Crop and soil management adaptation to sustain field crop productivity and improve soil water regime under global changing climatic conditions in Lithuania

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1. Summary

The goal of this study was to evaluate the changes of soil physical properties and conservation of plant available soil moisture content by implementing different tillage systems.

It was revealed that CT produced the best soil physical properties (the lowest bulk density, cone penetration resistance, and the highest air permeability). Significantly worse soil physical properties were registered after NT. NT caused greater soil moisture content after crop sowing in upper 0-5 and 5-10 cm layers, while this index in deeper layers was essentially lower compared to both conventional and reduced tillage. Because of improving of soil moisture regime in the upper 10 cm layer under no-tillage, its functional ability deteriorated in the 10-20 cm layer. The same tendency persisted during overall vegetation period of all crops investigated. After spring crop sowing the best conservation of soil productive moisture in the 0-10 cm layer was under NT. Optimal soil moisture content was also under NT. Unfortunately during later crop vegetation period of productive and optimal soil moisture reduction was significantly lower under NT compared to CT at the same soil layer. Soil productive and optimal moisture changes were similar in 10-20 cm layer in spite of tillage system used.

2. Introduction

Climate change is becoming one of the main factors directly or indirectly affecting the productivity of agricultural crops, the efficiency and stability of agriculture and related industries. Reality of climate changes requires a careful revision of traditional soil and plant management technologies. In addition, a new approach and propagation of sustainable soil management technologies implementation in practical farming becomes very important. Soil is a dynamic resource that supports plants. It has biological, chemical, and physical properties, some of which change in response to how the soil is managed. A wide range of different factors indicate a soil that functions effectively today and will continue to do that in the future. Creating soils with favourable characteristics can be accomplished by utilizing management practices that optimize the processes found in native soils.

Climate changes require careful revision of traditional soil and plant management technologies. Forecast of the global climate change emphasises that the air temperature in Lithuania will increase. The amount of precipitation will increase marginally; while rainfall will continue to decrease in summer. An increase of aridity will be the highest in the June - September period. Consequently, soil, nutrient assimilation level, tillage and sowing time and intensity may vary. Due to this a new approach and propagation of sustainable soil management technologies implementation in practical farming is vital. The new trend of land and soil management encourages to observe and to evaluate essential changes of soils and environment.

Numerous studies have shown that soil water deficiency has significant effects on plant growth (Li et al., 2001). Far fewer studies have focused on the below-ground response of plants, especially crops, to drought stress. Water deficiency in spring wheat has been shown to reduce growth of above-ground organs, leaf photosynthesis and leaf transpiration (Larionova et al., 1998; Sritharan et al., 1992).

The main goal of this study was to evaluate the changes in soil properties under different tillage treatments and to investigate physical, physico-hydrological (water regime, which describes water characteristics and parameters) properties of clay loam soil (*Endocalcari - Epihypogleyic Cambisol).*

3. Materials and methods

The study site was located in the Lithuanian Institute of Agriculture (LIA) on a cultivated field of Central Lithuania ($55^0$23'50'' N and $23^0$51'40'' E). Field trial was set up in 2005. The soil was *Endocalcari - Epihypogleyic Cambisol,* with texture of sandy clay loam (according to the USDA system of particle size distribution (Sheldric and Wang, 1993)). Field experiments consisted of 4 replicates of a randomized plot design. Each replicate included 3 tillage treatments (CT - Conventional tillage: deep ploughing (23-25 cm) + spring tine cultivation (4-5 cm); RT - Reduced tillage: shallow ploughing (14-16 cm) + spring tine cultivation (4-5 cm); NT – (No tillage + direct drilling). Crops grown: spring oil-seed rape and spring wheat. 2006 was dry, 2007 – wet.

Soil bulk density (BD) was determined according to Kachinsky method. Cone penetration resistance (PR) was determined under *in situ* 1 week after sowing and in middle of June. Measurement were taken in increments of 5.0 cm, from the soil surface down to 20 cm depth, with a penetration velocity of about 1 m min^{-1}. PR was determined at one position, i.e. in the untrafficked interrow. Soil air permeability (AP) was determined according to Anderson method. Field moisture capacity (FMC) – by Dolgov method; capillary water content at discontinuity of water capillarity functioning (MCD) – calculated according to Rode, Reppo (70% FMC); wilting point (WP) calculated according Vadiunina and Korchiagina (WP= Max. higroscopicity x 1.5), productive soil moisture content, mm (FMC – WP).

4. Results and discussion

4.1 Soil physical properties. Our data are in line with numerous experiments showing that *BD and PR* are greater in NT in the first 5-10 cm of soil, compared to CT (Lampurlanes and Cantero-Martinez, 2003; Taser and Metinoglu, 2005), but they are inverse to the results, which state, that no differences in BD are between tillage systems (Logsdon and Cambardella, 2000) or BD even decreased under NT (Edwards, 1996). Some authors state that BD is one of the most important indices of soil physical properties (Campbell and O'Sullivan, 1991). Unfortunately, over time, bulk density similar to penetration resistance has a feature to return its original state in spite of a tillage method used (Ferreras *et al*., 2000).

CT influenced lowest BD and PR in all experimental years. Data suggested that soon after different crops sowing BD was 1.32±0.02 Mg m^{-3} under CT in 0-20 cm soil layer (Fig. 1). RT conditioned significant increase in BD compared to CT. This index in NT plots was essentially higher, than in CT and RT plots. This consistent pattern was most evident in 5-10, 10-15 and 15-20 cm soil layers. Admittedly, during crop vegetation the soil BD returned back to the initial values registered before sowing. Nevertheless, the same regularity of tillage effects continued during overall vegetation period of all crops investigated.

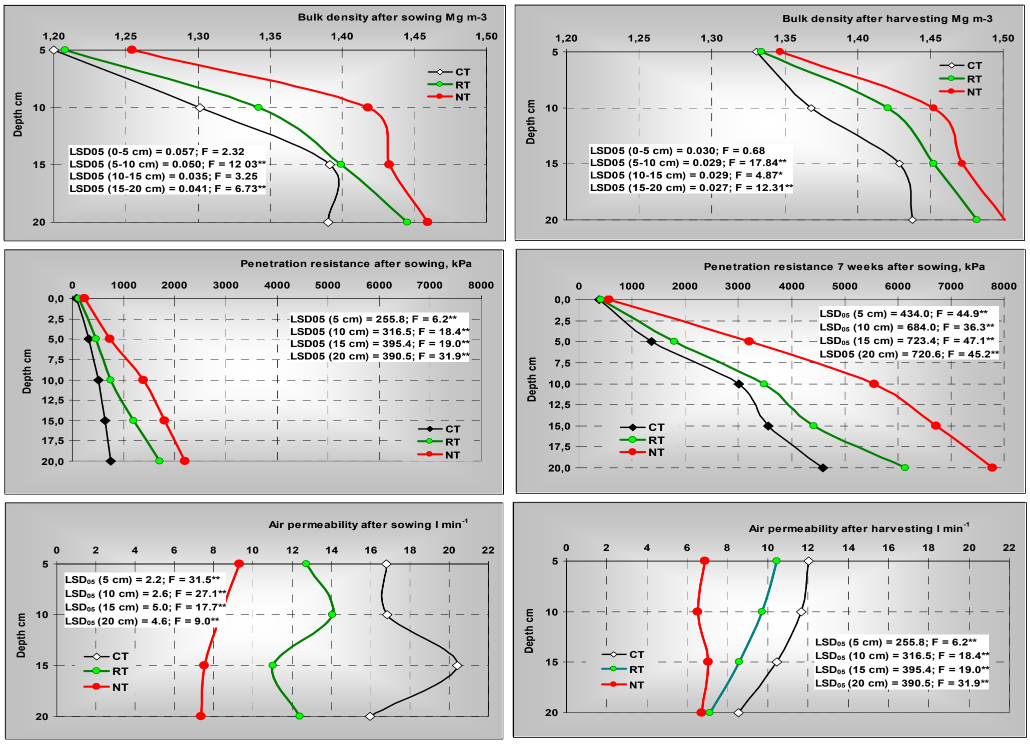

Figure 1 Soil physical properties under different tillage

Tillage treatments shoved significant differences in soil PR at the all investigated soil depth during 7 weeks period. Variation of PR during different years of investigation was not significant. Soil PR value of 2000 kPa is defined as the upper limit for unrestricted root penetration (Veiga et al, 2007). The greatest PR after sowing was founded under NT. In the 20 cm layer PR amounted on average to 1280±200 kPa. CT and RT determined lover PR by 2.8 and 1.5 times, respectively, compared to NT. Moreover, the greatest differences in PR among tillage systems were registered in the 5-20 cm soil layer. The deeper soil layers the higher differences among PR in unequal tillage plots was revealed. It was observed that PR increased noticeably during May-June period, while differences among tillage treatments still persisted. Crop residues significantly decreased penetration resistance in the 5-10 cm soil layer only.

Reduction of soil mixing causes not only increase in soil BD and PR, but also reduces soil *AP (*Schjønning and Rasmussen, 2000). Really, the best AP was registered after CT application. Under NT the AP was by 50-68 % lower compared to AP under CT system. AP values (like other physical properties of soil) as influenced by the application of RT were considered to be intermediate between CT and NT.

NT caused greater soil moisture content after crop sowing in upper 0-5 and 5-10 cm layers, while this index in deeper layers was essentially lower compared to both CT and RT. Because of improving of soil moisture regime in the upper 10 cm layer under NT, its functional ability deteriorated in the 10-20 cm layer. The same tendency persisted during overall vegetation period of all crops investigated. In summary, the results of the investigation revealed, that the NT was more favourable for increasing and keeping up of moisture in the top-soil layer unexceptionally. It was especially important during seed germination and early growth stages of crops. Therefore, our data corresponds with scientific results of other researchers, which propose that NT determines wetter soil conditions /Rasmussen, 1999; Riley et al., 2005; Licht and Al-Kaisi, 2005; Velykis and Satkus, 2005; De Vita et al., 2007/.

4.2 Soil water regime. In dry spring of 2006 after crop sowing field moisture capacity (FMC) under RT was significantly lower compared to CT in both 0-10 and10-20 cm layers. FMC after NT application was significantly greater compared to CT in 0-10 cm layer, while it did not differ in 10-20 cm layer. Dry summer conditions and long-term impact of primary tillage caused FMC differences after harvesting also. This index had tendency of reduction in RT and NT in 0-10 cm layer, while in 10-20 cm layer it was greater compared to CT (Fig. 2).

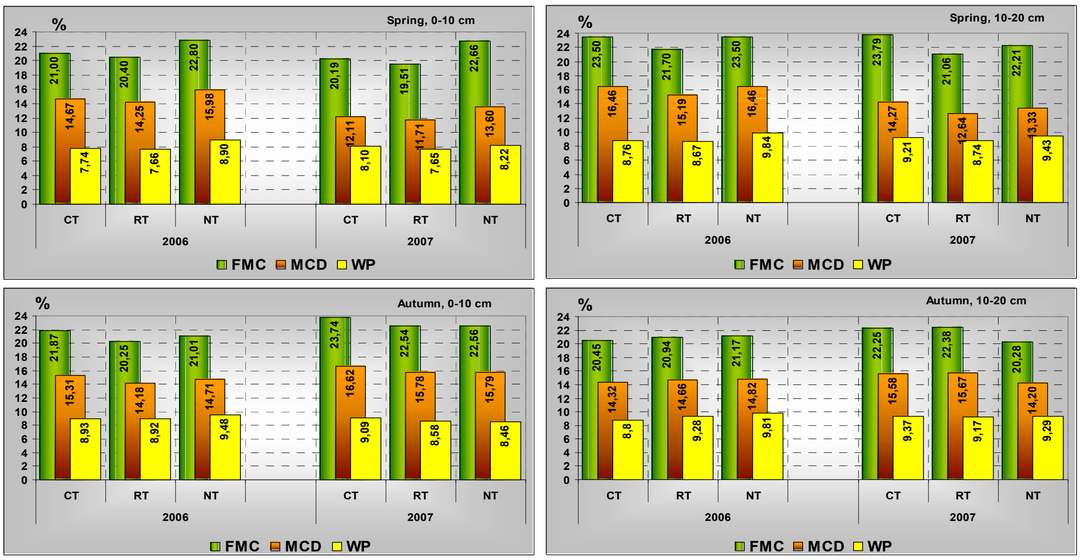

Figure 2 Soil hydrological properties

In spring of 2007 after crop sowing FMC under RT was significantly lower compared to CT in both 0-10 and 10-20 cm layers. FMC after NT application was significantly greater in 0-10 cm layer, and lower in 10-20 cm layer compared to CT. Differences among FMC under different tillage were not significant after harvesting.

Moisture at capillarity discontinuity (MCD) – soil moisture than water capillary move is discontinue and does not rise up surface of evaporation. Level of this index under NT in early stage of crops vegetation in both 2006 and 2007 in 0-10 cm layer was significantly higher compared RT and CT. Differences among MCD under different tillage were not significant in the 10-20 cm layer in spring time and after harvesting in both soil layers.

Wilting point (WP) - is defined as the minimum soil moisture at which a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. However, it is noted that the WP values under field conditions are not constant for any given soil, but are determined by the integrated effects of plant, soil and atmospheric conditions. Our data shoved that WP under NT was higher compared to RT and CT. It means that risk of plant wilting is higher in NT than in CT or RT, especially under dry climatic conditions.

FMC, MCD and WP are main indices for assessing the *range* of soil productive (RPM) and optimal (ROM) moisture. Soil productive moisture is in the interval between WP and FMC. Soil optimal moisture is in the interval between MCD and FMC. There was determined that RPM after spring crop sowing under NT in dry spring of 2006 in the 0-10 cm layer was marginally (5 – 9 %) higher than under CT or RT. These differences in wet spring of 2007 were 19 and 22 %, respectively. In the 10-20 cm layer RPM differences between NT and RT were not significant, while interval RPM under NT was straiter by 7 (in 2006) and 12 % (in 2007) than in the CT system. ROM after spring crop sowing under NT in dry spring of 2006 in the 0-10 cm layer was marginally (8 – 11 %) higher than under CT or RT. These differences in wet spring of 2007 were 12 and 16 % respectively. In the 10-20 cm layer ROM differences among NT, RT and CT were not significant.

Differences RPM and ROM under different tillage were not significant in the autumn, while character of changes of these indices during crop vegetation period (from May to September) were demonstrative. In dry 2006, in the 0-10 cm soil layer RPM did not essentially changed in CT and RT, while it reduced by 17 % in NT. In wet 2007 year this index increased in CT and RT by 21 and 18 % respectively, while it did not changed in NT. In the 10-20 cm soil layer, in 2006 RPM decreased by 17-21 %, in 2007 by 12-14 % in all tillage systems.

These results obtained let us to draw up these main conclusions: After spring crop sowing the best conservation of soil productive moisture in the 0-10 cm layer was under NT. Optimal soil moisture content was also under NT. Unfortunately during later crop vegetation period of productive and optimal soil moisture reduction was significantly lower under NT compared to CT at the same soil layer. Soil productive and optimal moisture changes were similar in 10-20 cm layer in spite of tillage system used.

4.3 Productivity of wheat and oil-seed rape. Different tillage and climatic conditions produced different crop yields. Mean wheat yield (2.91 Mg/ha) in 2006 was lower on average by 47.7% compared to yield in 2007. In both 2006 and 2007 years NT produced on average 27 % lower yield compared to CT and 10 % lower yield compared to RT. Mean oil-seed rape yield (1.57 Mg/ha) in 2006 was lower on average by 46.6% compared to yield in 2007. In dry 2006 years NT produced on average 13 % higher yield compared to CT and 2 % higher yield compared to RT. In wet 2007 yield was similar under different tillage systems and reach 2.92-2.96 Mg/ha.

5. Conclusions

1. CT produced the best soil physical properties (the lowest bulk density, cone penetration resistance, and the highest air permeability). Significantly worse soil physical properties were registered after NT.
2. NT caused greater soil moisture content after crop sowing in the upper 0-5 and 5-10 cm layers, while this index in deeper layers was essentially lower compared to both conventional and reduced tillage. Because of improving of soil moisture regime in the upper 10 cm layer under no-tillage, its functional ability deteriorated in the 10-20 cm layer. The same tendency persisted during overall vegetation period of all crops investigated.
3. After spring crop sowing the best conservation of soil productive moisture in the 0-10 cm layer was under NT. Optimal soil moisture content was also under NT. Unfortunately during later crop vegetation period the productive and optimal soil moisture reductions were significantly lower under NT compared to CT at the same soil layer. Soil productive and optimal moisture changes were similar in 10-20 cm layer in spite of tillage system used.

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