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Subsoil loosening eliminated plough pan but had variable effect on crop yield

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Subsoil compaction is a widespread problem on Danish arable soils and especially in form of plough pan compaction. Subsoil compaction may reduce crop yield and quality, increase negative environmental impact (e.g. in form of increased nitrogen leaching), and reduce soil workability and trafficability of the soil.

The Danish Institute of Agricultural Sciences has in a DARCOF project investigated the effect of subsoil loosening. The investigations were carried out in an organic crop rotation experiment at two sandy loams: Flakkebjerg (13% clay) and Foulum (8% clay).

Subsoil loosening

At the initiation of the organic crop rotation experiment in 1997 a root hampering plough pan was found at both Flakkebjerg and Foulum. During 2000 to 2004, we studied the effect of subsoil loosening to c. 35 cm depth using a Paraplow (Figure 1).

Figure 1. Subsoil loosening with a Paraplow in a juvenile grass-clover crop.

In each of the years 2000 to 2003, half of the area of 4 plots per site was loosened in the autumn in a juvenile grass-clover (established undersown in spring barley in the spring). The grass-clover crop was ploughed under in the following autumn and winter wheat was established. This means that after loosening there was a whole year without tillage, very limited traffic, and continuous crop growth.

Subsequently, on-land ploughing was applied for primary tillage to counteract plough pan reformation. Our aim was to minimize re-compaction and maximize structural stabilization of the disturbed soil. The winter wheat crop was succeeded by lupin/barley and subsequently by spring barley undersown with grass-clover. The treatments were carried out once in each plot and therefore the number of treated plots per site increased from 4 in 2000 to 16 in 2003.

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Effective plough pan loosening

The Paraplow treatment effectively loosened the plough pan **(Figure 2a)**. Subsoil loosening increased the volume fraction of coarse pores, which indicates increased saturated hydraulic conductivity. Due to the use of on-land ploughing and other means to reduce soil re-compaction it was possible to mitigate re-formation of a plough pan during the first 2 years after loosening.

After 3½ years there was still a significant effect of loosening but not as pronounced as in the first couple of years after loosening **(Figure 2b)**. A similar study on a Danish sandy loam showed that on-land ploughing was needed to mitigate plough pan re-formation (see **DARCOFenews Sept. 2003**).

Variable effect on crop yield

The subsoil loosening was carried out without significant visual damages on the juvenile grass-clover crop. However, reduced growth of the grass-clover crop was found in the following growing season. Especially, the white clover appeared to be sensitive to soil loosening (Figure 3). Apparently, this had marked effects on the growth of the succeeding winter wheat crop.

Figure 3.

Grass-clover plot 6th June 2003 with visible poorer growth of especially white clover in the loosened left part of the plot (loosened in September 2002).

In winter wheat that followed grass-clover there was a tendency to yield loss in loosened and unfertilized soil in 2002 and 2004 **(Table 1)**. In contrast, there was a tendency to increased yield in loosened soil at Flakkebjerg in 2003 (unfertilized and fertilized) and in 2004 (fertilized). It seems as if the nitrogen after-effect from the grass-clover crop has biased the effect of loosening. The winter wheat crop relies heavily on the nitrogen supplied by the preceding clover-grass crop. A low nitrogen after-effect was expected under conditions where a low amount of nitrogen had been collected by the grass-clover crop (i.e. poor performance of the clover) and/or in case of high nitrogen leaching during the winter (i.e. wet winter climate). Further, a low nitrogen after-effect is expected to have strongest impact on unfertilized soil. Our results were in accordance with this.

The winters 2001/02 and 2003/04 were wet (i.e. high nitrogen leaching) which may explain the observed low yield in loosened and unfertilized soil in 2002 and 2004. The winter 2002/03 was relatively dry (i.e. low nitrogen leaching) and relatively high yields were found for unfertilized soil 2003.

Other studies have shown a generally lower level of nitrogen leaching at Flakkebjerg than at Foulum due to difference in soil texture and winter precipitation. The poorer performance of unfertilized soil (relatively to fertilized) at Foulum than at Flakkebjerg may be related to the difference in

nitrogen leaching. Likewise, the relatively poorer performance of loosening at Foulum than at Flakkebjerg may reflect differences in nitrogen leaching.

The bias related to the after-effect of nitrogen from grass-clover was expected to decline strongly with time. Therefore, more or less unbiased results were expected for the succeeding crops in the rotation after winter wheat. The yield results showed no clear effect of loosening for the crops following winter wheat (lupin/spring barley and subsequently spring barley with grass-clover undersown).

Subsoil loosening not recommended under Danish conditions

Subsoil loosening has rarely resulted in positive plant response under Danish conditions. This must not be interpreted, as if subsoil compaction is an overestimated problem. A lacking plant response may in some cases be related to a fast re-compaction of the loosened soil. Yet, even in case of limited re-compaction - as in this study – a marked positive plant response has not been found. This may be due to detrimental effect of subsoil loosening on the macropore system, i.e. the continuity of the existing network of macropores (e.g. earthworm burrow and root channels) is broken. This may counteract the positive effect of subsoil loosening on porosity.

Our results suggest that subsoil loosening can only be recommended in case of very severe subsoil compaction under Danish conditions. Biological amelioration may comprise a favourable alternative to mechanical subsoiling. Root and earthworm channels constitute effective pathways through compacted layers and significantly improve soil functions like aeration, infiltration and deep rooting.

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