Effect of soil-tillage on soil physical properties, total organic carbon content and winter barley yield in a long-term experiment in Germany

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Abstract

Economic pressure and environmental legislation forces farmers to adopt conservation tillage systems. The yield decrease, however, is often quite substantial, which limits acceptance by the farmers. In a study conducted in eastern Germany the effects of long-term tillage treatments (1984 – 2001) with a mouldboard plough vs. a cultivator treatment were compared. Measurements included a number of soil properties as well as grain yield of winter barley. The soil physical properties of the uppermost layer of the top soil improved in the cultivator treatment compared with the plough treatment. Soil from the top layer sampled (0-6 cm) in the cultivator treatment showed an increase in total organic carbon and a slightly lower bulk density as well as an increase in the available water content compared with the soil from the plough treatment. Relevant differences were also detected in the 12-25 cm layer. Though the bulk density in the cultivator treatment was higher compared with the plough treatment, the hydraulic conductivity was not significantly affected, which indicates the continuity of the macropores. The differences in the deepest soil layer sampled (25-35 cm) were negligible. With the exception of the harvest years 1999 and 2000 no significant differences in the grain yield between the two tillage treatments were observed, which is in our opinion due to the long crop rotation used in this experiment.

Media summary

Long-term conservation tillage improves soil physical properties without negative effects for grain yield of winter barley.

Key words

Soil-tillage, soil physics, winter barley, grain yield

Introduction

Though ploughing is still the most common tillage, conservation and minimum tillage systems are increasing in importance in European farming systems in recent years. The main reasons are soil conservation issues and a strong economic pressure to introduce less expensive and less energy consuming tillage systems. Additionally in some countries conservation tillage systems are financially supported in agri-ecological programs and thus farmers receive special payments for implementation or lose out on subsidies if conservation tillage is not used. The success of conservation tillage systems, however, depends on site and husbandry factors which might or might not apply in certain years. Other important reasons for farmers to use conservation tillage systems are cost and labour saving; soil conservation is only important in areas with high soil erosion risk. Even within suitable areas for conservation tillage systems, the results are mixed due to differences in husbandry.

Conservation tillage systems in Germany are not restricted to specific, separate regions. Apart from the political and economic factors mentioned above, the major environmental reason to introduce such systems is to save water during the growing season. Therefore the proportion of farmers using conservation tillage systems is larger in the more continental climate of East Germany. Recent polls among farmers indicate that conservation tillage systems are mainly used on medium loamy soils, whereas heavy clays and sandy soils are less suitable according to farmers experience. A scientific approach to confirm such experiences is difficult to obtain, since comparable long-term experimental data from a number of different environmental areas is scarce. The aim of this experiment was to quantify the long-term effect of tillage systems on soil physical properties and crop yields.

Methods

Layout of the long-term field experiment

The field experiment reported herein was started in 1984. It consisted of a five course rotation: sugar beet – winter wheat – corn – winter wheat – winter barley. Sugar beet and corn were sown as a break crop. The experimental design enabled each crop to be grown each year. The two tillage systems compared were (a) mouldboard ploughing to depths suited to the crops following the tillage: 20 cm before winter wheat and winter barley crops and 25 to 30 cm before sugar beet; and (b) a conservation tillage treatment represented by an annual cultivator treatment to a depth of 10 to 15 cm. The entire husbandry (fertilization, crop protection etc.) was identical in all tillage treatments, so that all effects measured are solely due to the different tillage treatments over the years.

Environmental conditions at the experimental site

The experimental site “Seehausen” is located close to the city of Leipzig in the German state “Saxony”. The experimental site represents one of the major agricultural regions of Germany. At “Seehausen” the average annual precipitation is approximately 560 mm, and the long-term mean air temperature is 9.3??C (1963 – 1999). The soil is a sandy loam classified as a Stagno-Luvic Gleysol. It is susceptible to surface sealing and crust formation; the growth of crops may be adversely affected by water logging and drought stress. Lack of available water is in most years the limiting factor for crop yields. The top 30 cm of the soil can be described as follows: texture: clay 10 %, silt 46 % and sand 44 %. Cation exchange capacity is 109 mval/kg and pH (1:2.5 in water) is 6.7.

Measurements

Soil samples were taken in the barley plots in 2000 and 2001 from the depths 0-6 cm, 12-18 cm and 32-38 cm to characterize soil organic carbon content, bulk density (d_B), penetration resistance (PR) at a matrix potential of -6 kPa, saturated hydraulic conductivity, the water retention curve and the available water content (AWC).

Results

The long-term differences in tillage systems had a clear influence on the measured soil parameters (Fig. 1). In the uppermost layer sampled in this experiment (0-6 cm), the cultivator treatment showed a small but statistically significant increase in soil organic carbon after cultivator use compared with the plough-treatment. This result agrees with that reported by Alvarez (1995) and Arshad and Franzluebbers (1999). The increase in soil organic carbon induced a slightly lower bulk density and an increase in the available water content. The extremely low saturated hydraulic conductivity in the plough treatment compared with the cultivator treatment is an indication of surface sealing and crust formation on top of the soil in the plough treatment. Such surface sealing was observed in a number of years in the plough treatment.

In the next deepest layer (12-18 cm) the long-term use of the cultivator caused an increase in bulk density compared with the plough treatment and was associated with a decrease in the available water content. The saturated hydraulic conductivity in the cultivator treatment was higher than would be expected from the differences in bulk density. This indicates that the pores in the cultivator treatment are dominated by macropores due to the activity of earthworms and root channels, however, this result is not typical for the described soil type and is in our opinion due a compact layer cause by the cultivator. The smaller amount of crop residues in this soil layer in the cultivator treatment caused a smaller soil organic carbon content compared with the soil in the plough treatment. This result concurs with findings reported by Rasmussen (1999) and by Tebr?gge et al. (1999).

The results in the lowest layer sampled (32-38 cm) are thought to be affected by an old plough layer which caused the extremely low figures for the hydraulic conductivity in both treatments. This underlines the long term consequences of unfavourable tillage on soil physical properties. The other parameters in this soil depth were not affect by the treatments tested in this experiment.

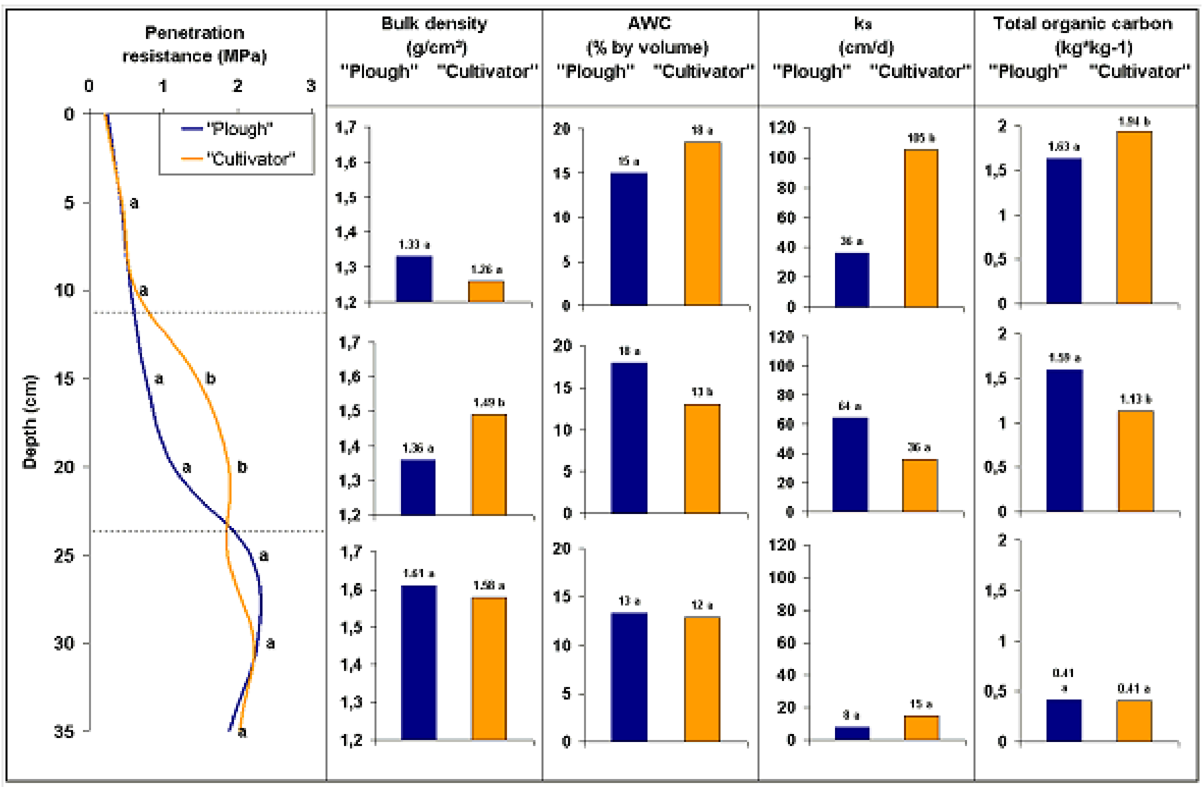

Fig. 1: Effect of the tillage treatments “plough” vs. “cultivator” on the penetration resistance (MPa), bulk density (g/cm?), available water content (AWC % by volume), hydraulic conductivity (cm/d) and total organic carbon at the experimental site “Seehausen” in Germany

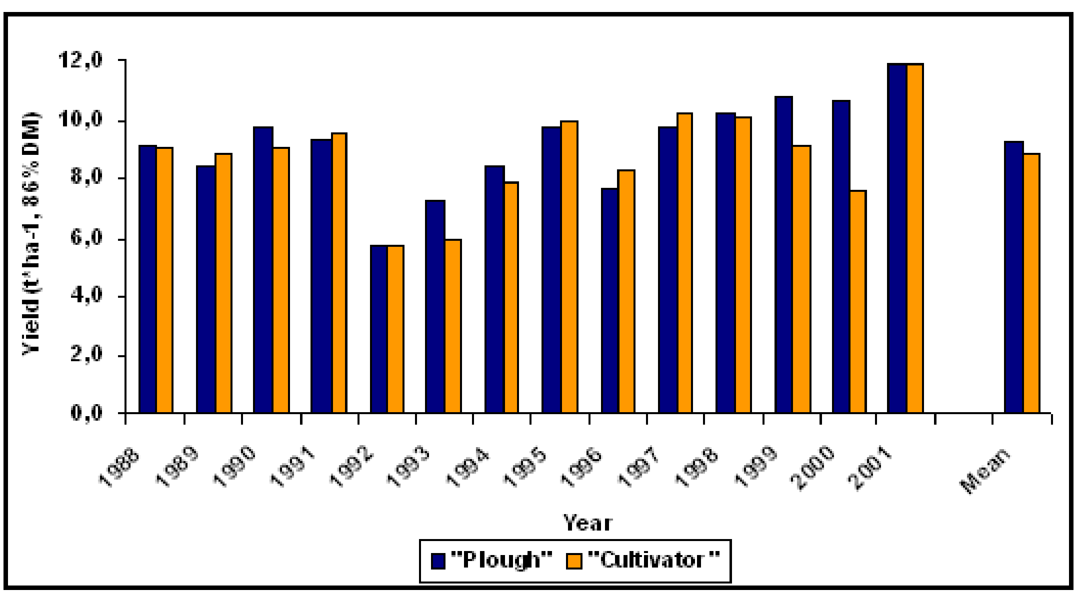

Fig. 2: Effect of the tillage treatments “plough” vs. “cultivator” the grain yield of winter barley in the experimental years 1988 to 2001 at the experimental site “Seehausen” in Germany

In the harvest years 1988 to 2001 the average grain yield of winter barley varied between 5.8 t/ha and 11.9?t/ha (Fig. 2). With the exception of the harvest years 1999 and 2000 no significant differences in the grain yield between the two tillage treatments were observed. In those two years, the lower yield in the cultivator treatment was due to a lower number of ears per m?. Averaged over all experimental years, winter barley showed only a small and statistically non-significant yield decrease in the cultivar treatment compared with the plough treatment. Though winter barley was in all years grown after winter wheat, differences in the incidence or severity of diseases of the lower stem like take-all (*Gaeumannomyces graminis*) or eyespot (*Pseudocercosporella herpotrichoides*) were not detected in either of the tillage treatments (data not shown).

The prerequisite for such favourable agronomic results of the cultivator treatment in the case of winter barley is in our opinion due to the crop rotation used in this experiment. The shorter and more cereal-based crop rotations become, the greater the difficulties that arise due to an increase in grassy weed infestation as well as an increase in soil and trash borne diseases, which limit grain yields in conservation tillage treatments (Olofsson 1993).

Conclusion

The results from a long-term field experiment with the two tillage systems plough vs. cultivator under the environmental conditions of eastern Germany clearly indicate that similar yields in winter barley in both systems are possible. The higher soil organic carbon content, especially in the uppermost soil layer, and a lower bulk density and a higher saturated hydraulic conductivity in the cultivator treatment demonstrate environmental advantages and underline the improved soil function properties in such systems. A prerequisite, however, is a diverse crop rotation.

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