ISSN 1392-3196
Zemdirbyste / Agriculture, vol. 93, No. 4 (2006), p. 32-46
UDK 631.51:631.82

TILLAGE - FERTILIZATION MANAGEMENT PRACTICES TO SUSTAIN INTEGRITY OF SOIL PROPERTIES AND YIELDS IN A CROP ROTATION

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Abstract

One two-factorial field experiment was carried out at the Lithuanian Institute of Agriculture during 2002-2005. It was set up on a loamy *Endocalcari – Epihypogleyic Cambisol* relatively rich in nutrients.

The goal of the investigation was to study the changes in soil physical properties and crop yield as affected by different tillage and fertilization systems. Conventional tillage (CT), reduced tillage (RT) and no-tillage (NT) were investigated.

It was revealed that application of reduced tillage led to an increase in penetration resistance in arable soil layer by on average 106 % and in a decrease in air-permeability by on average 29 %, compared to conventional tillage. The application of no-tillage led to an increase in bulk density and penetration resistance in arable layer by on average 10 and 195 %, respectively and in a decrease in air-permeability by on average 59 %, compared to conventional tillage. During the 4 experimental years soil mobile P content in 0-20 cm layer decreased by on average 27 % in CT, 22 % in RT and 24 % in NT systems. Renouncement of conventional tillage and application of RT or NT systems secured lesser losses of mobile K in 0-20 20 cm soil layer: decrease in K content in CT system was 20 %, in RT 18% and in NT 12 %. Application of high rates of mineral NPK fertilizers was significant only for the first crop (spring wheat) of the fourth-course crop rotation. Increasing of fertilization level for the other subsequent crops was not profitable. Reduction of tillage intensity caused a decrease in profitability. Average profitability in CT system was 29 %, in RT system 20 % and in NT system 6 %.

Key words: soil tillage, mineral NPK fertilizers, soil physical properties, soil PK, yields, profitability.

Introduction

Sustainable or no-tillage management changes many soil chemical and physical properties compared with conservation tillage. Numerous investigations revealed that reduced tillage application improves soil physical properties: soil structure, water infiltration, aggregate stability /Šimanskaitė, 2002; Bronick, Lal, 2005/. However, ploughless tillage exerts some negative effects – an increase in bulk density and penetration resistance /Lampurlanes, Cantero-Martinez, 2003/. Some authors state that over time, the bulk density, similarly to penetration resistance, has a feature to return to its original state in spite of a tillage method used /Ferreras et al., 2000/. Feiza and Cesevičius (2006) reported that soil physical properties depended on the method and depth of tillage. The least penetration resistance was registered in traditionally tilled soil (stubble cultivation + ploughing, presowing tillage with a spring tine cultivator) and the highest one - in untilled soil (direct drilling). By reducing tillage depth and intensity soil air-permeability and air-filled porosity reduced and bulk density increased. Air-permeability investigations were a valuable measure to determine the initial stage of soil 'cultivation pan' formation. Ploughing or soil chiselling was the right way to avoid this phenomenon.

Some of the more evident changes in no-till management relate to a different distribution of phosphorus and potassium in the top soil. It usually leads to P and K stratification in soils. Both nutrients accumulate in the soil surface as a result of minimal mixing of surface – applied fertilizers and crop residues with soil, limited vertical movement of P and K in most soils, and cycling of nutrients from deep soil layers to shallow layers through nutrient uptake by roots /Karathanasis, Wells, 1990; Holanda et al., 1998; Howard et al., 1999; Yin, Vyn, 2004; Feizienė, Kadžienė, 2006/. Furthe-more, phosphorus sorption and potassium retention by soil constituents in surface layers of no-till soils often are reduced compared with conventionally tilled soils /Karathanasis, Wells, 1990/.

Tillage and fertilizer effect on crop yield depends on many other factors such as soil condition, water availability and rainfall received and tillage and fertilizer levels. The investigation on direct drilling carried out at the Lithuanian Institute of Agriculture revealed that the yield of winter wheat did not decrease after the one year of its application /Šimanskaitė, 2002/. Ardell et al. (2000) reported the highest 12 - year average of wheat grain yield under no – tillage and the highest rate of N application compared to conventional tillage. They found that the effect of tillage and N treatments on wheat grain yield was dependent on total plant available water. Many researches have suggested that crop response to tillage is a function of several interacting factors including crop species, soil and climatic conditions, and weather fluctuations /Lal, 1996; Feizienė, 2000; Ishaq et al., 2001/.

The experiment was designed to investigate and evaluate tillage-fertilization management practices for sustainability of soil properties and yields in wheat-barley-peas -wheat crop rotation.

Materials and methods

Site and soil description. The study site was located at the Lithuanian Institute of Agriculture in Dotnuva. The field trial was set up in July, 1999. The soil is an *Endocalcari - Epihypogleyic Cambisol,* sandy clay loam. Table 1 presents general soil characteristics of the site.

Experimental design. The field experiment consisted of four replicates of a randomized split-plot design. Each replicate included 3 tillage treatments as main plots (Factor A), which were split into 3 subplots with different mineral fertilizer application rates (Factor B). Table 2 shows the tillage and fertilization treatments.

Table 1. Soil characteristics at trial establishment
1 lentelė. *Dirvožemio charakteristika įrengiant bandymą*

Plough layer *Armens sluoksnis* cm	Bulk density *Tankis* Mg m^{-3}	Clay content *Dumblo kiekis* %	Available *Judrusis* P mg kg^{-1}	Available *Judrusis* K mg kg^{-1}	Total *Bendrasis* N %	Humus *Humusas* %	pH_{KCl}
34	1.30	25	140	217	0.123	2.10	6.8

Table 2. Experimental design
2 lentelė. *Tyrimų schema*

Tillage (factor A) / *Žemės dirbimas (veiksnys A)*		
Treatment *Variantas*	primary tillage / *pagrindinis dirbimas*	presowing tillage *priešsėjinis dirbimas*
CT	Conventional tillage: deep ploughing *Įprastas dirbimas: gilus arimas* (23-25 cm)	Spring tine cultivation *Seklus kultivavimas* (4-5 cm)
RT	Reduced tillage: shallow ploughing *Supaprastintas dirbimas - seklus arimas* (14-16 cm)	Spring tine cultivation *Seklus kultivavimas* (4-5 cm)
NT	No tillage / *Be žemės dirbimo*	Direct drilling / *Tiesioginė sėja*
Fertilization (factor B) / *Tręšimas (veiksnys B)*		
1	Not fertilized / *Netręšta*	
2	Moderate rates: NPK fertilizers according to soil properties and expected yield *Vidutinės trąšų normos, atsižvelgiant į dirvožemio savybes bei planuojamą derlingumą*	
3	High rates: NPK fertilizers according to soil properties and for 25-30 % greater expected yield than in treatment 2 / *Trąšų normos didesnės 25-30 % nei antrame variante*	

Crop rotation: 1) spring wheat (*Triticum aestivum* L.*)* cv. 'Munk'; the yield expected for this crop was 4.5 Mg ha^{-1} with moderate fertilizer rates and 6.0 Mg ha^{-1} with high fertilizer rates; 2) spring barley (*Hordeum vulgare* L.) cv. 'Luokė'; the yield expected for this crop was 4.0 Mg ha^{-1} and 5.5 Mg ha^{-1}, respectively; 3) peas *(Pisum sativum* L.) cv. 'Profi', the yield expected for this crop was 4.0 Mg ha^{-1} and 5.5 Mg ha^{-1}, respectively; 4) winter wheat (*Triticum aestivum* L.*)* cv. 'Širvinta'; the yield expected for this crop was 5.5 Mg ha^{-1} and 7.0 Mg ha^{-1}, respectively.

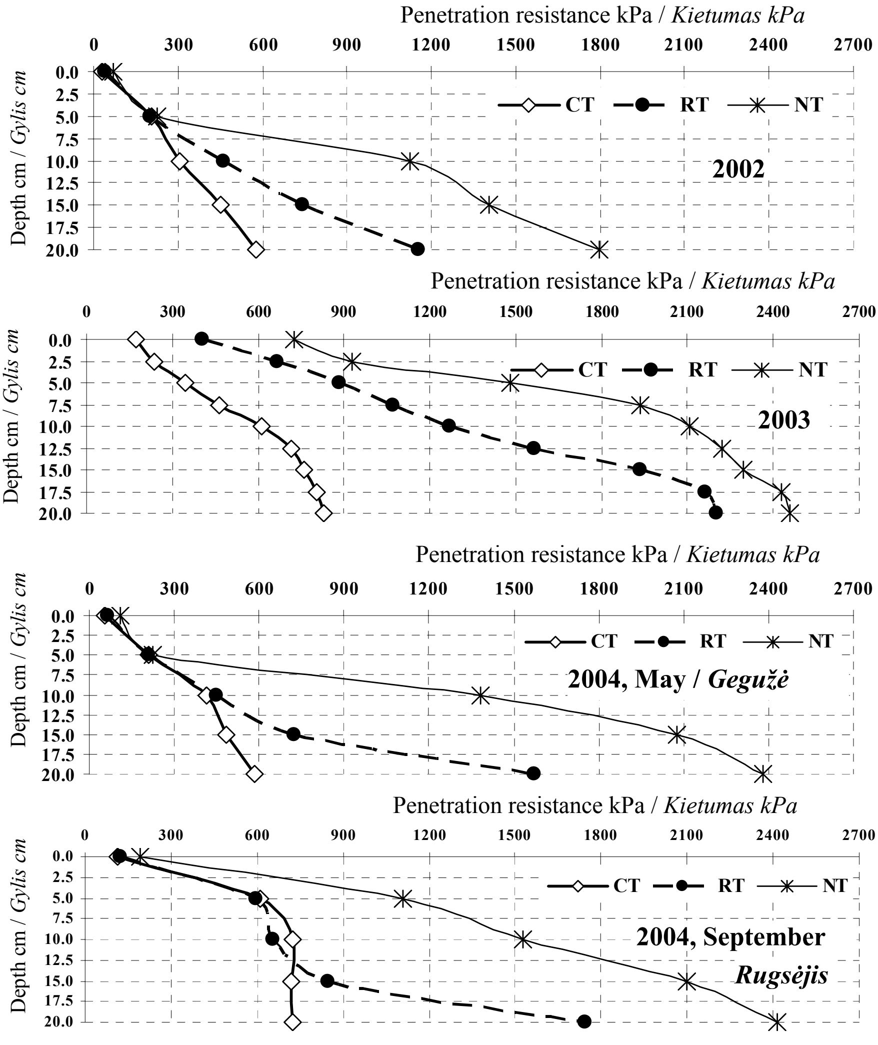
Fertilization. During crop rotation there were incorporated: moderate fertilizer rate $N_{222}P_0K_{118}$, high rate $N_{469}P_0K_{186}$.

Methods. Soil bulk density was determined according to Kachinsky method, soil penetration resistance – with Alex penetrometer, soil air permeability - according to Anderson method. Available P and K in the soil were determined by ammonium lactate (A-L) extraction.

Statistics. Analysis of variance was performed using the computer programme ANOVA. Statistical indices (probability level P, LSD_{05}, correlation coefficient) were calculated for treatment factor A, factor B, and for their interaction by STAT_ENG.

Results

Soil physical properties. *Penetration resistance*. The most favourable for crop growing level of penetration resistance in 0-20 cm soil layer was registered in soil after CT system application (Fig. 1). After different crops sowing it varied from 314 to 579 kPa. In RT system this index was by 66-146 % higher than in CT system. After direct drilling (NT system) it was by 154-236% higher compared to penetration resistance in CT system. Higher penetration resistance in RT and especially in NT system determined slower germination and growth of crops. Furthermore, the highest differences in penetration resistance among tillage systems were registered in 5-20 cm soil layer.



N o t e . In 0-5, 5-10, 10-15 and 15-20 cm soil layers LSD_{05} was as follows: 2002 – 46, 205, 150, 312; 2003 – 211, 450, 391, 562; 2004 – 41, 332, 219, 501; 2005 – 280, 262, 520, 665.

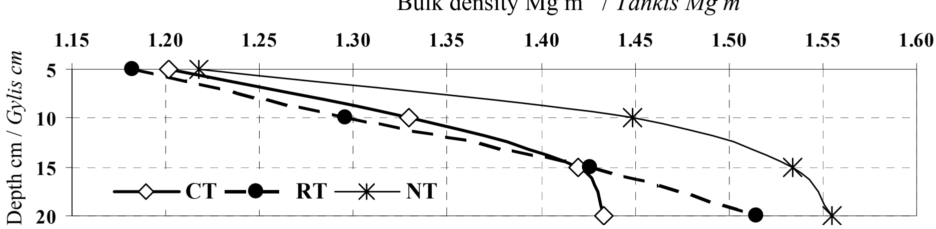
P a s t a b a . 0-5, 5-10, 10-15 ir 15-20 cm dirvožemio sluoksniuose R_{05} yra tokie: 2002 – 46, 205, 150, 312; 2003 – 211, 450, 391, 562; 2004 – 41, 332, 219, 501; 2005 – 280, 262, 520, 665.

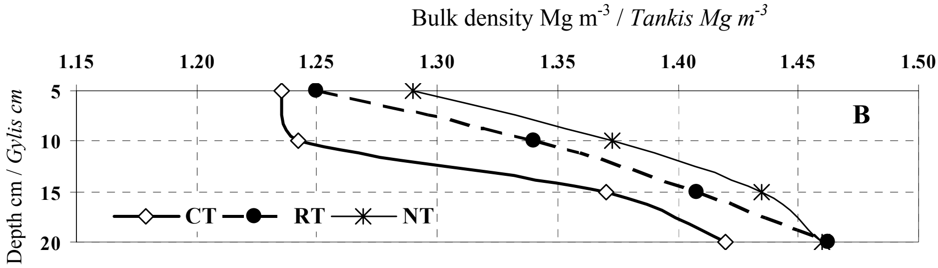
Figure 1. Soil penetration resistance after sowing of spring wheat (2002), spring barley (2003), peas (2004, May) and winter wheat (2004, September)

1 paveikslas. *Dirvožemio kietumas po vasarinių kviečių (2002 m.), vasarinių miežių (2003 m.), žirnių (2004 m., gegužė) ir žieminių kviečių (2004 m., rugsėjis) sėjos*

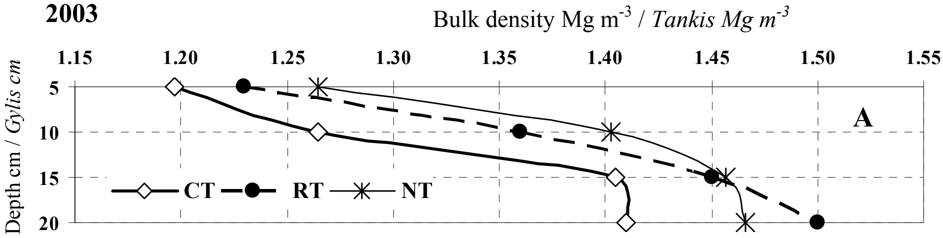
Soil bulk density after sowing in all experimental years was the lowest in the conventional tillage system. Application of RT and NT systems caused an increase in soil bulk density after crop sowing (Fig. 2). This index in different soil layers varied insignificantly. In the RT system it was only by 1-5 % higher and in the NT system by 6-14 % higher compared to bulk density index in the CT system. This tendency remained after harvesting. In experimental plots with application of RT system soil bulk density at this time of investigation was 2-4 % higher and in NT system 6-9 % higher as compared to bulk density index in the CT system.

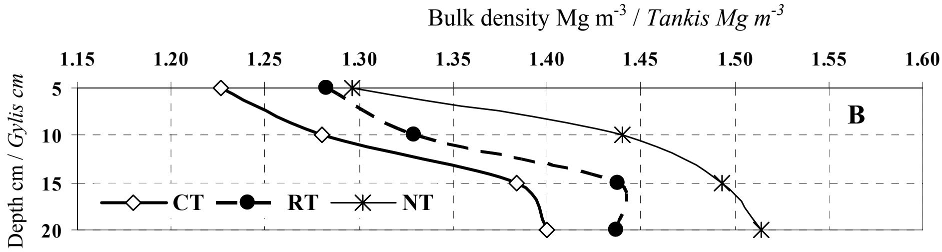
2002





2003





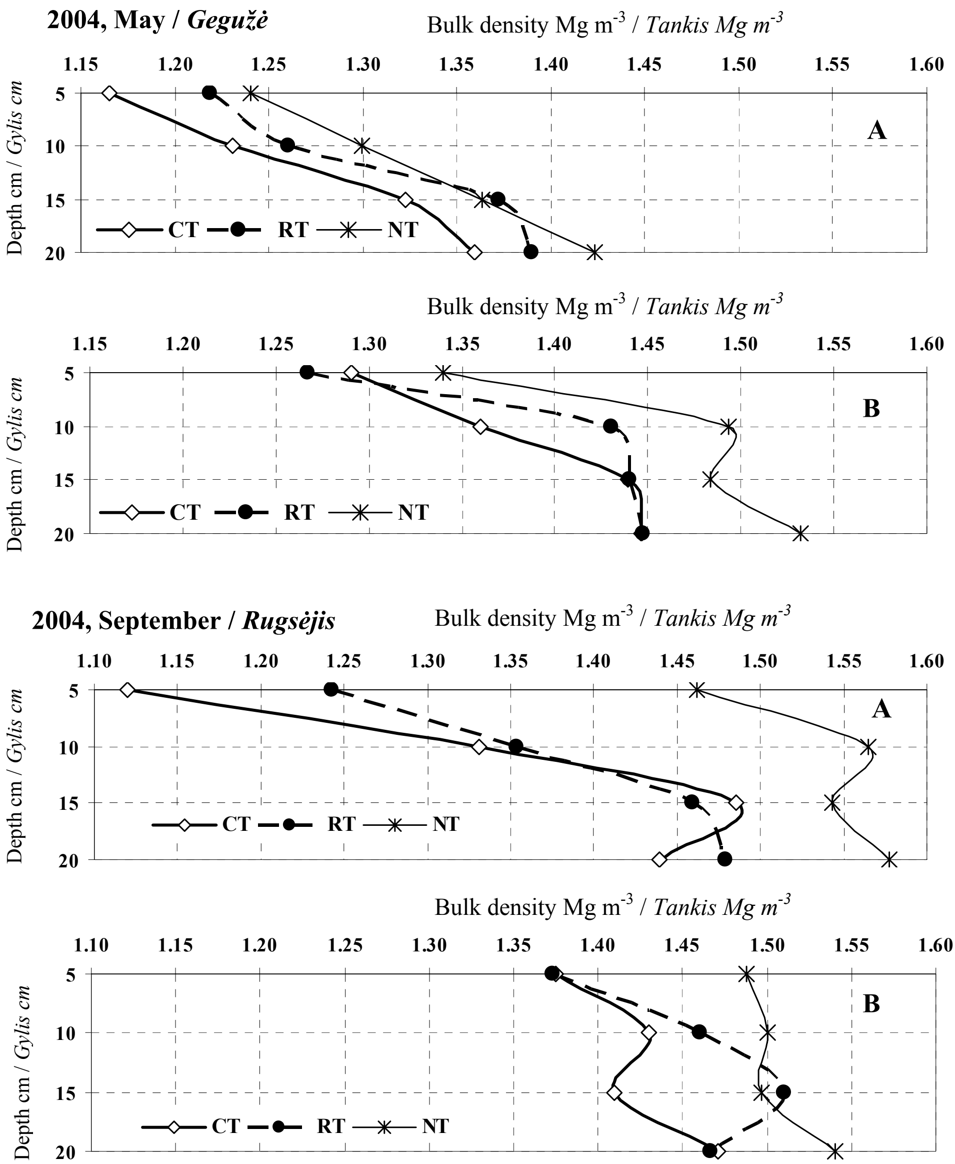
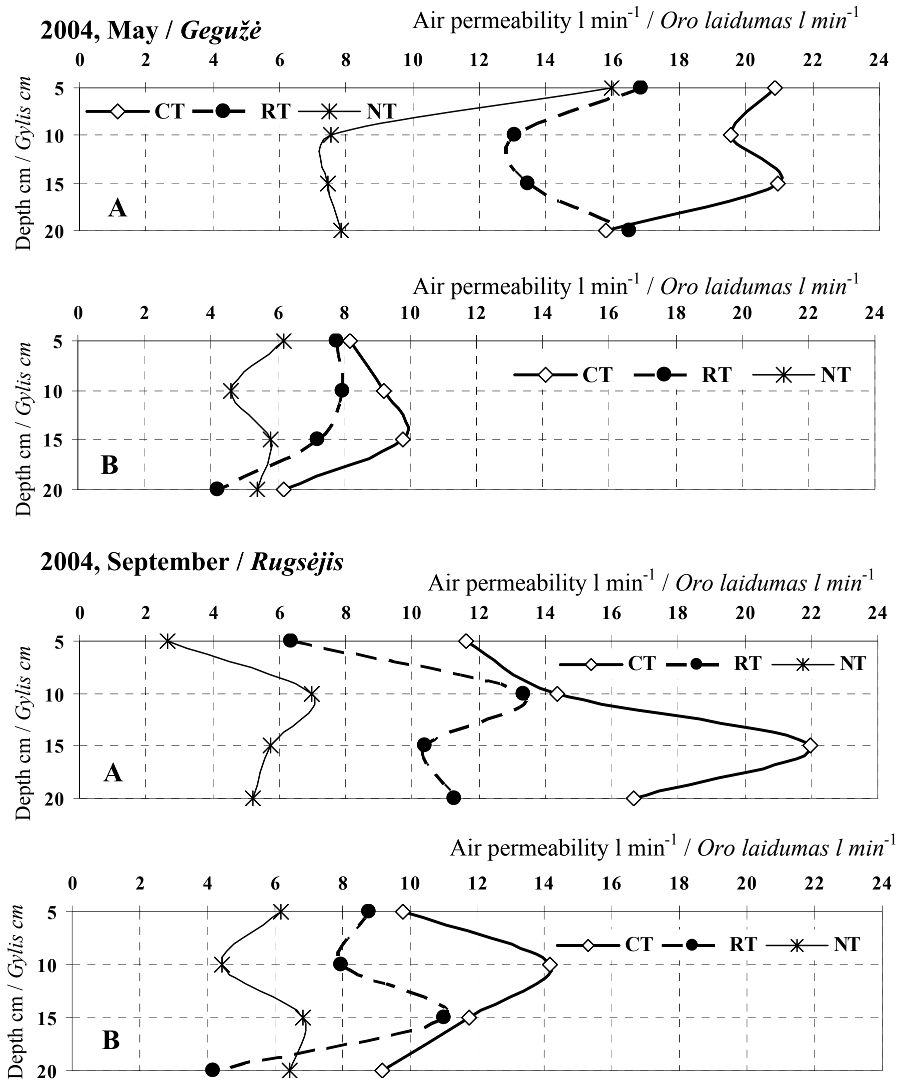


Figure 2. Soil bulk density after spring wheat (2002), spring barley (2003), peas (2004, May) and winter wheat (2004, September) sowing (A) and after harvesting (B)
2 paveikslas. *Dirvožemio tankis po vasarinių kviečių (2002 m.),vasarinių miežių (2003 m.), žirnių (2004 m., gegužė) ir žieminių kviečių (2004 m., rugsėjis) sėjos (A) ir derliaus nuėmimo (B)*

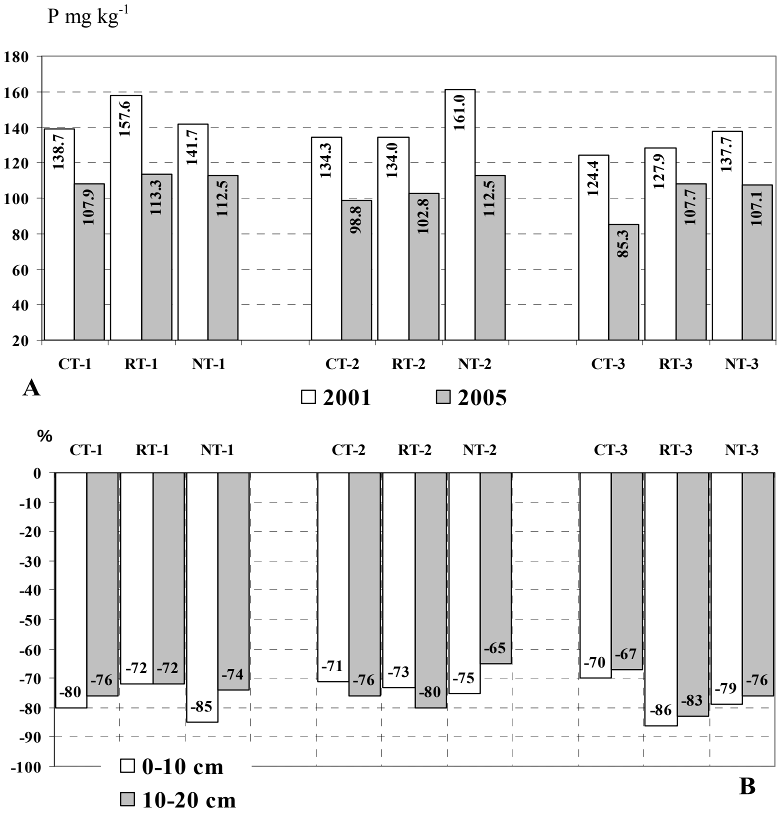


N o t e . In 0-5, 5-10, 10-15 and 15-20 cm soil layers LSD_{05} is as follow: in figure A: 2004 – 9.1, 15.7, 15.7, 22.4, 14.2; 2005 – 16.8, 9.1, 12.6, 10.2; in figure B: 2004 – 7.2, 14.5, 20.7, 11.2; 2005 – 12.1, 10.4, 8.5, 5.9.
P a s t a b a . 0-5, 5-10, 10-15 ir 15-20 cm dirvožemio sluoksniuose R_{05} yra tokie: paveiksle A: 2004 – 9.1, 15.7, 15.7, 22.4, 14.2; 2005 – 16.8, 9.1, 12.6, 10.2; paveiksle B: 2004 – 7.2, 14.5, 20.7, 11.2; 2005 – 12.1, 10.4, 8.5, 5.9.

Figure 3. Soil air-permeability after sowing (A) of peas (2004, May) and winter wheat (2004, September) and after harvesting of these crops (B)
3 paveikslas. *Dirvožemio laidumas orui po žirnių (2004 m., gegužė) ir žieminių kviečių (2004 m., rugsėjis) sėjos (A) ir derliaus nuėmimo (B)*

Soil air-permeability. The best air-permeability of 0-20 cm soil layer was registered after CT system application (Fig. 3). After peas (2004) and winter wheat (2005) sowing it varied from 16 to 19 L min^{-1}. In RT system this index was by 22-36 % lower than in CT system. After direct drilling (NT system) air-permeability was by 50-68 % lower compared to that in CT system. Low air-permeability in the soil in RT and especially in NT system determined worse conditions for germination and growth of the crops.

Soil phosphorus and potassium. At establishment of the experiment *Soil P content* in 0-20 cm layer varied from 124 to 161 mg kg^{-1} (Fig. 4, A). During a 4-year course crop rotation soil P content in the trial decreased and it varied from 85 to 113 mg kg^{-1}. This index in 0-20 cm layer decreased by on average 27 % in CT, 22 % in RT and 24 % in NT systems.



N o t e . In figure A: 2001 - $LSD_{05}(A) = 19.65$; $LSD_{05}(B) = 19.65$; $LSD_{05}(AB) = 34.04$; 2005 - $LSD_{05}(A) = 13.46$; $LSD_{05}(B) = 13.46$; $LSD_{05}(AB) = 23.32$.

P a s t a b a . Paveiksle A: 2001 - $R_{05}(A) = 19.65$; $R_{05}(B) = 19.65$; $R_{05}(AB) = 34.04$; *2005 -* $R_{05}(A) = 13.46$; $R_{05}(B) = 13.46$; $R_{05}(AB) = 23.32$.

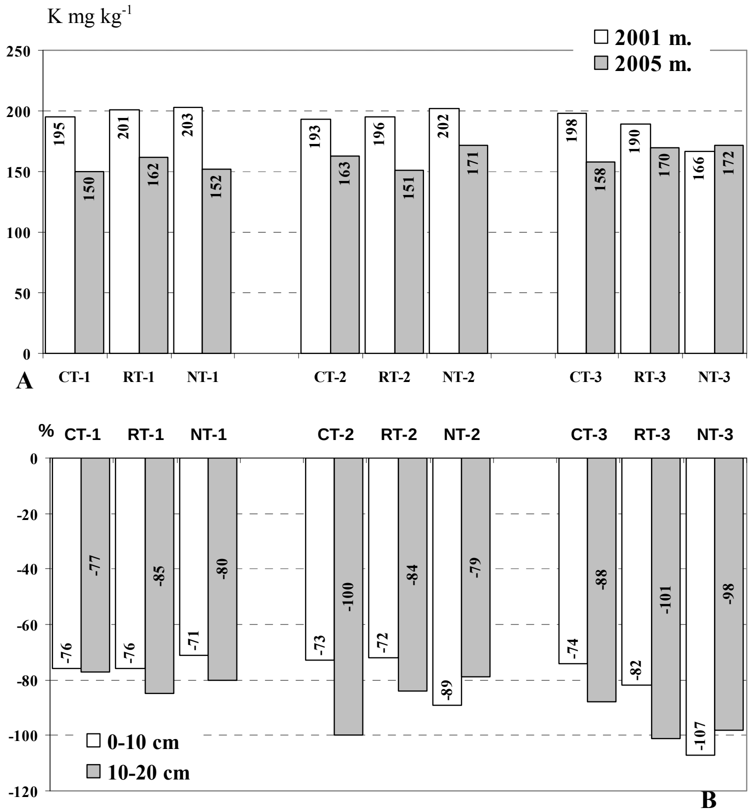
Figure 4. Actual P content at trial establishment and upon completion (A) and P content changes in % during crop rotation (B)

4 paveikslas. *Faktinis fosforo kiekis įrengiant ir užbaigus bandymą (A) ir fosforo kiekio pokytis % per sėjomainos rotaciją (B)*

Tillage influenced changes in soil mobile P content during crop rotation (Fig. 4, B). In the CT system in 0-10 cm soil layer P content decreased by on average 26 %, in the 10-20 cm layer – by 27 %. In the RT and NT systems the decrease reached 23 and 22 %, 20 and 28 %, respectively.

The increased rates of mineral fertilizers slacked up the decrease in soil P content, but did not block this process.

Soil K content varied from 166 to 203 mg kg^{-1} at establishment of the experiment (Fig. 5, A). During the 4-year course crop rotation soil K content in the trial decreased and varied on average from 150 to 172 mg kg^{-1}. Renouncement of conventional tillage and application of RT or NT systems secured lesser losses of mobile K in 0-20 cm soil layer: decrease of K content in CT system was 20 %, in RT 18 % and in NT 12 %.



N o t e . In figure A: 2001 – $LSD_{05}(A)$ = 24.61; $LSD_{05}(B)$ = 24.61; $LSD_{05}(AB)$ = 42.63; 2005 – $LSD_{05}(A)$ = 13.41; $LSD_{05}(B)$ = 13.41; $LSD_{05}(AB)$ = 23.23.

P a s t a b a . Paveiksle A: 2001 – $R_{05}(A)$ = 24.61; $R_{05}(B)$ = 24.61; $R_{05}(AB)$ = 42.63; 2005 – $R_{05}(A)$ = 13.41; $R_{05}(B)$ = 13.41; $R_{05}(AB)$ = 23.23.

Figure 5. Actual K content at trial establishment and upon completion (A) and K content changes in % during crop rotation (B)

5 paveikslas. *Faktinis kalio kiekis įrengiant ir užbaigus bandymą (A) ir kalio kiekio pokytis % per sėjomainos rotaciją (B)*

Tillage influenced changes in soil mobile K content during the crop rotation (Fig. 5, B). In the CT system in the 0-10 cm soil layer K content decreased by 26 %, in the 10-20 cm layer by 11 %. In the RT and NT systems the decrease reached 23 and 28 %, 11 and 14 %, respectively.

Moderate and high rates of mineral NPK fertilizers had no significant influence on the changes in mobile K content in soil during crop rotation period as compared to not fertilized soil.

Different tillage systems caused soil phosphorus stratification (Table 3). Experimental results showed different changes of ratio *P content at 0-10 cm layer / P content at 10-20 cm layer.* This ratio did not essentially change during the 4 years' period in CT and RT system, however in NT system it increased by 12 %.

Table 3. Ratio *P content at 0-10 cm layer / P content at 10-20 cm layer* and ratio *K content at 0-10 cm layer / K content at 10-20 cm*
3 lentelė. *Fosforo kiekio santykis 0-10 ir 10-20 cm dirvožemio sluoksniuose bei kalio kiekio santykis 0-10 ir 10-20 cm dirvožemio sluoksniuose*

	Treatment / *Variantai*								
	CT-1	CT-2	CT-3	RT-1	RT-2	RT-3	NT-1	NT-2	NT-3
	Ratio between soil P content in 0-10 and 10-20 cm layers *P kiekio santykis 0-10 ir 10-20 cm sluoksnyje*								
2001	0.99	0.98	0.99	1.03	0.98	0.96	0.92	1.01	1.02
2005	1.04	0.92	1.03	1.03	0.89	1.00	1.07	1.17	1.05
Change *Pokytis*	5	-6	4	0	-9	4	16	16	3
	Ratio between soil K content in 0-10 and 10-20 cm layers *K kiekio santykis 0-10 ir 10-20 cm sluoksnyje*								
2001	1.07	1.33	1.36	1.18	1.33	1.42	1.46	1.38	1.45
2005	1.06	0.96	1.14	1.06	1.14	1.16	1.29	1.55	1.57
Change *Pokytis*	-2	-28	-16	-10	-14	-19	-12	12	9

Different tillage systems caused soil potassium stratification. Experimental results showed different character in changes of ratio *K content at 0-10 cm layer / K content at 10-20 cm layer.* This ratio essentially decreased during 4 yeas in CT and RT systems (by on average 15 and 14 %, respectively) in NT-1 system it decreased also by 12 %, however in NT-2 and NT-3 systems it increased by 12 and 9 %, respectively.

The implication is that different soil physical conditions caused different availability of nutrients and different assimilation of these nutrients by crops.

Yields. Application of high rates of mineral fertilizers was significant only for the first crop (spring wheat) of the 4-course crop rotation. Increasing of fertilization level for other crops was not profitable (Fig. 6).

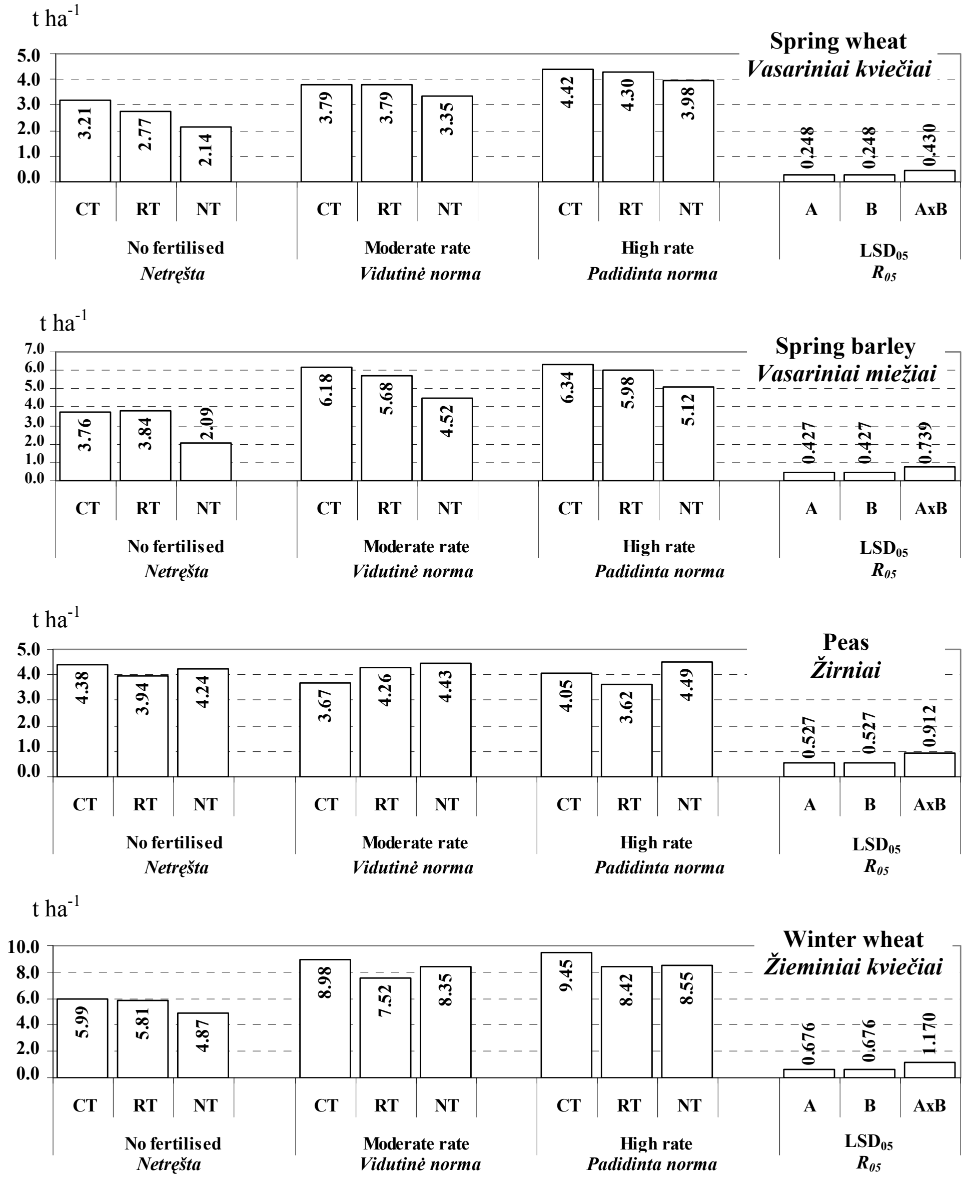


Figure 6. Grain yield of spring wheat, spring barley, peas and winter wheat after application of different tillage-fertilization systems
6 paveikslas. *Vasarinių kviečių, vasarinių miežių, žirnių ir žieminių kviečių grūdų derlingumas skirtingose žemės dirbimo-tręšimo sistemose*

The best grain yield of *spring wheat* was in the CT system (on average 3.81 t ha^{-1}). Grain yield in the RT system was by 5 % lower and in the NT system by 17 % lower compared to grain yield in the CT system. Moderate and high rates of fertilizers consistently increased grain yield. The yield after application with moderate rate was by

34 % higher and after application with higher rate of fertilizers was by 56 % higher than in the plots without fertilizers.

Average grain yield of *spring barley* in the CT system was 5.43 t ha^{-1}. Grain yield in the RT system was by 5 % lower and in the NT system by 28 % lower compared to grain yield in the CT system. Moderate rate of fertilizers increased grain yield by on average 69 % compared to unfertilized treatment. The yield after application with the high rate of fertilizers was by 80 % higher than in the plots without fertilizers. However, an extra grain yield after application with the high rate of mineral fertilizers was only by 6 % higher compared to the yield after application with the moderate rate.

Average grain yield of *peas* in the trial was 4.12 t ha^{-1}. Different tillage and fertilization did not cause any significant differences among grain yields in the trial plots.

Average grain yield of *winter wheat* in the CT system was 8.14 t ha^{-1}. Grain yields in the RT and NT systems were by 11 % lower compared to those in the CT system. Moderate rate of fertilizers increased grain yield by on average 49 % compared to unfertilized treatment. The yield after application with the highest rate of fertilizers was by 58 % higher than in the plots without fertilizers. However, the use of high rates of fertilizers was not effective. An extra grain yield after application with the high rate of mineral fertilizers was only by 7 % greater compared to the yield after application with the moderate rate.

The main factors which influenced yield were soil penetration resistance and fertilization level. The increase in penetration resistance tended to decrease yields. Correlation coefficient between penetration resistance and wheat and barley grain yield varied from -0.19 to -0.44. The correlation between this index and grain yield of peas was 0.56. This means that the increase of penetration resistance from 349 to 1236 had no affect on the yield. The correlation between fertilizer rate and wheat and barley grain yield was very strong, and the correlation coefficient varied from 0.77 to 0.94, while moderate and high rate of fertilizers for peas showed only a weak tendency to decrease yield ($r = -0.18$).

Profitability of unequal tillage-fertilization systems. Average expenditures in CT system were 1381 Lt ha^{-1} per year, in RT system 1374 Lt ha^{-1} per year and in NT system 1329 Lt ha^{-1} per year (Fig. 7). Net income was low. It varied in different tillage systems from 109 to 411 Lt ha^{-1} per year. Direct drilling practice without fertilizers caused economical unprofitability. There was registered a loss of 254 Lt ha^{-1} per year.

Moderate rate of fertilizers produced net income on average 420 Lt ha^{-1} per year. While, high rate of fertilizers produced lower net income by on average 4 % compared to moderate fertilisation.

Reduction of tillage intensity caused a decrease in economic profitability. Average profitability in CT system reached 29 %, in RT system 20 % and in NT system 6 %.

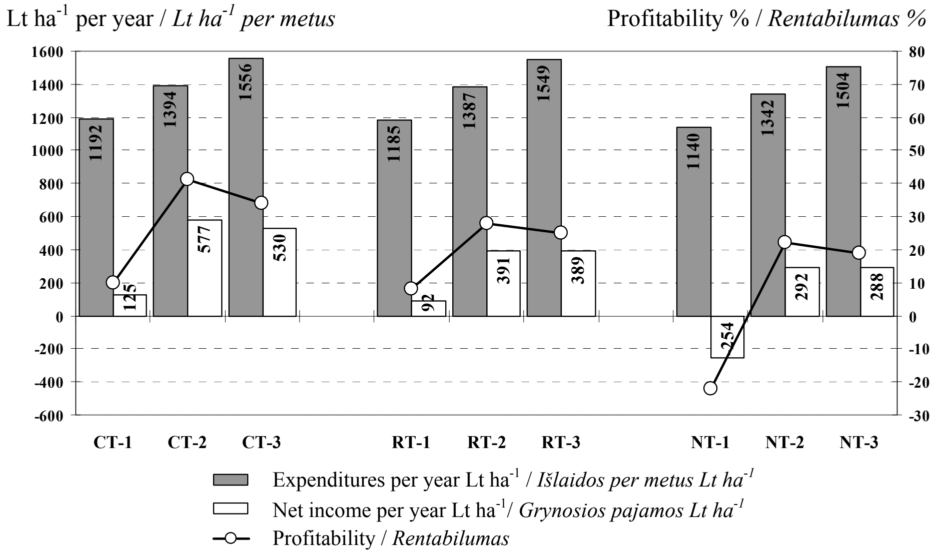


Figure 7. Expenditures, net income (Lt ha^{-1}) and profitability (%) per year after application of different tillage and fertilization systems
7 ***paveikslas.*** *Išlaidos, pelnas (Lt ha^{-1}) ir rentabilumas (%) per metus skirtingose žemės dirbimo-tręšimo sistemose*

Conclusions

1. Application of reduced tillage led to an increase in penetration resistance in arable soil layer by on average 106 % and to a decrease in air-permeability by on average 29 %, compared to conventional tillage.

2. The application of no-tillage led to an increase in bulk density and penetration resistance in arable soil layer by on average 10 and 195 %, respectively and to a decrease in air- permeability by on average 59 %, compared to conventional tillage.

3. During the 4 years of the experiment soil mobile P content in 0-20 cm layer decreased by on average 27 % in CT, 22 % in RT and 24 % in NT systems.

4. Renouncement of conventional tillage and application of RT or NT systems secured lower loss of mobile K in 0-20 cm soil layer: a decrease in K content in CT system was 20 %, in RT 18 % and in NT 12 %.

5. Application of high rates of mineral fertilizers was significant only for the first crop (spring wheat) of the four-course crop rotation. Increasing of fertilization level for other crops was not profitable.

6. Reduction of tillage intensity caused a decrease in profitability. Average profitability in CT system was 29 %, in RT system 20% and in NT system 6 %.

Received 18 09 2006
Accepted 02 11 2006

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ISSN 1392-3196
Žemdirbystė, t. 93, Nr.4 (2006), p. 32-46
UDK 631.51:631.82

ŽEMĖS DIRBIMO IR TRĘŠIMO ĮTAKA DIRVOŽEMIO SAVYBIŲ INTEGRALUMO PALAIKYMUI BEI AUGALŲ DERLINGUMUI SĖJOMAINOJE

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Santrauka

Vienas dviejų veiksnių lauko bandymas darytas Lietuvos žemdirbystės institute 2002-2005 m. Dirvožemis – giliau karbonatingas sekliai glėjiškas rudžemis (*Endocalcari-Epihypogleyic Cambisol*), smėlingas priemolis, sąlyginai turtingas augalų maisto medžiagų. Tyrimų tikslas – ištirti dirvožemio fizikinių savybių pokyčius bei augalų derlingumą naudojant skirtingas žemės dirbimo-tręšimo sistemas.

Nustatyta, kad žemės dirbimą supaprastinus dirvožemio kietumas armenyje padidėjo 106 %, oro laidumas sumažėjo 29 %, nei žemę dirbant įprastu būdu. Tiesiogiai sėjant į nedirbtą dirvą dirvožemio tankis ir kietumas armenyje buvo atitinkamai 10 ir 195 % didesni, o oro laidumas 59 % mažesnis, nei žemę dirbant įprastu būdu. Per 4 tyrimų metus, dirvožemio judriojo P kiekis 0-20 cm dirvožemio sluoksnyje, dirbant žemę įprastai, sumažėjo vidutiniškai 27 %, dirbant ją minimaliai – 22 %, o taikant tiesioginę sėją – 24 %. Kalio kiekis dirvožemyje sumažėjo taikant įprastą žemės dirbimą 20 %, taikant supaprastintą – 18 %, o taikant tiesioginę sėją – 24 %. Naudoti padidintas mineralinių NPK trąšų normas verta buvo tik auginant pirmąjį sėjomainos rotacijos augalą – vasarinius kviečius. Trąšų normas didinti kitiems sėjomainos augalams buvo ekonomiškai nenaudinga. Mažinant žemės dirbimo intensyvumą, mažėjo ir rentabilumas. Žemę dirbant įprastu būdu, supaprastintai bei taikant tiesioginę augalų sėją į nedirbtą dirvą, vidutinis rentabilumas buvo atitinkamai 29; 20 ir 6 %.

Reikšminiai žodžiai: žemės dirbimas, mineralinės NPK trąšos, dirvožemio fizikinės savybės, dirvožemio PK, derlingumas, rentabilumas.

Acknowledgements

The research has been supported by the Lithuanian State Science and Studies Foundation and UAB "Litagros chemija".

Padėka

Tiriamąjį darbą rėmė Lietuvos valstybinis mokslo ir studijų fondas ir UAB „Litagros chemija".