrugių šiaudai*	Straw rape *Rapsų šiaudai*	-
Green manure 1st cut *Žalioji trąša, 1-oji pjūtis*	Straw triticale *Kvietrugių šiaudai*	Straw rape *Rapsų šiaudai*	-
Green manure 2nd cut *Žalioji trąša, 2-oji pjūtis*	Straw triticale *Kvietrugių šiaudai*	Straw rape *Rapsų šiaudai*	-
Manure *Mėšlas*	Straw triticale *Kvietrugių šiaudai*	Straw rape *Rapsų šiaudai*	-

Results and discussion

Soil physical state. Soil structure is the main indicator of soil physical state. Tillage has a profound effect on the soil structure. Proper tillage management, rotation and organic fertilizer addition maintain aggregate stability. Intensive tillage can destroy soil aggregates and result in degradation of soil structure. Our trial data indicate the same tendency. The amount of water stable aggregates was under the effect of soil tillage means (Table 2). A significant increase in the content of water stable aggregates > 0.25 mm was determined in the soil with the shallow tillage plots.

Table 2. Effect of primary tillage on the amount (%) of water stable aggregates > 0.25 mm in topsoil
2 lentelė. *Pagrindinio žemės dirbimo įtaka vandenyje patvarių agregatų >0,25 mm kiekiui (%)*

Vėžaičiai, 2004-2005

Treatment *Variantas*	Investigation year / *Tyrimų metai* Winter triticale *Žieminiai kvietrugiai* 2004	Spring rape *Vasariniai rapsai* 2005	Average *Vidurkis* 2004-2005
Deep ploughing / *Gilus arimas*	59.32	49.26	54.79
Shallow ploughing / *Seklus arimas*	61.20	46.42	53.32
Shallow tillage / *Seklus dirbimas*	64.97*	50.76	57.86
LSD_{05} / R_{05}	3.99	3.28	3.08

* Significant at the 0.05 level / *Patikimumo lygis 0,05*

The content of stable aggregates in topsoil layer amounted to 65 % or it was by 3.2 and 5.7 percentage units higher as compared with shallow and deep ploughed soil.

It was revealed that morain loam soil structure was under the influence of crop rotation. The amount of water stable aggregates in the soil with winter triticale was by 10-14 percentage units higher than in the soil with spring rape.

Different soil tillage methods did not have any significant effect on the soil bulk density (Table 3).

Table 3. Effect of primary tillage on topsoil bulk density and moisture
3 lentelė. *Pagrindinio žemės dirbimo įtaka dirvožemio tankiui ir drėgniui*
Vėžaičiai, 2004-2006

Treatment *Variantas*	Bulk density Mg m^{-3} *Tankis* Mg m^{-3}			Moisture % *Drėgnis %*		
	winter triticale *žieminiai kvietrugiai* 2004	spring rape *vasariniai rapsai* 2005	spring barley *vasariniai miežiai* 2006	winter triticale *žieminiai kvietrugiai* 2004	spring rape *vasariniai rapsai* 2005	spring barley *vasariniai miežiai* 2006
Topsoil layer depth 0-5 cm / *Armens gylis 0-5 cm*						
Deep ploughing / *Gilus arimas*	1.13	1.29	1.22	8.61	15.93	6.90
Shallow ploughing / *Seklus arimas*	1.20	1.32	1.25	7.77	19.57**	6.14
Shallow tillage / *Seklus dirbimas*	1.27	1.31	1.19	7.97	17.71*	6.92
LSD_{05} / R_{05}	0.16	0.20	0.08	3.18	1.30	1.33
Topsoil layer depth 5-10 cm / *Armens gylis 5-10 cm*						
Deep ploughing / *Gilus arimas*	1.24	1.30	1.15	9.02	15.62	9.25
Shallow ploughing / *Seklus arimas*	1.26	1.29	1.24	10.70	19.22*	8.59
Shallow tillage / *Seklus dirbimas*	1.35	1.34	1.27	9.68	18.04*	8.29
LSD_{05} / R_{05}	0.19	0.20	0.08	2.93	2.98	1.87
Topsoil layer depth 10-20 cm / *Armens gylis 10-20 cm*						
Deep ploughing / *Gilus arimas*	1.30	1.41	1.16	9.75	16.34	9.34
Shallow ploughing / *Seklus arimas*	1.25	1.36	1.17	11.44	19.50*	8.93
Shallow tillage / *Seklus dirbimas*	1.26	1.33	1.13	10.35	18.11*	8.62
LSD_{05} / R_{05}	0.14	0.08	0.10	2.97	1.97	2.87

* Significant at the 0.05 level / *Patikimumo lygis 0,05*

During the vegetation period a trend of an increase of topsoil (0-20 cm depth) bulk density was determined in the shallow tillage soil when spring rape was grown. The soil bulk density in the 0-5 cm topsoil layer was the lowest (1.13 Mg m^{-3}) when the soil was deep ploughed and winter triticale was grown.

Different soil tillage methods did not have any effect on soil moisture in 2006 with much lower than average precipitation. Under the drought conditions the soil moisture was only 8-9 % in both deep ploughed and shallow tilled soil. But when the

climatic conditions were favourable the topsoil layer (0-20 cm) in shallow ploughed and shallow tilled was by 2-3 percentage units wetter as compared with conventional tillage – deep ploughing. The changes in soil bulk density and moisture content under the effect of different organic fertilizers were not significant (Tables 4, 5).

***Table 4*.** Effect of primary tillage and organic fertilizers on topsoil bulk density during spring rape growing period

4 lentelė. *Pagrindinio žemės dirbimo ir organinių trąšų įtaka dirvožemio tankiui vasarinių rapsų vegetacijos laikotarpiu*

Vėžaičiai, 2005

Treatment *Variantas*	After sowing / *Po sėjos* BBCH-00			Flowering / *Žydėjimas* BBCH-65		
	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm
Deep ploughing / *Gilus arimas*						
Plant residues / *Augalų liekanos*	1.37	1.35	1.42	1.28	1.33	1.32
Plant residues + straw *Augalų liekanos + šiaudai*	1.33	1.31	1.33	1.18	1.22	1.19
Green manure +straw *Žalioji trąša +šiaudai*	1.27	1.40	1.40	1.16	1.22	1.30
Green manure +straw *Žalioji trąša +šiaudai*	1.23	1.23	1.31	1.25	1.25	1.30
Manure+straw / *Mėšlas + šiaudai*	1.29	1.32	1.27	1.26	1.33	1.29
LSD_{05} / R_{05}	0.08	0.16	0.05	0.16	0.21	0.18
Shallow ploughing / *Seklus arimas*						
Plant residues / *Augalų liekanos*	1.24	1.29	1.32	1.17	1.27	1.32
Plant residues + straw *Augalų liekanos + šiaudai*	1.33	1.29	1.37	1.13	1.26	1.24
Green manure +straw *Žalioji trąša +šiaudai*	1.21	1.20	1.28	1.16	1.37	1.29
Green manure +straw *Žalioji trąša +šiaudai*	1.15	1.23	1.24	1.18	1.22	1.32
Manure+straw / *Mėšlas + šiaudai*	1.18	1.20	1.34	1.28	1.36	1.37
LSD_{05} / R_{05}	0.21	0.20	0.09	0.19	0.16	0.21
Shallow tillage / *Seklus dirbimas*						
Plant residues / *Augalų liekanos*	1.08	1.02	1.22	1.24	1.28	1.30
Plant residues + straw *Augalų liekanos + šiaudai*	1.11	1.15	1.28	1.09*	1.23	1.28
Green manure +straw *Žalioji trąša +šiaudai*	1.14	1.27	1.32	1.16	1.24	1.25
Green manure +straw *Žalioji trąša +šiaudai*	1.23	1.29	1.34	1.22	1.33	1.31
Manure+straw / *Mėšlas + šiaudai*	1.28	1.32	1.39	1.16	1.24	1.29
LSD_{05} / R_{05}	0.22	0.28	0.12	0.13	0.14	0.12

* Significant at the 0.05 level / *Patikimumo lygis 0,05*

Table 5. Effect of primary tillage and organic fertilizers on topsoil moisture during spring rape growing period

5 lentelė. *Pagrindinio žemės dirbimo ir organinių trąšų įtaka dirvožemio drėgniui vasarinių rapsų vegetacijos laikotarpiu*

Vėžaičiai, 2005

Treatment *Variantas*	After sowing / *Po sėjos* BBCH-00			Flowering / *Žydėjimas* BBCH-65		
	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm
Deep ploughing / *Gilus arimas*						
Plant residues / *Augalų liekanos*	13.13	14.54	17.37	14.77	15.22	15.21
Plant residues + straw *Augalų liekanos + šiaudai*	15.56	15.16	17.52	14.96	15.53	15.96
Green manure +straw *Žalioji trąša +šiaudai*	11.46	16.06	17.28	13.48	13.17*	13.73
Green manure +straw *Žalioji trąša +šiaudai*	17.01	16.67	16.74	15.38	15.46	15.03
Manure+straw / *Mėšlas + šiaudai*	14.58	16.30	17.51	15.00	15.58	15.68
LSD_{05} / R_{05}	4.73	3.33	1.22	1.43	2.05	3.33
Shallow ploughing / *Seklus arimas*						
Plant residues / *Augalų liekanos*	16.53	18.17	18.63	14.68	15.40	14.62
Plant residues + straw *Augalų liekanos + šiaudai*	16.13	18.54	20.61	14.70	16.34	16.48
Green manure +straw *Žalioji trąša +šiaudai*	18.00	18.94	19.74	15.72	16.24	16.36
Green manure +straw *Žalioji trąša +šiaudai*	16.87	18.40	18.23	14.62	15.14	15.30
Manure+straw / *Mėšlas + šiaudai*	17.45	18.33	18.99	14.96	15.85	15.53
LSD_{05} / R_{05}	5.05	4.22	2.57	2.09	1.38	1.90
Shallow tillage / *Seklus dirbimas*						
Plant residues / *Augalų liekanos*	18.00	19.26	18.42	14.93	15.33	13.63
Plant residues + straw *Augalų liekanos + šiaudai*	14.53*	17.48	17.03	14.67	14.88	14.50
Green manure +straw *Žalioji trąša +šiaudai*	16.88	17.84	18.33	14.70	14.88	13.73
Green manure +straw *Žalioji trąša +šiaudai*	15.94	17.97	17.20	15.66	15.91	14.37
Manure+straw / *Mėšlas + šiaudai*	16.63	18.97	17.91	14.38	14.47	14.28
LSD_{05} / R_{05}	2.41	2.96	2.17	1.82	2.02	2.18

* Significant at the 0.05 level / *Patikimumo lygis 0,05*

A trend of a decrease in soil bulk density and an increase in soil moisture was obtained after incorporation of green manure and straw or manure and straw in the deep ploughed soil. A decrease in soil moisture content by 1-1.5 percentage units was identified after incorporation of organic mater in shallow tilled soil compared with ploughed soil.

Crop yield was under the influence of soil tillage and organic fertilizers. The highest winter triticale grain yield (4.07 t ha^{-1}) was obtained in deep ploughed soil as compared with the shallow ploughing and shallow tillage (Table 6).

Table 6. Effect of different tillage and organic fertilizers on crop rotation yield t ha^{-1}
6 lentelė. *Įvairaus žemės dirbimo ir organinių trąšų įtaka sėjomainos augalų derliui t* ha^{-1}

Vėžaičiai, 2004-2006

Treatment / *Variantas*	Winter triticale *Žieminiai kvietrugiai* 2004	Spring rape *Vasariniai rapsai* 2005	Spring barley *Vasariniai miežiai* 2006
Soil tillage in autumn (factor A) / *Žemės dirbimas rudenį (A veiksnys)*			
Deep ploughing / *Gilus arimas*	4.07	2.48	3.36
Shallow ploughing / *Seklus arimas*	3.71	2.41	3.38
Shallow tillage / *Seklus dirbimas*	3.34	2.12	3.02
$LSD_{05/01}$ / $R_{05/01}$	0.111 / 0.148	0.078 / 0.104	0.094 / 0.122
Organic fertilizer (factor B) / *Organinės trąšos (B veiksnys)*			
Plant residues / *Augalų liekanos*	3.60	2.15	3.11
Plant residues + straw *Augalų liekanos + šiaudai*	3.58	2.21	3.29
Green manure +straw *Žalioji trąša +šiaudai*	3.82	2.43	3.46
Green manure +straw *Žalioji trąša +šiaudai*	3.57	2.38	3.33
Manure+straw / *Mėšlas + šiaudai*	3.95	2.51	3.58
$LSD_{05/01}$ / $R_{05/01}$	0.143 / 0.192	0.101 / 0.135	0.118 / 0.157

From the viewpoint of spring rape and barley yield the deep and shallow ploughing did not differ essentially. In the shallow tillage soil the yield of spring rape and spring barley was significantly ($p > 0.02$) lower as compared with conventional deep ploughing. The lack of soil moisture during growing period was the main reason why a lower crop yield in shallow tillage soil was obtained.

The positive effect of organic fertilizers: green manure (biomass of red clover), straw (winter triticale and spring rape) on crop rotation plant yield was determined. Significantly ($p > 0.02$) highest yield of winter triticale was obtained in the soil with incorporation of green manure (biomass of red clover 1st cut) and cattle manure. All

organic fertilizers had a positive effect on spring barley yield. The spring barley yield was by 5.8-15.1 % higher as compared with the yield in plots where plant residues were incorporated into the soil. The effect of organic fertilizer in different tillage background was not the same. The highest winter triticale grain yield (4.35 t ha^{-1}) was obtained when green manure (biomass of red clover 1st cut) and deep ploughing or cattle manure and shallow ploughing were used. All organic fertilizers had a positive effect on spring rape yield in deep and shallow ploughed soil.

Conclusions

1. The amount of water stable aggregates was affected by the soil tillage means. The highest content of stable aggregates (65 %) was obtained in the plots of soil with shallow soil tillage. It was by 3.2 and 5.7 percentage units higher as compared with shallow and deep ploughed soil.

2. Different soil tillage means did not have any significant effect on the soil bulk density. A trend of an increase in topsoil (0-20cm depth) bulk density in the soil with shallow tillage was determined. The lowest (1.13 Mg m^{-3}) bulk density was obtained when the soil had been deep ploughed and winter triticale was grown.

3. Shallow ploughed or shallow tilled soil was by 2-3 percentage units wetter as compared with deep ploughed soil under favourable climatic conditions. From the viewpoint of soil moisture accumulated in topsoil under drought conditions mouldboard and shallow soil tillage means did not differ essentially.

4. A trend of a decrease in soil bulk density and an increase in soil moisture was obtained after incorporation of green manure and straw or manure and straw in the ploughed soil. A decrease in soil moisture content by 1-1.5 percentage units after incorporation of organic mater in shallow tilled soil in comparison with deep and shallow ploughed was estimated

5. The highest yield of crops: winter triticale grain (4.35 t ha^{-1}), spring rape seed (2.68 t ha^{-1}) and barley grain (3.93 t ha^{-1}) was obtained when the deep ploughing and organic fertilizers (cattle manure and straw) were used. The organic fertilizers (farmyard manure + straw or green manure + straw) had an essential effect on crop yield.

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ĮVAIRIŲ ŽEMĖS DIRBIMO BŪDŲ IR ORGANINIŲ TRĄŠŲ ĮTAKA DIRVOŽEMIO FIZIKINEI BŪKLEI IR AUGALŲ DERLIUI

D. Ožeraitienė, S. Čiuberkis

S a n t r a u k a

Straipsnyje apibendrinti 2003-2006 metais LŽI Vėžaičių filiale atlikti lauko ir laboratorinių tyrimų duomenys. Tirtas pagrindinio žemės dirbimo: 1. gilaus (22-25 cm) arimo; 2. seklaus (10-12cm) arimo; 3. seklaus (8-10cm) žemės dirbimo ir skirtingų organinių trąšų (šiaudų, kraikinio galvijų mėšlo ir žaliosios trąšos) įtaka moreninio priemolio dirvožemio pagrindiniams fizikinės būklės rodikliams (struktūrai, tankiui, drėgmei) ir sėjomainos augalų derliui. Nustatyta, kad žemės dirbimo būdai neturėjo esminės įtakos dirvožemio tankiui. Vandenyje patvarių agregatų > 0,25mm kiekis buvo didžiausias sekliai įdirbtame dirvožemyje. Moreninio priemolio dirvožemio fizikinei būklei pagerinti efektyvios buvo visos organinės trąšos, ypač mėšlas ir po jų kitais metais įterpti šiaudai. Didžiausias pirmosios sėjomainos augalų derlius gautas giliai suartuose laukeliuose. Sekliai įdirbtuose laukeliuose nustatytas esminis augalų derliaus sumažėjimas ($p > 0,01$). Dėl organinių trąšų (mėšlas + šiaudai ar žalioji trąša + šiaudai) poveikio iš esmės padidėjo sėjomainos augalų derlius ($p > 0,01$).

Reikšminiai žodžiai: dirvos dirbimas, organinės trąšos, dirvožemio fizikinė būklė, augalų derlius.

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