European Journal of Agronomy 94 (2018) 12–24

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

After-effects of long-term tillage and residue management on topsoil state in Boreal conditions

Dalia Feiziene[a,*], Virginijus Feiza[b], Aldis Karklins[c], Agne Versuliene[b], Daiva Janusauskaite[a], Sarunas Antanaitis[a]

[a] Department of Plant Nutrition and Agroecology, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Instituto al. 1, Akademija, Kedainiai distr., LT-58344, Lithuania

[b] Department of Soil and Crop Management, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Instituto al. 1, Akademija, Kedainiai distr., LT-58344, Lithuania

[c] Institute of Soil and Plant Sciences, Latvia University of Agriculture, Liela str. 2, Jelgava, LV-3001, Latvia

ARTICLE INFO

Keywords:
No-tillage
Residues
Top-soil
Pore-size distribution
Soil organic carbon
Water content
Soil texture

ABSTRACT

It is known that all processes in soil act in close interdependence and are site- and soil-specific, and climate and human activity dependent. Numerous studies have been done worldwide on soil structural composition, soil organic carbon (SOC) sequestration and soil CO_2 efflux investigation, although most of published results were obtained in conditions different from the soil type, texture and climate conditions in the Nemoral-2 environmental/Boreal climatic zone. The effects of long-term tillage treatments on soil properties are seldom reported in Boreal conditions. The objective of this study was to assess the subsequent long-term cumulative effects of 17 years of conventional (CT) and no-tillage (NT) in combination with straw removal or return, on SOC accumulation, soil pore-size distribution (PSD), water release characteristics (WRC) and CO_2 efflux on loam and sandy loam within a 0–10 cm layer of *Cambisol* during the main development stages of winter wheat.

A more pronounced superiority of NT over CT for SOC sequestration rate within the topsoil layer emerged on loam than on sandy loam. The total volume of transition and storage pores, which is responsible for better soil water movement, was higher in sandy loam then in loam and under NT than under CT. However, a higher retention of topsoil moisture during the main growing stages of winter wheat was on loam than on sandy loam.

Straw on loam acted as a material for soil loosening by increasing the total volume of fissures, transition and storage pores. Meanwhile, on sandy loam, the straw acted as a pore clogging material by decreasing the total volume of the same pores. Consequently, on loam, in spite of a high capability of NT with residue return to storage plant available water (PAW), the topsoil moisture during dry weather conditions at the main growing stages of winter wheat was lower than under other soil management practices. On sandy loam, NT with residue returning governed the highest PAW content and maintained the highest topsoil moisture. Nevertheless, the highest potential to reduce CO_2 efflux on both loam and sandy loam has been demonstrated by CT with residue return.

1. Introduction

Soil degradation remains one of the most important issues in the context of modern land use and anthropogenic transformation of the environment. Agro-ecological theory highlighted the negative changes in soil properties and structure in different soils due to human activities. The degradative impact of the anthropogenic factor is evident in the formation of strongly aberrant soil layers due to the use of heavy machinery and inappropriate soil management practices, and/or by reduction of organic matter (OM) and soil water availability (Volungevicius et al., 2015). A declining trend of soil carbon (C) sequestration has been observed in the agricultural soils in many European countries (Riley and Bakkegard, 2006; Capriel, 2013; Heikkinen et al., 2013; Wiesmeier et al., 2015). At present, there is great concern over increasing the soil C sequestration rate. Aboveground residue management tends to have a surprisingly small effect on soil C stocks, which can be related, e.g., to the relatively small significance of the aboveground residue. The benefits of no-till are clearly controlled by the annual precipitation rate, predicting poor C sequestration potential in Northern European conditions. Most studies suggest that the soil

* Corresponding author.
E-mail address: dalia.feiziene@lammc.lt (D. Feiziene).

https://doi.org/10.1016/j.eja.2018.01.003
Received 6 November 2016; Received in revised form 5 January 2018; Accepted 8 January 2018
1161-0301/

carbon in mineral soils is decreasing and it is not predicted that the C stock of mineral agricultural soils can be remarkably increased by changing agricultural practices (Heikkinen et al., 2013; Singh et al., 2015).

There is no consensus of opinion that soil structure formation, C sequestration and CO_2 emissions can be affected by soil management practices, or any consensus as to their relationships with soil texture. It is known that reduced tillage practices, such as no-tillage (NT) and direct seeding, have had very different adoption levels in practical farming worldwide. Europe is not an exception. According to Eurostat data (2013), almost two-thirds of the arable land in the EU-27 is conventionally tilled, while about a fifth of it is under conservation tillage. NT is practiced rarely. This demonstrates that NT is both site-specific and soil and climate dependent.

Crop residues and reduced tillage have become preferred practices in modifying tillage due to their better water management and soil organic matter (SOM) and nutrient supply (Glab and Kulig, 2008; Becher, 2005; Sharma et al., 2016; Farina et al., 2016; Augustin and Cihacek, 2016; Whisler et al., 2016). Küstermann et al. (2013) recorded the highest soil organic carbon (SOC) content under the lowest tillage intensity. A higher content of OM and nutrients under NT is observed only in the surface layer (Munkholm et al., 2003). However, some researchers (Hooker et al., 2005; Villamil et al., 2015) noted that within the tillage treatment, residue management had little effect on SOC in the surface soil layer. The newest research data state that the rate of long-term C stabilization within SOM can decrease with increasing residue addition (Shahbaz et al., 2016) and that greater soil C inputs can accelerate the loss of C in cropping systems with low nitrogen (N) input (Diochon et al., 2016). OM has a great influence on initial soil structural stability (e.g., bulk density, air-filled porosity). In Norway, on morainic loam soil with a high initial SOM content, a high soil structural stability was found in an arable system without ploughing but with rotary tillage (Riley et al., 2008).

Soil texture plays an important role in SOC storage. Manns et al. (2014) identified soil texture as the primary physical process that controls variability in soil water content. Soil physical quality reduction in the untilled topsoil has been reported on weakly structured soils in humid temperate climates (Munkholm et al., 2003). Poor soil structure was found for NT in a 30-year, long-term experiment on Canadian silt loam soil, compared to CT (Munkholm et al., 2013). According to Pagliai et al. (2004), soil porosity is the best indicator of soil structure quality. Barros et al. (2016) indicated that soil pores positively relate to SOM content. Soil pore-size distribution (PSD) depends on the combined effects of texture and structure, and it controls water and air storage and their transport into the profile (Ding et al., 2016). However, Mielke and Wilhelm (1998) ascertained that the tillage treatments affected soil physical properties when the same tillage system has been practiced for a longer time. Short-term (< 10 years) management effects on soil C and soil physical properties are complex and often vary (Sharma et al., 2016). Furthermore, the need for more comprehensive studies on management impacts on physical soil properties, that control GHG emissions been emphasized by various research groups (Nakajima and Lal, 2014; Schwen et al., 2015). Thus, the results from the long-term field trials are of a great importance to reveal the changes occurring in soil under site-specific soil and climatic conditions.

Some results of field experiments established in Lithuania revealed significant tillage impact on soil physical states (Boguzas et al., 2010; Feiza et al., 2011; Romaneckas et al., 2012; Velykis et al., 2014), SOC accumulation (Boguzas et al., 2015) and soil respiration (Feiziene et al., 2011, 2015). However, our long-term observations of the effectiveness of different agricultural practices at the farm level revealed that residue management tends to have a marginal effect on SOC accumulation, and does not always reveal eligible effects on soil water retention. Therefore, research on changes in soil properties after long-term ploughless tillage management on *Cambisol* is of great scientific interest. This research was undertaken to increase our understanding of the influence of long-term contrasting tillage systems in combination with crop residue management on the properties of two textured soils. The objective of this study was to assess the cumulative effects of long-term CT and NT in combination with straw removal or return on topsoil SOC accumulation, soil porosity characteristics, water release characteristics (WRC) and CO_2 efflux in loam and sandy loam soil. We hypothesized that the topsoil of *Cambisol* after 17 years of NT application in combination with straw return would produce a new physical state, and determine other conditions that differentiate CO_2 efflux origination decreasing CO_2 loss in loam and sandy loam during the main development stages of winter wheat.

2. Methods and materials

2.1. Site and soil description and experimental design

The research area is situated in the mid-Lithuanian lowland. The surrounding relief is glacial and flat, the experimental site is about 60 m above sea level. Long-term annual precipitation in this area is 568 mm, the average annual air temperature is 6.4 °C and evapotranspiration amounts to 471 mm. The country belongs to the Nemoral-2 environmental/Boreal climatic zone (Metzger et al., 2012; Biogeographical regions in Europe, 2012). The investigations were carried out at the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry on *Endocalcari-Epihypogleyic Cambisol* (according to the FAO-UNESCO) in 2015 (55°23′ N and 23°51′ E). Two 2-factorial field experiments were established in 1999 according to the same trial design. One of them was set up on loam and the other on a sandy loam textured soil (Table 1). The experiment consisted of four treatment combinations, i.e., two levels of tillage (conventional tillage (CT) and no-tillage (NT)) and two levels of crop residue (residue removal and residue return). Both field experiments had a split-plot design in four replications. Straw handling methods were tested on the main plots (210 m^2), while tillage systems, both conventional tillage (CT) and no-tillage (NT), were tested on sub-plots (70 m^2). A five-course crop rotation of winter wheat (*Triticum aestivum,* L.), spring oil-seed rape (*Brassica napus,* L.), spring

Table 1
Particle size distribution and soil properties (0–10 cm layer) at the 17th experimental year (2015).

Tillage	Soil indices						
	Texture composition (soil particles%)			pH_{KCl}	N_{tot} %	P_{A-L} mg kg^{-1}	K_{A-L} mg kg^{-1}
	sand (2.0–0.05 mm)	silt (0.05–0.002 mm)	clay (< 0.002 mm)				
Loam							
CT	52	29	19	6.49	0.122	91	146
NT				6.60	0.145	117	178
Sandy loam							
CT	54	33	13	6.22	0.110	73	149
NT				5.53	0.126	85	142