Effects of temporarily reduced tillage in organic crop rotations on yield, earthworm biomass and development of weed pressure. -First results of a case study from Schleswig-Holstein/Germany-

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Abstract

Farming systems applying reduced tillage measures are expected to be beneficial for sustaining important soil functions (ecosystem services) and (soil) biodiversity. Furthermore, a reduction in tillage intensity is connected to reduced need for energy and labour input.
On the other hand waiving the plough is, especially in organic farming systems, suspected to lead to increased weed pressure and therefore decreases in yields.
In this paper, first results of a study on temporarily reduced tillage in organic crop-rotations are presented. Here the plough was set aside before drilling triticale at the end of four crop rotations, and expectable yields, earthworm biomass and weed pressure were investigated. First one-year-results of the experiment on temporarily reduced tillage to triticale at the end of organic crop-rotations did not show enormous decreases in yields, but also the expected positive effects (increase in earthworm biomass) could not be statistically secured.

Introduction

Tillage systems without using a plough are predominantly applied in conventional farming. For example, this concept is widely used in the USA since the enormous problems caused by wind erosion in the 1930s. But also in organic farming, reduced tillage systems are an object of interest for many years now, and scientific work in this area started at least in the early 1990s (Carr et al. 2013). To give but one example there is the on-going pan-European TILMAN-ORG project (http://orgprints.org/20830/; www.tilman-org.net).
In general, preserving and improving of soil functions (ecosystem services) and protection and promotion of (soil) biodiversity are expected benefits of reduced tillage. Furthermore, waiving the plough in soil tillage leads to reduction of labour and energy input (Peigné et al. 2007, Carr et al. 2013). These positive effects are anticipated in conventional as well as in organic farming systems.
Besides, also negative impacts are expected: mainly an increase of weed pressure, which may cause a decrease in yields. This is especially a problem in organic farming, because here no herbicides are used for weed control. Hence effective weed control seems to be a major topic when applying reduced tillage to organic farming systems. Because of many other factors influencing crop-yields the applicability of reduced tillage systems has to be tested site-specific.
Against this background the effects of temporarily reduced tillage at the end of a crop rotation on yield of triticale, weed pressure and earthworm biomass are presented.

Material and methods

Investigations were carried out at the experimental farm of the Thuenen-Institute of Organic Farming in Trenthorst, Schleswig-Holstein, Germany (53°77' N, 10°53' E). The dominating soil types are Stagnic-Luvisols (FAO) with a texture ranging from sandy loam to loamy sand and a soil ranking of 50-55 (German system). Mean total annual precipitation is about 700 mm and mean annual temperature is 8.8 °C.
In Trenthorst four different organic crop-rotations are established with triticale as final crop of each. In September 2012 the triticale-fields were halved and on one half reduced tillage was conducted. For the purposes of this study, the term reduced tillage (rt) means tillage restricted to 15 cm depth waiving the plough. This is compared with a conventional tillage (ct) regime with ploughing up to a depth of 30 cm. The half-fields are addressed by the abbreviation LTM-plots (long term monitoring plot) and a number code in the following. The LTM-plots are arranged in couples (6&7, 17&171, 24&25, 57&571), where one is under conventional and the other one under rt.

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Expectable yields were determined in August 2013 at four fixed sampling points per LTM-plot on 0.25 m^2 by number of ears per m^2, kernels per ear and thousand grain weights. To check the calculated yields for significant differences t-test was used and to reveal potential underlying mechanisms an ANOVA was applied to the data. Additional yield data (grain & straw of threshed square meter samples) will be available in the running project.
Earthworm biomass was investigated, because earthworms are a widely accepted indicator for soil conditions (van Capelle et al. 2012). Earthworms were sampled using Allyl isothiocyanate (Zaborski 2003) coupled with hand-sorting at three locations (at 1-1.5 m, 4.75-5.25 m and 8.5-9 m) along two 10m-transects per half-field. Here pits of 50x50x10 cm were excavated and the soil searched for earthworms. Into these pits the Allyl isothiocyanate solution was poured in two portions of 5 L to expel earthworms from deeper soil layers. In laboratory earthworm biomass per transect was measured. To reveal differences and underlying mechanisms t-test, Kruskal-Wallis-test and ANOVA were used.
To investigate the weed dominance and community structure, in June 2013 on each half-field vegetation assessments following the method of Braun-Blanquet were conducted.
Within the project all statistics were calculated using R 2.15.2.

Results and conclusions

When comparing the couples of LTM-plots, the only significant difference in expectable yield*m^{-2} can be found between LTM 24 and 25 (t-test; p=0.002) (Fig. 1).

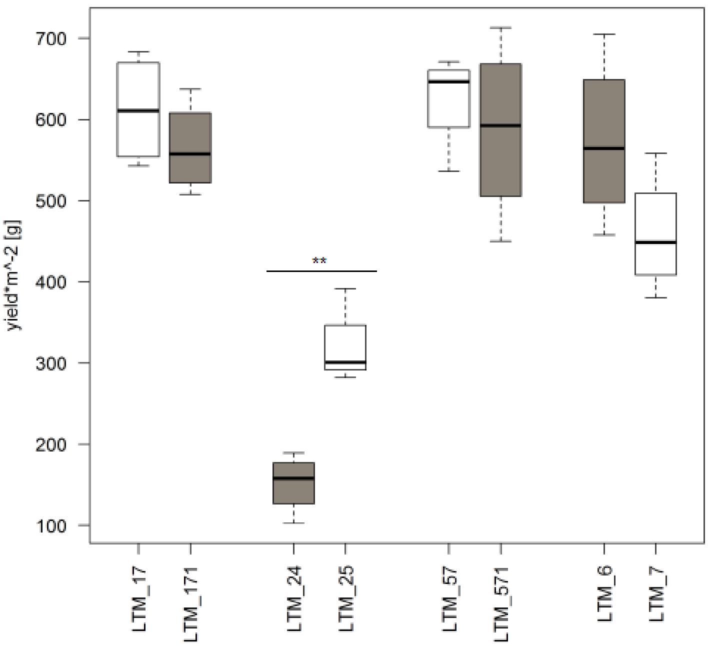
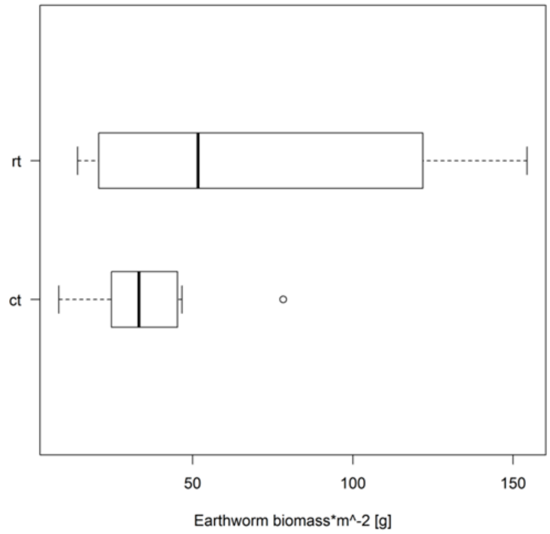


Fig. 1: Expected triticale yields per LTM-plot (dry matter), n=32.
Grey boxes showing results of half-fields under reduced tillage measures.
Significant differences within couples as calculated using t-test are marked using * (p<0.05 *, p<0.01 **, p<0.001 *).**

When comparing expectable yields between conventional and reduced tillage regime no significant difference can be found. Two-way-ANOVA with location (LTM-plot) and type (ct vs. rt) as factors revealed significant influence of location. This significant influence can be totally assigned to yields calculated for LTM-plot 24 and 25. LTM-plot 24 and 25 differ from all remaining LTM-plots in terms of management, because they belong to the cash crop farming system of the experimental farm. Contrary to the other systems on the station no farmyard manure is applied here and only one year of clover in the crop rotation is established since 2003 (Schaub et al. 2007). The fields of the experimental farm belonging to the cash crop farming system are known to generate lower yields, mainly because of lacks in nutrient supply, and to have partly great problems with weed infestation. These problems are well known from other organic farming researches (Carr et al. 2013). In summary on fields with farmyard manure application and higher density of clover and clover grass in the Trenthorst crop rotations no significant reduction in yield was found under a one year reduced tillage regime.
Earthworms were used as one predictor for the status of soil biological activity. The first sampling in spring after tillage in autumn shows no significant difference in earthworm biomass based on statistical tests, when comparing the two tillage measures. But a slightly enhanced mean value could be observed under reduced (69.63 g*m^{-2}) compared to conventional (36.59 g*m^{-2}) tillage (Figure 2).
Van Capelle et al. (2012) mention “the interacting effects of reduced injuries (of earthworms), microclimate-changes, decreased exposure to predators at the soil surface, and an increased availability of organic matter providing a convenient food source” as drivers for the increase in earthworm biomass under conditions of reduced tillage. In return higher abundance of earthworms increases the positive effects assigned to these animals, like enhancement of soil aggregation and creation of channels for drainage, aeration and root growth (van Capelle et al. 2012).

In the combination of weed species no differences could be shown between the soil treatments. Indeed mean values for weed dominance differ between conventional (20 %) and reduced (31.5 %) tillage (Fig. 3), but this difference is not significant.



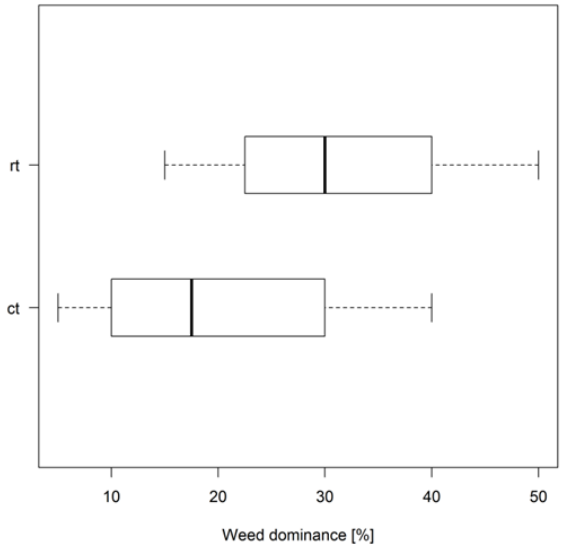


Fig. 2 (left): Earthworm biomass*m^{-2} for the two treatments reduced (rt) and conventional (ct) tillage. No significant differences could be shown. Results from April 2013, n=16.

Fig. 3 (right): Weed dominance for the two treatments reduced (rt) and conventional (ct) tillage. No significant differences could be shown, n=8.

Because of bad weather conditions in spring 2013, no measures of weed control could be executed at the survey fields. So probably if the regularly planned measures could have been used the difference between the tillage regimes would have been even smaller.

To sum up first one-year-results, of the experiment on temporarily reduced tillage to triticale at the end of organic crop-rotations, it can be stated, that:

- The suspected decrease in yield by reduced tillage appeared only in the rotation with lowest yield level.
- The expected positive effects of reduced tillage on earthworm biomass could not be statically secured.
- The suspected increase in weed density couldn't be statistically secured by the Braun-Blanquet method at harvest, even without any measure of weed control.

Soil and weather conditions will have strong effects on the yield performance in different years and no general advice to introduce reduced tillage methods can be expected. But in the upcoming part of the project additional data on the biomass yield will be available and evaluated. Also the possible role of temporarily reduced tillage to enhance biological soil activity and biodiversity will be explored in more detail. Number of individuals and species composition of collembolans (springtails) and also of earthworms will be investigated. In summer 2013 the comparison of tillage regimes was continued in the second year on the research fields, this before drilling clover respectively grass-clover leys. So more results on the parameters discussed above will be generated to investigate consequences of prolongation of temporarily reduced tillage in organic crop rotations on biological activity in soils.

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