

Soil fertility in relation to management strategies in German organic apple orchards

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Abstract

The goal of the study was the assessment of the impact of soil management practices currently implemented by organic apple growers in Southern Germany on soil fertility. Data was collected on nine farms in the Lake Constance region in summer 2024: Farmers were interviewed on their orchard management strategies, soil samples were analysed for nutrient content and water infiltration rates were measured in the tree rows. On the nine farms, the fertilisation strategies were already adapted to the high nutrient levels in the soil, e.g. by not fertilising at all or only applying nitrogen fertilisers. The infiltration rate was higher in orchards where the soil was tilled and the inter-row biomass was transferred to the tree row than in orchards without tillage or where mulch transfer did not take place. When compared to the data in the literature, the infiltration rates measured on all farms in this study were similar or higher. We therefore conclude that organic apple orchards in the Lake Constance region have a high water storage capacity which also contributes to minimizing erosion and maintaining a good water supply to the trees.

Keywords: Water infiltration, tillage, organic matter, erosion, water runoff.

Introduction

Maintaining a fertile soil is key for a sustainable orchard management. Soil fertility can be defined as biological, chemical and physical soil properties which positively affect plant growth. Management strategies are often assessed only for their effect on soil nutrient contents. However, measurements on biological or physical properties are rarely done. Within the EIP-Agri-Project "Appreciation, value creation and valorisation of environmental services in organic fruit growing" organic fruit farmers across Germany participated in an online survey on the topic of soil fertility and their soil management practices (Lepp & Zikeli, 2024). In addition, soil data were collected in fruit orchards on farms with different strategies on soil cultivation and management in the Lake Constance region. The goal was to assess the current soil nutrient status in orchards and to detect an effect of different management strategies on the water infiltration rate as one of the physical soil properties.

Material and Methods

Based on the online survey and by consulting with fruit growing consultants, soil management practices relevant for soil fertility were defined and sorted into four representative categories that reflect the current status of management practices. Organic apple growers in the Lake Constance region, representing all four categories, were invited to participate in the study via the newsletter of the fruit growing consultants or were asked directly by the consultants. The precondition for participation was an orchard design with 3.5 m distance between the tree rows for a better comparability of the farms and data. Nine farmers participated and were grouped as follows:

- Category 1: Interrow-mulch is transferred to the tree row with every cut, and mainly commercial organic fertilisers (e.g. hair meal pellets, vinasse) are used (Farms 1a-1d)

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- Category 2: Interrow-mulch is transferred to the tree row with every cut, and mainly bulk fertilisers (e.g. compost, grass cuts from other fields) are used (Farms 2a-2b)
- Category 3: Interrow-mulch is never transferred to the tree row (Farms 3a, 4b)
- Category 4: No till (Farms 4a-4b)

In the period between June and August 2024, semi-structured interviews were done with the nine farmers on soil cultivation and the fertilisation strategy in one representative orchard of the farm: the depth and number of soil tillage treatments per year, the amount and type of fertilisers used and the transfer of inter-row biomass to the tree row as mulch. In that same orchard a mixed soil sample was collected of approx. ten auger samples up to 30 cm depth in the tree rows across the orchard. Soil was analysed for organic carbon (C_{org}), plant available phosphorus (P_{CAL}), potassium (K_{CAL}) and magnesium (Mg_{CaCl2}) content and pH_{CaCl2} . Infiltration measurements were carried out with a double-ring infiltrometer (inner diameter: 30 cm) in the tree row. Over a period of two hours water was constantly refilled in both rings. The infiltration rate was defined as the decrease of water level in the inner ring by one centimetre in the measured time. It was measured at several points in time within the two hours. Three measurements were carried out per orchard and farm. Infiltration rate data were analyzed by the following model:

$$\eta_{ijk} = \tau_i \cdot x_{ijk}^{\beta_i}$$

where η_{ijk} is the expected infiltration rate at time k of measurement j on farm i , τ_i is the farm-specific intercept and β_i is the farm-specific slope on the cumulative time (x_{ijk}). Parameters in this multiplicative model were estimated by fitting a linear model after logarithmic transformation of the equation:

$$\log(y_{ijk}) = \log(\tau_i) + \beta_i \log(x_{ijk}) + e_{ijk},$$

where y_{ijk} is the observed infiltration rate at time k of measurement j on farm i and e_{ijk} is the first order auto regressed error of y_{ijk} . Means and slopes were compared and differences were presented via letter display.

Results

Infiltration rates differed significantly, ranging from 13 to 80 cm/h. They were higher in the orchards where mulch was transferred to the tree row and soil was tilled (Figure 1, Table 1). According to the nutrient content classes for fruit orchards of the Landwirtschaftliches Technologiezentrum Augustenberg (LTZ, 2023), P, K and Mg contents were at least in the optimum range in eight of the nine orchards. Only one farm had low P and Mg contents.

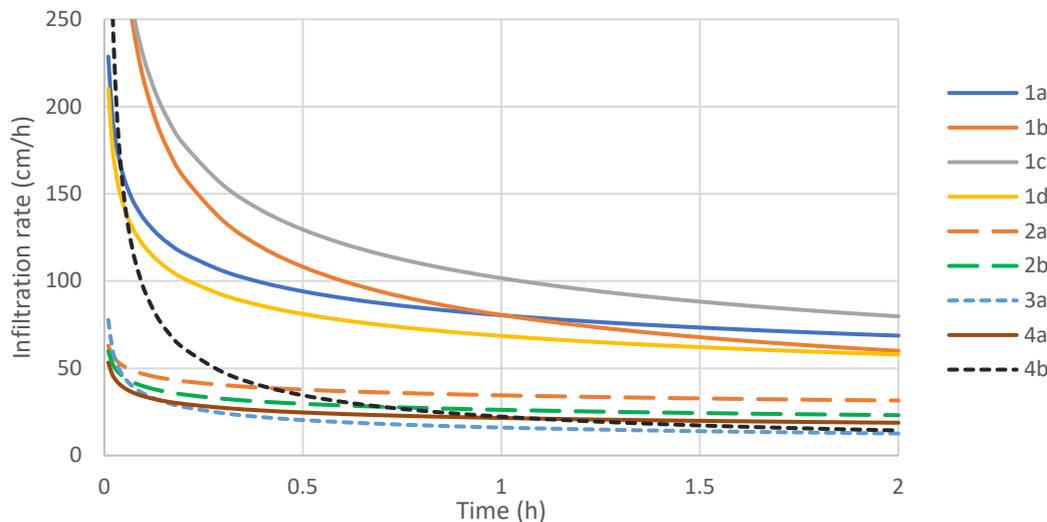


Figure 1: Predicted infiltration rates in the tree row on the nine farms (mean of three measurements).

Table 1: Management strategies on the nine farms, soil analysis data and infiltration rate (Tillage depth 0: only superficial soil treatment, 0-10: superficial and deeper soil treatment up to 10 cm, 5-10: soil treatment up to 10 cm without superficial treatments. Tillage treatments: Number of treatments per year without counting superficial treatments. Different letters at the infiltration rates show significant differences between farms).

Farm	Fertilisation (kg N/year)	Tillage depth (cm)	Tillage treatments	Interrow mulch transfer to row	Soil type	C _{org} (%)	pH	Infiltration rate after 2 h (cm/h)
1a	40	0-10	3	Every cut	Sandy clayey loam	3.06	7.0	69 a
1b	20	0-10	3	Every cut	Sandy loam	3.62	6.0	60 ab
1c	Only weak trees	5-10	n.d.	Every cut	Sandy loam	2.76	5.7	80 a
1d	0	5-10	4-5	Every cut	Sandy loam	2.45	5.6	58 ab
2a	Grass cuts	5-10	4	Every cut	Clayey loam	2.94	6.4	32 abc
2b	Grass cuts	5-10	4	Every cut	Loamy sand	1.82	6.6	23 bc
3a	35	0-10	2-3	No	Sandy loam	1.98	7.0	13 c
4a	25	0	0	Every cut	Sandy loam	4.09	6.8	19 c
4b	0	0	0	No	Sandy loam	1.64	5.7	14 c

Discussion

As the amount of nutrients removed by the apple harvest are low compared to arable crops, levels of plant-available nutrients in the soil change very slowly. Therefore, we cannot deduce from one sampling if fertilisation strategies tend to lead to nutrient enrichment or depletion. According to documents and assessments by some farmers, there were no or only minor changes in soil nutrient levels compared to previous analyses commissioned by themselves, although fertilisation strategies on farms had been adapted to the high soil contents since 5 to 15 years. In one orchard, for example, no fertilisation was done in the last 12 years, in others, N-fertilisers such as hair meal pellets were chosen to avoid further inputs of P and K due to their high contents in the soil. However, the transferred mulch from the inter-row to the tree row also contains considerable amounts of those nutrients (Lepp et al., 2022).

Regarding infiltration rates, the number of sites sampled is too small to be able to make a reliable statement about the effects of cultivation strategies on soil properties. However, the measurements provide initial results on the values and range in organic orchards. The results indicate that the infiltration rate increases when the soil is tilled and organic matter is added. Other studies in arable land confirm higher infiltration rates in organic farming, i.e. with the supply of compost or organic matter (e.g. Fueki et al., 2012). Two of the farmers also observed an improved crumb structure in the soil after the conversion to organic farming due to hoeing or the incorporation of organic matter. The effect of tillage on infiltration is not clear in the literature, as there are contradictory results (Vogeler et al., 2009; Blanco-Canqui

& Ruis, 2018; Martínez-Mena et al., 2021). Blanco-Canqui & Ruis (2018) cite reasons for a higher infiltration rate with reduced tillage, e.g. intact vertical pores, higher C_{org} levels or, indirectly, protection against silting by soil coverage. Although more extensive tillage increases the C_{org} content, the soil compacts at the same time (Peigné et al., 2018), which has opposite effects on infiltration and may lead to the contradicting results in literature. In addition, the results can vary greatly, depending on the location and the time of measurement (Vogeler et al., 2009). The infiltration rates measured in this project are comparable to other sources (e.g. Fueki et al., 2012; Martínez-Mena et al., 2021), despite the differences between the tillage strategies. This means that large quantities of water can be stored in the orchards, making the practices adopted by the farmers an important contribution to erosion control and the landscape water balance. Organic farming with the supply of organic matter has a positive effect on soil physical properties, but it should be noted that high amounts of bulk fertilisers can result in nutrient imbalances in the soil (Lepp et al., 2024). Depending on the nutrient content in the soil, it should therefore be considered to apply lower amounts of fertiliser, which has already been implemented on the farms in this study.

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