RESULTS AND FINDINGS OF LONG TERM EXPERIMENTS AIMED TO HELP IMPROVE TILLAGE PRACTICES

Márta BIRKÁS

SZENT ISTVÁN UNIVERSITY GÖDÖLLŐ, HUNGARY

The Crop Production Institute of Szent István University carried out soil quality trials in the region of Gödöllő between 1977 and 2002, followed by similar experiments near the town of Hatvan since 2002. Soil quality factors that can be improved by tillage include the looseness of the root zone, the depth of the loosened layer, the duration of the loosened state, the thickness of the compact layer impeding water transport, the structure, the level of surface protection, the water intake/water loss balance, the organic material balance and earthworm activity. Optimising these factors can help reduce climate stress and extreme weather conditions do not undermine the reliability of farming. Most of the tillage interventions worked out with the aim of alleviating climate stress on the basis of the findings of the trials are different from conventional recommendations.

Key words: tillage experiment, soil quality, climate stress mitigation

Introduction

Tillage experiments play a particular role in field crop production research. Scientists have, in recent decades, been focusing on conventional subjects of international importance along with a variety of new challenges. Studies of crop rotation, crop sequence, tillage effects, manures and chemicals used for soil improvement are so-called conventional tillage trial tasks and they fit in well with scientific crop production programmes. Highly valuable results that are adaptable to smaller or larger regions were produced in this area during the past 60 years (*Gyuricza et al.* 2007, *Pepó and Balogh* 2008, *Tóth et al.* 2009). Tillage is still a crucial element of energy plant production technologies. Subjects of research on an international level have been changing constantly, a number of them have been and are being successfully researched in the Pannonian region as well. Direct drilling has been the subject of research across the world for decades – and in Hungary since 1962 – and the goals include exploring ecological effects, adaptability and risk mitigation (*Birkás et al.* 2004). Climate change may give a new impetus to the research of the theme (*Malatinszky* 2008). Soil compaction has been the subject of studies for decades and it has been approached from both practical and theoretical aspects. Model studies, tracing and impact assessment have been underway at renowned soil-physics research institutions all over Europe (*Koós et al.* 2005, *Várallyay* 2008). Adopting innovative solutions in Hungary as quickly as possible is a crucial requirement in view of the climate stress aggravating effects of soil compaction (*Birkás* 2000). The principle of sustainability called for new tillage tasks, but the improvement and preservation of soil quality was and has remained an important one among them. In line with climate research programmes new subjects of studies include carbon-dioxide flux as a characteristic of tillage systems, the consequences of climate change and the tracing of soil carbon-balance (*Tóth and Koós* 2006). Climate change imposes new challenges on science and practice. Farmers expect solutions to alleviate damage while science, based on its findings and achievements, is urgently calling for soil quality improvement and preservation and for a radical change of attitude and methods.

Materials and method

In working out this paper the authors drew on output from tillage experiments that have been underway at the Soil Management Department of Szent István University for 33 years, and on findings from soil monitoring in as many as 67 micro-regions. At Gödöllő the authors conducted experiments set up on settling sandy loam soils, while at the town of Hatvan experiments were carried out on plots of loam soil moderately susceptible to compaction in four repetitions, and in a random arrangement in patches. From among the different tillage systems applied in the experiments - direct drilling (DD), shallow disking (D), shallow and medium deep tillage with cultivator (SK, K), ploughing (P), loosening (L) – the following variants could be distinguished in terms of tillage effects (*Birkás* 2008): tillage pan formation below 15 cm and below 30 cm and soil loosened to the 20 or 40 cm depth. The combinations of crops grown in the experiments were designed to enhance the soil organic material contents and to protect the soil surface. In the experiments at Gödöllő (1977 - 2002) maize and winter wheat was grown in alternation, while at Hatvan (from 2002) maize which is sensitive to soil condition, winter wheat, rye, and sunflower which are less sensitive to the state of the soil were grown, along with, between two winter wheat harvests, peas, mustard and phacelia as catch crops.

Soil state parameters (resistance, moisture, structure, surface), and crop response (depth of rooting, biomass, yield), were established in accordance with the relevant standards and regulations (*Birkás* 2000, 2008, *Farkas et al.* 2009, *Sabo et al.* 2007). The biometric evaluation was carried out on the basis of the methodology worked out by *Sváb* (1981). The authors studied quality parameters recommended by recognised authors (*e.g. Dexter* 2004), such as: the looseness of the root zone, the depth of the loosened layer, the duration of the loosened state, the thickness of the compacted layer blocking water transport in the soil, the soil structure, the protection of the surface during the critical months, water transport (the intake/loss balance), the workable soil moisture range, the organic material balance and earthworm activity.

Results and conclusions

The looseness of the root zone and the depth of the loosened layer

Our studies have shown that compaction in the top 45 cm soil layer restricts water intake and the movement of water into the root zone. Serious damage is caused by compaction near the surface. By contrast, plants fare much better during a dry period in deeply loosened soil. Accordingly, soil loosened to a depth of 35-45 cm qualifies as suitable, soil loosened to 28-34 cm is to be rated as adequate while soil loosened only to a depth of 18-20 cm is conditionally adequate (in a favourable season) or inadequate. The depth of the loosened layer is the same as the depth of the layer suitable for storing and for crops to take up water. These categories are described not in order to apply deep tillage but to draw attention to the need for proper knowledge of the depth of the loosened soil layer. The closer the harmful tillage pan is to the surface, the shallower the soil layer available for root growth (*Figure 1*) and the more susceptible plants will be to adverse environmental impacts. The length of the period during which the soil remains loosened is an important factor. In our trials the degree of looseness decreased – by the middle of the growing season – in ploughed and loosened soil by 25 %, while in soils tilled with cultivators and disk it decreased by up to 28 %. Under direct drilling the soil was 40 % more settled in comparison to loosened soil, as a consequence of which the risks of cropping are low in wet years, medium in years of average precipitation and high in dry years.

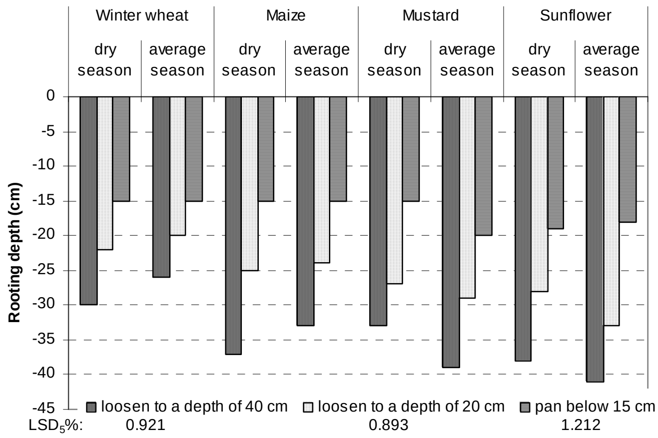

Figure 1 Crops rooting depth in soils of different states and in different seasons (Hatvan, 2002-2008)

The depth of the compact layer obstructing water transport

The depth of the compacted layer – in connection with the soil moisture transport – is an important soil state indicator, from which conclusions may be drawn even with regard to the likely risks. In evaluating data from as many as 1342 measuring points in our studies we created the following four categories: modest damage is to be expected if there is a compacted layer of up to 10 mm in the soil, while if the thickness of the compacted layer is 10-30 mm, 30-50 mm or 50-100 mm, medium, heavy and severe damage should be expected, respectively. Modest damage may be caused in a moist soil (0-10 mm) even by seedbed preparation, while medium damage (10-30 mm) may be caused in a wet soil by primary tillage as well as by seedbed preparation. Heavy (30-50 mm) and severe (50-100 mm) soil damage tends to occur when the necessary depth of tillage and the workability of the soil are ignored.

Soil structure

The soil crumbliness is – except for soils of naturally poor structures – indicative of the processes affecting the soil structure during a given period of time (build-up, degradation). Soil conserving tillage results in increasing aggregation – which can be proven by means of mathematics – although the production of wide-row crops may impede the positive trend (*Figure* 2). Crumb forming is assisted by minimised soil disturbance, conserving of soil moisture, growing narrow-row crops and covering the surface during the critical summer months. Deficient soil cover has been proven to add to soil structure degradation during seasons of extreme weather conditions.

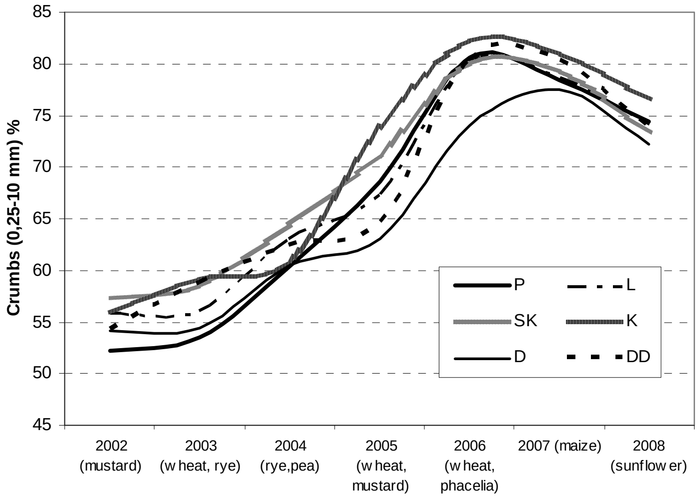

Figure 2 Effects of tillage and crops on crumb forming (Hatvan, 2002-2008)
LSD_5%: year: 5.14; variant: 1.996

Soil surface protection during the critical months

Covering the soil surface with chopped field residues during the critical period provides increased protection, while the lack of cover leads to increased exposure entailing damage by heat and downpours (silting and capping). We have data on the changes in different stubble field cover rates (0-70 %) after tillage and on the possible levels of protection (*Table 1*).

Table 1 Soil surface cover by chopped field residues and the expected risk

Circumstances	Coverage rate (%) and resulting protection		
	Good	Medium	Poor
After harvest, without stubble stripping	55 – 65	35 – 45	< 10
After stubble treatment (summer	45 – 55	35 – 45	< 10
After primary tillage (summer)	25 – 35	15 – 25	0 – 5
After primary tillage (winter)	15 – 25	10 – 15	0
Wide row crops, during days of heat in the spring	15 – 25	10 – 15	0
Risk	low	medium	high

Soil moisture transport

Soil natural water transport characteristics cannot be improved by tillage but water intake and water loss can be controlled. Efforts should always be made to maximise water intake, while minimising water loss is particularly important in dry seasons. Water intake can be improved by loosening the soil, while water loss can be decreased by reducing the size of soil surface and by covering the surface. The balance is optimised by improving the soil water absorption capacity, by utilising the water held in the soil and by minimising tillage-induced water loss. Intake is the part of the total precipitation that ends up in the soil, under favourable conditions it may be as high as 80 %, though in the majority of cases it is about 65-70 %. Water loss is affected by practices applied over years of land use, tillage (water loss increasing or decreasing), and plant water consumption. Crops grown in soils that have been subjected to water loss increasing tillage practices are fully exposed to damage by drought.

Organic material balance

The soil OM and organic C contents are important quality indicators, preserving them was one of the key elements of the trials. In our experiment a total of 12-17 t ha^{-1} organic carbon was recycled over a period of 7 years. The soil original C content (1.83 g kg^{-1}) was increased by 0.53 g kg^{-1} in the case of direct drilling, 0.19 g kg^{-1} in the case of tillage using cultivators, 0.08 g kg^{-1} at the disking, 0.19 g kg^{-1} at the loosening and by 0.27 g kg^{-1} in the case of ploughing. Factors contributing to the increase of organic C content include the adding of organic material to the soil, carbon conserving tillage and heat-stress alleviation. This is particularly important in the case of regularly ploughed soils where the OM and C content may increase only if the requirements of carbon conservation (e.g. pressed soil surface) are met. Conservation tillage keeps CO_2 flux low even over a longer period of time, contributing to the controlling of organic material decomposition and of the build-up of OM contents. The research provided data concerning the CO_2 flux of soils disturbed to different depths and with different tools, in three different soil moisture states (dry, humid and wet) and three different temperature categories (cool, warm and hot).

Earthworm activity

Thanks to conserving tillage earthworm activity has been observed year after year, regardless of the crops – primary or secondary – being grown. In contrast to data to be found in literature ploughed soil (after secondary tillage) was found to be good while soil not disturbed by inverting proved was found to be very good habitat. Undisturbed soil (DD) was a less favourable habitat than soils subject to tillage combined with mulch cover (SK, K).

The following tillage techniques were worked out with the aim of improving soil quality and reducing climate damage: 1) Applying water and carbon conserving stubble treatment techniques. 2) Covering disturbed soils with chopped field residue during the summer months. 3) Reducing the soil surface through which water is lost, during the critical months. 4) Water and carbon preserving primary tillage – ploughing, loosening, disking, tillage with cultivators – regardless of season. 5) Eliminating compact layer impeding water transport, by loosening, without creating large water and carbon wasting surface. 6) Refraining from the use of tillage-pan forming tools in secondary tillage after primary tillage, particularly in wet soils. 7) Preserving the soil structure. 8) Abandoning conventionally adopted techniques that jeopardise the quality of the soil. 9) Rationalising seedbed preparation and sowing. 10) Organic material recycling, keeping field residues on the field and mixing them into the soil.

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