CLAY SOIL MOISTURE IN SPRING CEREAL CULTIVATION AS RELATED TO TILLAGE MANAGEMENT

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Abstract

Conservation tillage with crop covered soil surface has been found to reduce the risk of erosion and nutrient leaching. The reduction of tillage intensity changes topsoil structure affecting soil physical conditions relevant to crop growth. In this study, the effects of autumn tillage management on soil moisture during the growing season of spring barley (*Hordeum vulgare*) was examined on two field experiments on clay soils (Vertic Cambisol, Eutric Cambisol) in southwestern Finland in 2004–11. The objective of the study was to investigate the effects of reduced tillage intensity on soil moisture conditions of two different clay soils in different weather conditions. Autumn mouldboard ploughing (to 20–25 cm depth, P) was compared to stubble cultivation (10–15 cm, S) and zero tillage (N). During the growing season, soil moisture was determined once a week at the depth of 0−30 cm with a TRASE system I (Time Domain Reflectometry (TDR)). Daily weather conditions (precipitation, air temperature) were also determined. Zero tilled soil stayed moister than the soil in other tillage treatments. When the beginning of the growing season was dry, higher soil moisture content in zero tilled soil improved the growth conditions of barley. In an unexceptional rainy beginning of growing season, the wetness of clay soils in zero tilled treatment hampered the crop growth and yield production clearly.

Keywords: mouldboard ploughing, zero tillage, stubble cultivation, drought, soil wetness

Introduction

During the last ten years, Finnish farmers have been increasingly interested in conservation tillage systems. In 2010, the zero (direct drilling) and reduced tilled (shallow stubble cultivation) areas were 13 and 25% of the annually tilled area (1.15 milj. ha), respectively (1). The increasing adoption of conservation tillage systems follows the high cost of fuel and labour with conventional tillage. Besides that the guidance of Agri-Environmental Programme and the accompanying Support Scheme encourages increasing the crop covered area outside the growing season as one of the measures to decrease erosion and nutrient transport from land to watercourses. Conservation tillage practices have been reported to be advantageous in respect to erosion control in boreal areas (2, 3, 4, 5).

Adopting conservation tillage creates gradual changes in soil properties relevant to soil moisture conditions during growing season. Changes can be expected in evaporation of water from the soil surface due to increased amount of crop residue left on soil surface. Also organic carbon accumulation into the soil surface layer (6,7) may improve soil self mulching properties of soil reducing evaporation. However, in several cases lower hydraulic conductivity and infiltration rate under conservation tillage in fine texture soils were found (8, 9, 10). Yield reductions in small grain cereal cultivation have been reported in wet growing seasons on clay soils (11, 12, 13).

On the other hand, conservation tillage was found to increase vertically oriented macroporosity (14) enabling fast root growth into deeper soil layers (12) ensuring crop water uptake during dry growing seasons. The potential of shallow tillage (11, 12) and zero tillage (13) in water conservation during dry growing seasons has probably also encouraged farmers to adopt new tillage systems.

In boreal conditions, where the potential annual evapotranspiration is less than precipitation and the year contains could period, the objectives and possibilities to conservation tillage are different than in warmer and dryer areas. The long-term effects of shallow stubble cultivation and zero tillage on soil moisture conditions and crop growth are seldom studied in same field experiments on soils having high clay content in boreal climate. We addressed the question by investigating the effect of conservation tillage on clay soil (topsoil clay content > 0.46 g g^{-1}) moisture content in spring barley cultivation on two long-term field experiments located at latitude 60º. Our objective was to evaluate the possibilities to utilize conservation tillage in water conservation in dry early summers and to evaluate the further needs to develop the system.

Materials and Methods

Field experiments

Field experiments were conducted on a clay soil (Vertic Cambisol (15) established in 2000), and a silty clay soil (Eutric Cambisol ((15), in 2001) at Jokioinen (60°49'N, 23°28'E) in southwestern Finland. The texture, organic carbon content and bulk density of the experimental soils at the beginning of the experimental period are given in Table 1.

The experiments were laid out in a randomized complete-block design with four replicates. The plot area of clay and silty clay fields was 6×40 m^2 and 10×25 m^2, respectively. The three autumn tillage treatments were: (P) ploughing to 20−25 cm depth, (S) stubble cultivation to 10−15 cm depth, and (N) zero tillage. In spring, the P and S plots were first levelled by a harrow (one pass, 3−4 cm tillage depth) before combined rotary harrowing and drilling (one pass method; combined drill: seed (shoe coulters) and fertilizer placed at the same time in separate rows). N plots were drilled with a direct drill (double disk coulters) placing seed and fertilizer in the same row. Sowing depth was 4 to 5 cm.

In the present study, the experimental period covered years 2004–11. On both field experiments, the crop was spring barley (*Hordeum vulgare*, variety Saana (2004–07) and Annabell (2008–11). The target seed rate was 500 viable seeds per square meter. The annual nitrogen and phosphorus fertilization rates were 90−100 kg N ha^{-1} and 0−14 kg P ha^{-1}, respectively, as NPK-fertilizer. The spacing of seed rows was 140 mm for direct drill and otherwise 125 mm. Except for direct drill, the fertilizer was placed between every second crop row.

In spring, the sowing time was decided based on the drying of the soil. On clay soil field in 2004, the autumn tilled plots were sown 14 days earlier than direct drilled plots since the precipitation in May was 60 mm mean precipitation being 35 mm (Figure 1). Zero tilled plots dried very slowly after the showers of rain delaying the sowing. With the exception of tillage and drilling, field operations were carried out following the common farming practice in Finland.

Table 1. Average soil organic carbon content, particle size distribution and dry bulk density. The values are means of 4 measurements except bulk density being a mean of 3 measurements.

Depth (cm)	Soil organic carbon (g g^{-1})	Particle size distribution (g g^{-1}) Clay < 0.002	Silt 0.002–0.02	Sand > 0.02 mm	Dry bulk density[a] (g cm^{-3})
			Clay soil field		
0−20	0.027	0.617	0.190	0.193	1.13/1.16
20−40	0.010	0.808	0.113	0.079	
			Silty clay field		
0−20	0.025	0.461	0.287	0.252	1.14/1.17
20−40	0.012	0.547	0.271	0.182	

[a] ploughed/zero tilled soil in 2006 by (16)

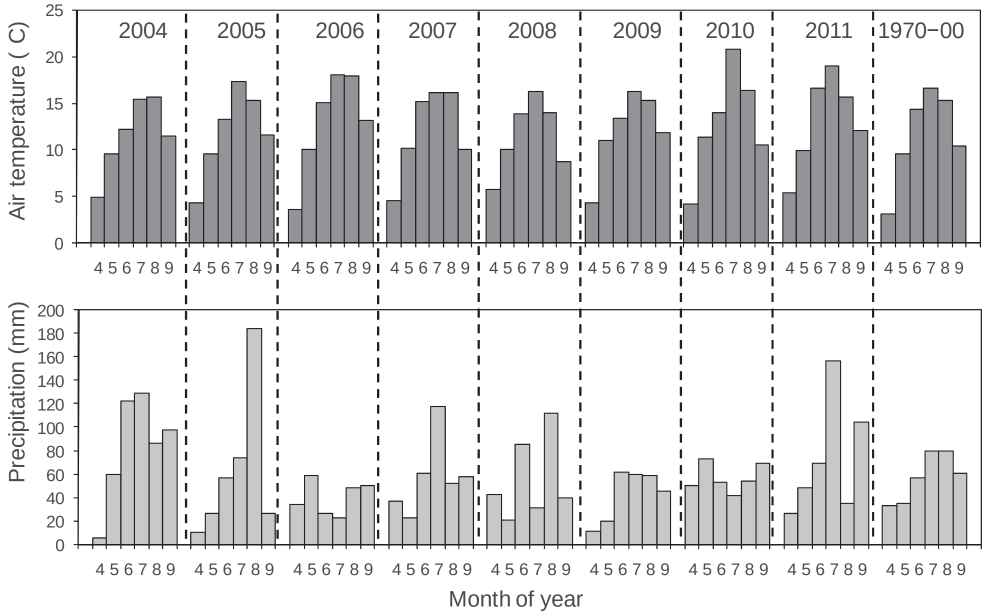

Figure 1. Monthly mean temperature (°C) and precipitation (mm) during the experimental period and the long-term mean of years 1970–2000 (17). Data: weather database of MTT.

Measurements

During the growing seasons 2004–11, soil water content was determined in the layer of 0–30 cm with a TRASE system I moisture meter using Time Domain Reflectometry (TDR) (Soil Moisture Equipment Corp., Goleta, CA, USA). Determinations were carried out from two sites of a plot (2x4 determinations per treatment). To cover the dielectric constant values of soil determined by the TRASE to soil volumetric water content, manufactures relationship between dielectric constant and soil volumetric water content was used. From clay soil field, also gravimetric samples were taken to determine soil volumetric water content.

An area of 43 to 63 (clay) or 27 to 38 (silty clay) m^2 was harvested from each plot and the dry matter content of grain was determined by drying a subsample of 40 g at 105ºC overnight. Daily weather data was monitored at the observation of the Finnish Meteorological Institute located about 2 km from the field experiments (data was available at the database of MTT).

Results and discussion

Soil moisture content of the layer of 0–30 cm during the wettest (2004, Figure 1), driest (2006) and the last growing season of the experimental period of 2004–11 is shown in Figure 2. On both fields, mean soil water content of zero tilled soil was higher than that of other tillage treatments. This was also supported by the gravimetric soil moisture determinations on clay soil field. In the beginning of the growing season, before the crop reach full cover, crop residue on the surface of zero tilled soil probably decreased the evaporation rate. In rainy season 2004, the difference in soil water content between zero tilled and ploughed soil stayed greater than in drier years. In dry year 2006, soil dried nearby to the field capacity, reported to be 22–26 m^3 $100m^{-3}$ for similar clay soils (12, 18).

On the clay soil field during the experimental period of years 2004–10, the mean yield of ploughed treatment was by 5 and 18% greater than that of stubble cultivated or zero tilled treatments, respectively. The yield reductions were highest in the rainy year 2004 when the soil staying wet (Figure 2) especially in the zero tilled treatment hampered the crop growth and yield production clearly (Figure 3, precipitation 120 mm). Also in 2010, when rained 51 mm during the week after sowing, germination and seedling growth was hampered by wet soil conditions in zero tilled plots (yield reduction 1980 kg ha^{-1} compared to ploughed treatment, 56%). These results were in agreement with the results reported by (11, 13).

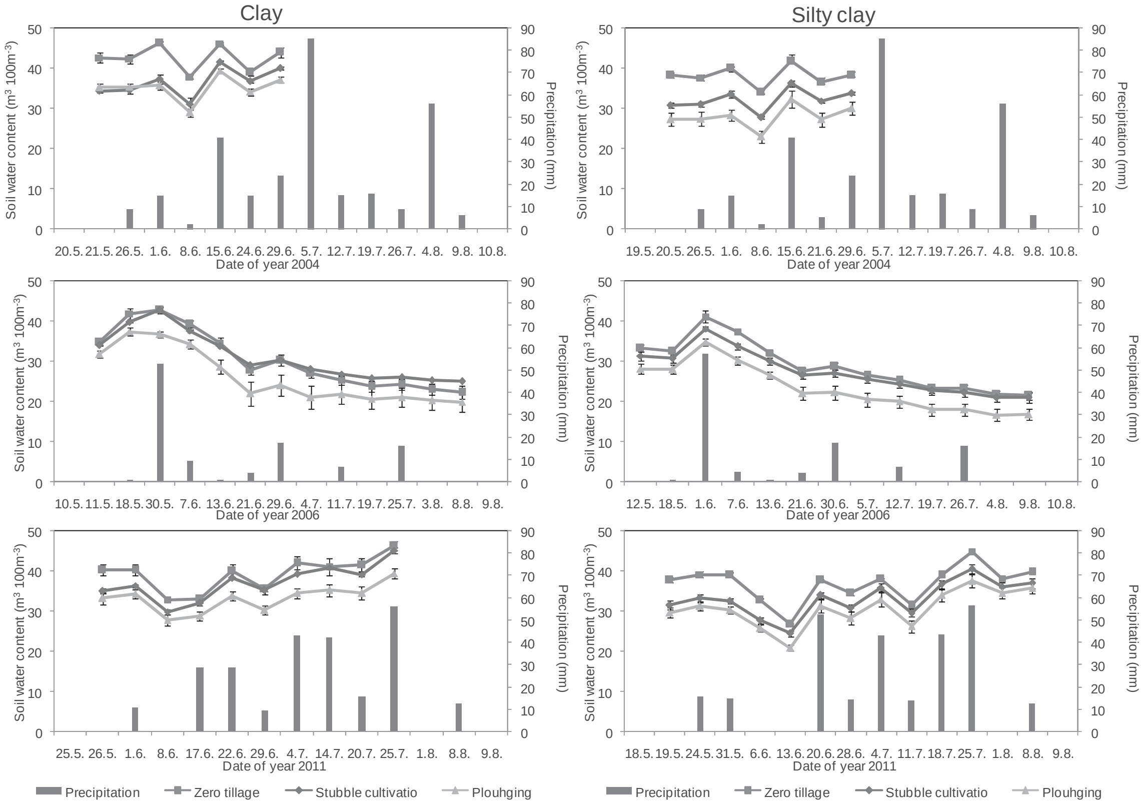

Figure 2. Soil water content in the layer of 0–30 cm on clay and silty clay experiments during a rainy (2004), dry (2006) and the last growing season of the experimental period of 2004–11. Precipitation between two moisture determinations is also given. Lines indicate the ±SE, n=4. Precipitation: weather database of MTT.

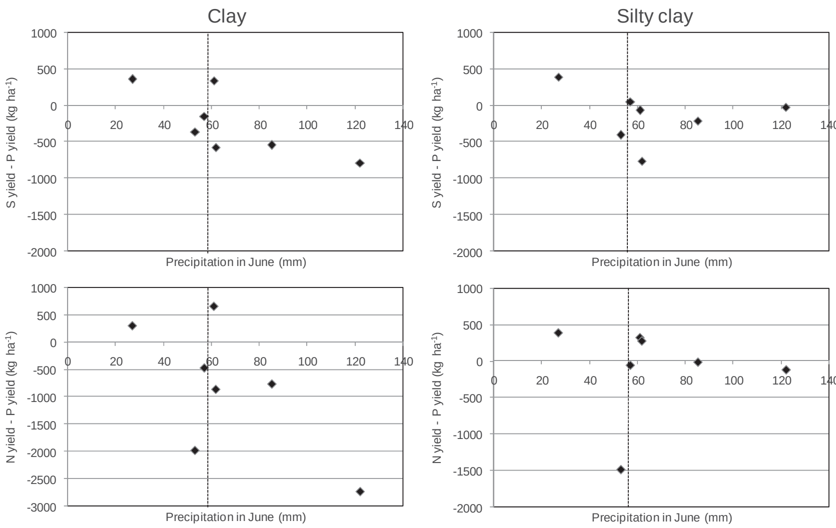

Figure 3. Difference in grain yield between stubble cultivation (S) and ploughing (P) (S yield – P yield; upper diagrams) and zero tillage (N) and ploughing (P) (N yield – P yield; lower diagrams) as relation to the precipitation in June during the experimental period of 2004–10. The average precipitation in June (1970–00) is 57 mm in Jokioinen, marked as a dotted line in the figure.

With the exception of years 2004 and 2010, the mean yields for ploughed, stubble cultivated and zero tilled treatments were 4840, 4730 and 4620 kg ha^{-1}, respectively. When the beginning of growing season was dry (2006 and 2007), the conservation tillage clearly improved the yield (Figure 3) probably by saving soil moisture (Figure 2) or fast root growth to deeper soil layers via continuous macropores as found by (12). Also (11, 13) reported that dry growing seasons favored conservation tillage.

On the silty clay field, the yield differences between tillage treatments were small even in rainy growing season 2004 (Figure 3). Only in 2010, with the heavy rain (52 mm during the week after sowing), crop yield was clearly less in zero tilled treatment compared to ploughed treatment. As a mean of the experimental period of seven years, the mean yield of stubble cultivated and zero tilled treatments was 4 and 2% less than that of ploughed treatment.

The yield differences between tillage treatments were clearly greater on the clay than on the silty clay field (Figure 3). Regina and Alakukku (16) found that the macroporosity (> 0.003 mm) of silty clay in the layer of 0–20 cm was greater than that of clay soil. Likewise the number of earthworm burrows at the depth of 20 cm was clearly greater in silty clay indicating higher earthworm activity. This indicated greater temporal water storage capacity in wet conditions for silty clay.

Conclusions

As a mean of the experimental period of seven years (2004–10), the difference in spring barley yield between tillage treatments was small (4% or less) on silty clay. When the beginning of the growing season was rainy, crop growth and yield production was hampered due to the wet soil conditions in zero tilled clay soil. On both fields, dryness in the beginning of the growing seasons favored conservation tillage.

Acknowledgements

We are grateful to Matti Ylösmäki, Marja-Liisa Westerlund, Ilkka Sarikka, and Pirkko Mäki for their assistance in organizing the experiment and making the measurements. The study was financed by the Ministry of Agriculture and Forestry and Maa- ja vesitekniikan tuki ry.

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