Soil Structural Changes Caused by Continuous Conservation Tillage and its Effect on Yield Formation of Sugar Beet

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Introduction

In a long-term field experiment near Göttingen sugar beet yield was substantially lower after continuous shallow mixing tillage compared to deep annual mouldboard ploughing. Previous investigations have shown that this yield decrease was partially caused by a shortage in N supply (Tomanová et al., 2006). Even if N deficiency was avoided by high N fertilizer application yield was substantially lower after shallow-mixing tillage compared to ploughing. It is hypothesized that this yield decline is caused by high soil mechanical impedance restricting fibrous root and taproot growth. This poster presents results from recent studies conducted with x-ray computed tomography to evaluate tillage effects on soil structure and plant growth.

Material and Methods

Site, treatments, experimental design:

- Clayey silt soil; 8.8 °C, 602 mm (mean annual values)
- Annual cultivation of each main crop (sugar beet - wheat - barley) on 3 neighbouring fields
- Tillage treatments: **MP** = mouldboard ploughing 30 cm deep, **SM** = shallow mixing with a cultivator 10 cm deep (stationary plots)
- N-fertilization of sugar beet: 110 kg N ha^{-1}, singling to equal plant density, 4 replicates

Measurements:

- Plant (1993-2004): Yield, fangy beet, crown height above soil
- Soil (2004): X-ray computed tomography (CT) of undisturbed soil cores taken in (i) May (10-20 cm) and (ii) August (1-19 cm, incl. taproot), Dry bulk density (DBD) was calculated per cm of depth

Sampling of undisturbed soil cores (20 cm in diameter) incl. taproot; August 2004 (~ 130 days after sowing).

Results

- Dry matter yield was diminished by SM compared to MP by about 10 % (Fig. 1a).
- The portion of fangy beet (Fig. 1b) and the crown height above soil (Fig. 1c) was increased with SM compared to MP.

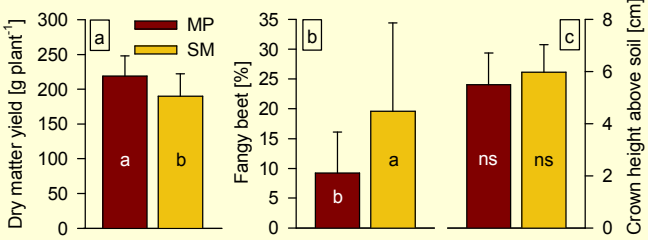

Fig. 1: *Effect of tillage (MP, SM) on (a) dry matter yield of total plants, (b) fangy beet and (c) crown height above soil; a, b indicate significant differences, ns=not significant; 1993-2004.*

- In May, higher values of DBD were detected in the lower layer of the formerly ploughed topsoil (> 10 cm depth) of SM, going along with a clear reduction in macroporosity compared to MP (Fig. 2).
- In August, DBD did not differ between tillage treatments in 1-10 cm depth (1.32 g cm^{-3}). In the 10-19 cm horizon, results from the May measurements were confirmed: DBD was substantially higher after SM compared to MP (Fig. 3).
- In August, no confined zones of compaction were detected in close vicinity to the beet surface. In contrast, radial cracks occurred down to 20 cm soil depth (Fig. 3).

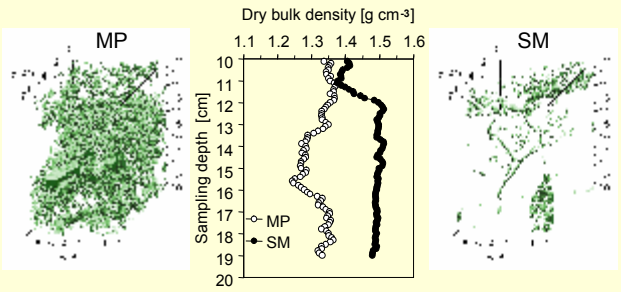

Fig. 2: *Comparison of spatial macropore distribution (macropores: green) and vertical dry bulk density distribution between mouldboard plowing (MP) and shallow mixing (SM); May 2004.*

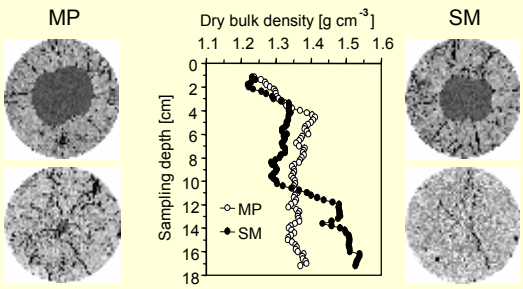

Fig. 3: *Soil structural state at two depths and vertical dry bulk density distribution as affected by soil tillage and sugar beet growth; August 2004.*

Conclusions

- Higher DBD observed with SM compared to MP tillage obviously increased fanging of beets and crown height above soil. As a consequence, formation of the taproot may have been impaired and yield was reduced.
- Nevertheless, it is still not clear by which physiological processes high DBD may limit growth if supply of nutrients and water is not limiting.
- Radial soil cracks are clearly caused by taproot thickening causing soil displacement presumably along predetermined lines of soil mechanical weakness.

References: Tomanová, O., N. Stockfisch & H.-J. Koch, 2006: Einfluss langjährig pflugloser Bodenbearbeitung auf Wachstum und Nährstoffversorgung von Zuckerrüben während der Vegetationsperiode. German Journal of Agronomy, 10 (in press).