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Perforation of the lower topsoil and the upper subsoil in a beet-cereal crop rotation after 24 years of tillage with and without plowing with and without green manure

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Introduction

When ploughing, there is a risk that over time a compacted, poorly perforated plow pan will form directly under the plow horizon (crumb base) at a depth of 30 to 35 cm. Compaction directly under the topsoil impairs root penetration and water availability for the crop plants. However, shallow tillage is also not without its problems. The weight of heavy machinery, especially if the soil is too moist, can compact the deeper layer of topsoil at a depth of 20 to 30 cm (deep crumb) over time. Such compaction can easily occur if, for example, the beet harvester drives over the moist soil with a full bunker during the sugar beet harvest in the fall. Plants with an allorhizal root system that are grown as catch crops in the crop rotation can possibly improve perforation in the deep crump and in the crumb base. Good root penetration is particularly important in regions with early summer drought so that the plant roots can penetrate the deeper, wetter soil layers as quickly as possible. Since 1998, the effects of shallow, plowless tillage with and without green manure (GM) on yields and soil fertility have been investigated in a long-term field trial at the University of Applied Sciences Bingen in the dry region of south-western Germany. The results of the water infiltration performance, which indicate differences in soil perforation in the deep crumb and crumb base, are reported here.

Material und Methods

The long-term field trial began in 1998. The soil at the trial site is a sandy-loamy loam (Lts) from diluvial high-flood loam. The average annual precipitation (2001 to 2022) was 488 mm, the average annual temperature was 11.2 °C. The soil at 0-30 cm contains an average of 2 % humus. When the trial was set up, the formerly uniformly farmed arable land was divided into three neighboring fields: North, middle and south field. The crop rotation on the three fields was sugar beet - winter wheat - winter barley, each staggered by one year. Straw was removed in most years and beet leaves were always left on the field. Nutrients were only added in the form of minerals (no organic fertilization with slurry, manure or compost). On each of the three fields, eight plots (43 m x 24 m) were established in 1998, which were cultivated with four treatment variants: with and without turning tillage (plow vs. cultivator), with and without yellow mustard as green manure before the beets (with vs. without green manure).

Double-ring infiltrometers were used to determine the permeability of the soil. The measurement of infiltration simulates the conditions of waterlogging and irrigation. For this purpose, water is filled into a ring that was previously pressed a few centimeters deep into the soil. In this experimental set-up, the water in the soil would not only spread vertically, but also laterally. A double ring is used to prevent lateral spreading. The water filled in the outer ring and infiltrating there suppresses the lateral spread of the water infiltrating in the inner ring (Fig. 1).

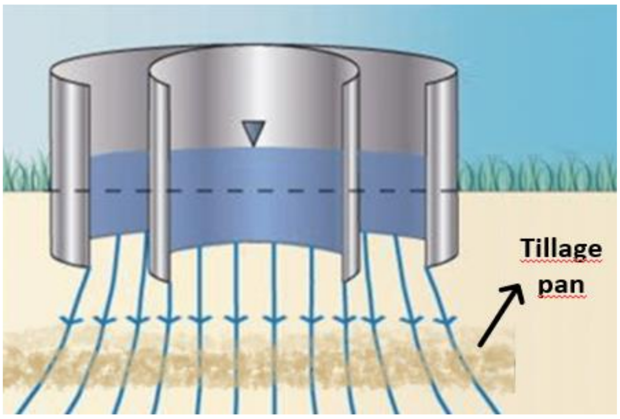

Fig. 1: Water flow into the soil and through the crumb base after filling the infiltrometer

Before infiltration, one centimeter of coarse quartz sand was distributed in the double ring infiltrometer to prevent silting of the soil surface (Fig. 2).

Fig. 2: Double-ring infiltrometer

Water is then poured into both rings to a height of approx. 10 cm and the time taken for the water level in the inner ring to drop by 2 cm is measured. The process of filling and infiltration is repeated until the infiltration rate stabilizes, in other words the infiltration rate reaches a steady-state. This infiltration rate at steady-state is then used for evaluation because it indicates the perforation of the soil in the layer of the deep crumb and the crumb base. As a rule, the steady-state is reached after 4 to 5 infiltration cycles of the infiltrometer. If the top soil had dried out at the beginning of the measurement, sometimes up to 8 filling infiltration cycles were required until the steady-state condition was reached (Fig. 3).

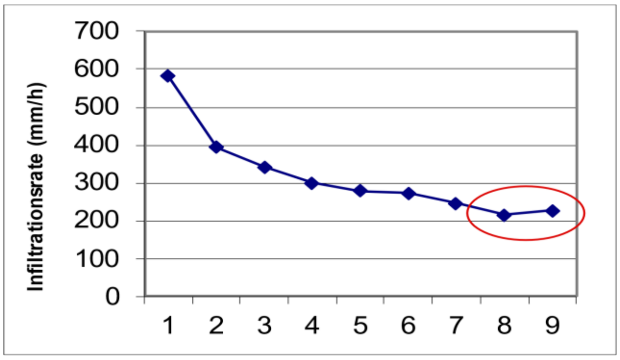

Fig. 3: Example of a measurement where the steady state flow rate was reached after refilling the infiltrometer eight times

The infiltration performance was determined in two measurement campaigns. One campaign took place between 2012 and 2014. Measurements of this first campain were taken at intervals of 2 to 3 weeks in the spring from the beginning of April to the end of May in the field that was in the specific year cultivated with sugar beet. At least two positions per plot on each date were examined. This gives a total of at least 8 infiltrometer measurements per plot. The measured values within each plot were avervaged and the plot mean values were then used for further statistical analysis.

A second measurement campaign was carried out in the years 2021 to 2023. In contrast to the first campaign described above, measurements were carried out on all 24 plots of the three fields in each of the three years of the second campaign. At least two positions were measured on each plot per year. This gives a total of at least 6 infiltrometer measurements per plot. The measured values within each plot were averaged and

the plot mean values were then used for further statistical analysis. Because the three fields were cultivated with wheat, barley or beet in each specific year, the infiltrometer measurements of the second campaign were sometimes taken in the wheat, sometimes in the barley and sometimes in the beet, depending on the year and field.
For the statistical evaluation, the average plot values of the respective variants were used (plots = experimental units). The error bars represent the standard error of the n = 6 plots for each treatment.

Results

In the first measurement campaign in 2012, 2013 and 2014, which was carried out when the plots were planted with beets, infiltration was significantly higher in the plowless plots than in the plowed plots ($p = 0.039$) (Fig. 4). Green manure also resulted in better infiltration on average, but the effect was not significant ($p = 0.204$).

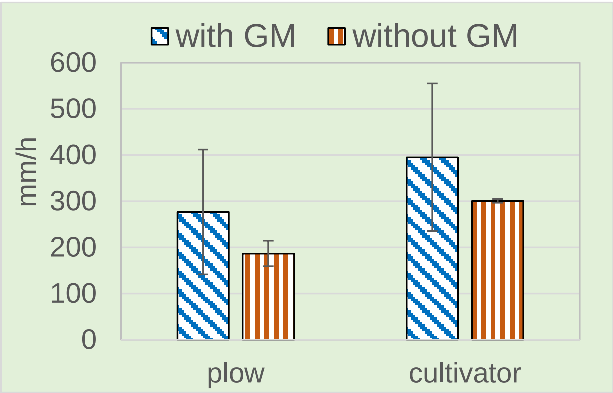

Fig. 4: Infiltration rate measured in the first campaign 2012, 2013 and 2014, the plots were planted with sugar beet at the time of imeasurement; GM = green manure

In the second measurement campaign, plowless cultivation no longer showed any advantage in the infiltration rate (Fig. 5). However, green manuring had a significantly positive effect ($p = 0.003$).

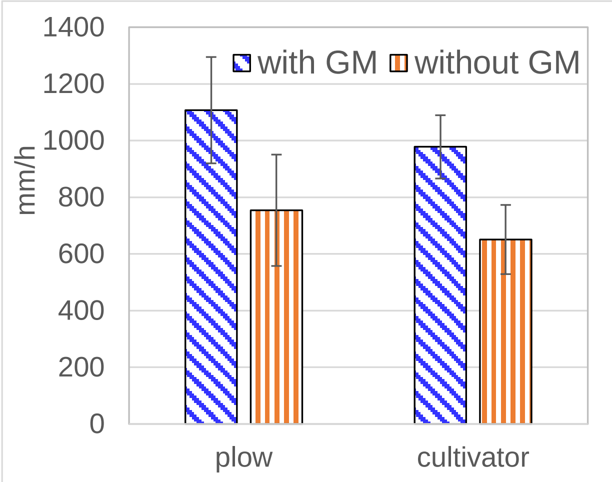

Fig. 5: Infiltration rate measured in the 2[nd] campaign in 2021, 2022 and 2023, measured each year on all three fields; GM = green manure

In the second measurement campaign, infiltration was measured on all three fields in each of the three years. This made it possible to quantify the effect of the crop type on the infiltration rate (Fig. 6). The infiltration rate was highest in wheat (measured in spring five months after the beet harvest) and lowest in barley (measured approximately 2½ years after the beet harvest).

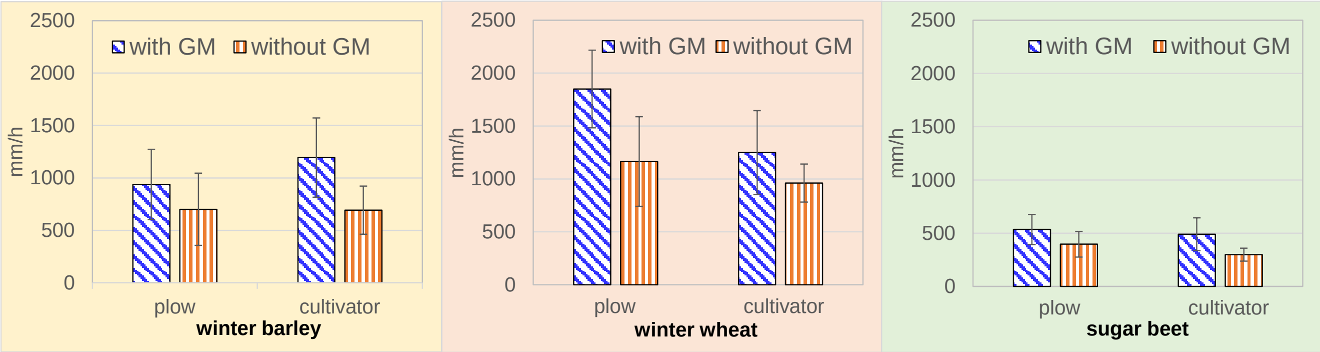

Fig. 6: Infiltration rate averaged over the 3 fields, measured in the years 2021, 2022 and 2023; infiltration was measured at 2 locations on each plot every year; error bars represent the standard error of the n = 6 different plots of each treatment in the field trial

Discussion and conclusion

In the long term, plowing was by no means detrimental to soil perforation. However, regular intercropping with yellow mustard was quite beneficial in the long term, in contrast to not plowing. This plant species forms deep taproots. It can be assumed that this plays a role in better perforation of the soil. Regular green manuring also promoted earthworms in the soil (Mangerich et al. 2024). Earthworm burrows and the activity of endogenous earthworms in the deep crumb are also likely to have a positive effect on the infiltration rates.

In regenerative agriculture, particular attention should therefore be paid to the cultivation of catch crops with allorhizal root systems, as these significantly improve soil perforation in the long term. On the other hand, it does not seem absolutely necessary to avoid plowing, at least not in crop rotations with beets. This is because we suspect that uprooting the beets when harvesting contributes to the perforation of the deep topsoil and the crumb base, as the infiltration rate was significantly higher after beet cultivation in the crop rotation (wheat was always cultivated after the beets and showed the highest infiltration rates). In the course of beet harvesting, the soil is loosened, especially the deep topsoil and the crumb base. Effects caused by plowing (whether positive or negative) may be compensated for by this.

References

Mangerich, J., Haßler, P, Appel, T., 2023: Earthworms in the soil under a beet-cereal rotation after 24 years of no plowing with and without green manure. Berichte der DBG (e-prints) https://eprints.dbges.de/1872/