Draught requirement and soil deformation during soil tillage
- working depth more important than implement

• During the autumn of 2001 and 2002, the specific draught requirement (energy consumption per volume of soil tilled) was measured for mouldboard plough, chisel plough and disc implement under different moisture conditions and at different working depths.

• The specific draught requirement was lowest for the mouldboard plough and highest for the chisel plough, especially under dry conditions.

• The actual (average) tillage depth was considerably less than the pre-set depth for the chisel plough.

• The disc implement was most effective at disintegrating the soil.

• The actual tillage depth has a very great effect on the total draught requirement. Shallow ploughing is a very competitive form of reduced tillage, particularly since ploughless tillage often requires several passes.

• ‘Just right is best’ – a water content just below plastic limit (‘moist’ soil) seems to be the best compromise in terms of both draught requirement and tillage effect.
Reduced tillage is always relevant in agriculture to reduce costs, energy use and labour in crop growing. It often takes the form of ploughless tillage, i.e. replacing the mouldboard plough with a shallow cultivation using a chisel plough or disc implement. This can reduce the tillage costs, as shown in calculations by e.g. Ekman (2000).

However, there are few studies comparing the draught requirement and energy consumption of different types of implement. An exception is Danfors (1988), who measured fuel consumption of 21 litres per hectare for ploughing compared with 9 for chisel plough and 8 for disc implement. This difference was mainly due to the fact that the implements worked at different depths. To accurately assess differences between different implements, the draught requirement must be related to the volume of soil tilled. This is called specific draught requirement (force per cross-section tilled area, N/m²). To measure factors such as specific draught requirement, a project was started in autumn 2001 in which mouldboard plough, chisel plough and disc implement were operated on different soils, at different depths and in different moisture conditions.

**Tillage and draught**

Soil tillage involves breaking the soil up into small pieces, soil aggregates. The way in which the soil is broken up (deformation) and the amount of draught required depend on a number of factors, including the design of the implement and the working depth (Factfile 1). The water content and structure of the soil are also extremely important for draught requirement during tillage. The draught requirement can sometimes be twice as great in dry soil as in damp soil and 20–100 per cent greater in compacted soil than in non-compacted soil (Watts & Dexter, 1994).

**Water content key factor**

The aim in tillage is often to obtain a large number of small aggregates – e.g. the optimal size to prevent evaporation is a diameter of 1–2 mm. The optimal water content for tillage can therefore be defined as the water content that...
produces the greatest number of small aggregates. The effect of water content on tillage has been relatively poorly investigated, both in Sweden and abroad, but tillage in both dry and wet conditions increases the proportion of large aggregates compared with an intermediate water content. Various studies indicate an optimal water content for tillage of around 90 per cent of Atterberg plastic limit (Dexter & Bird, 2000). Plastic limit is the water content at which hand-rolled soil breaks at a diameter of approximately 3 mm.

**Autumn tillage at Ultuna**

A specially equipped tractor was used for the study (Factfile 2). It was driven with mouldboard plough, chisel plough and disc implement on a light and a heavy soil at Ultuna (see cover photo, Factfile 2 and Figure 8). To obtain three different water contents (Dry, Moist and Wet), we carried out measurements at different times during the autumn. The mouldboard plough and chisel plough were operated at three pre-set depths, 13, 17 and 21 cm (for the chisel plough, this corresponded to the height difference between the tip of the chisel plough tine and the carrying wheel). We measured the actual working depth by removing and weighing all the loose soil within an area bounded by a steel frame (Figure 3). We also sieved the tilled soil to find the aggregate size distribution as a measure of the tillage effect.

**Uneven base after chisel plough**

When the loose soil was removed, it was apparent that the tillage base in the chisel plough plots was often very uneven (Figure 4). This meant that the actual tillage depth was much smaller than the pre-set depth for the chisel plough, but not for the mouldboard plough (Figure 5).

**Mouldboard plough needs least draught**

The specific draught requirement, i.e. the energy needed in relation to the volume of soil tilled, for the different implements on the heavy clay (Figure 6) was least for the mouldboard plough and greatest for the chisel plough, especially in dry conditions. A similar trend was seen on the light soil but the actual values were much lower.

The specific draught requirement changed with tillage depth (Figure 7). For the mouldboard plough, it was...
for soil disintegration, i.e. soil disintegration per unit energy used, could then be calculated (Figure 10). This showed that the disc implement gave the greatest disintegration per unit energy (J/m² aggregate surface).

**Shallow ploughing good**

The measurements showed that the draught requirement was determined mainly by the working depth. The mouldboard plough had a lower draught requirement than the chisel plough per volume of soil tilled. Thus the potential energy savings in ploughless tillage depend totally on the shallower tillage depth and not on the fact that different implements are used. In other words, shallow ploughing can be an excellent form of reduced tillage! Deep tillage with a chisel plough is often a waste of energy.

Shallow tillage with a chisel plough and disc implement often give a more thorough break-up of the soil than conventional ploughing. This is mainly effective in drilling winter wheat, when it is often more important to get a good tilth than to loosen large amounts of soil.

The draught requirement decreased with increasing water content, while the finest tilth was produced at the intermediate water content on the clay soil. 'Just right is best', a water content just under plastic limit seems to be the best compromise in terms of the draught requirement and the tillage result.

**Key words**

Soil tillage, draught, mouldboard plough, chisel plough, disc implement

**Further reading**


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