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# Occasional reduced tillage in organic farming can promote earthworm performance and resource efficiency

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A B S T R A C T

Reduced tillage has several advantages over conventional tillage (CT), including the promotion of earthworm communities and the reduction of input of energy and labour. However, its application in organic farming is mainly hindered through increasing weed pressure. One way to counteract this drawback might be to introduce occasional reduced tillage (ORT), which means applying methods of reduced tillage only in combination with selected crops. Against this background we hypothesized that (i) ORT rapidly promotes biomass, abundance and species richness of earthworm communities and that (ii) ORT generates a financial surplus for farmers. Therefore, a field experiment was established for triticale (*x Triticosecale*) cultivation on loamy soils in Northern Germany. The influence of tillage regimes on earthworms was investigated in a non-randomized design with n = 3 fields for the ORT and CT treatment. Earthworm biomass, abundance and species richness were investigated in October 2012 and in April and October 2013. Yields were determined for the three fields under each tillage system, each field with four non-randomized replicates, before harvest in 2013. The ORT treatment consisted of two to three tillage operations prior to seeding with a maximal cultivation depth of 15 cm and without ploughing, whereas the CT treatment consisted of a ploughing depth of 25–30 cm and one to four other steps for seedbed preparation prior to seeding. In total, seven earthworm species were identified. Our data revealed that earthworm biomass was significantly reduced under CT, both four weeks and about seven months after tillage. This effect holds true for the number of earthworm individuals in autumn (four weeks after ploughing), but not for the number of earthworm individuals in spring (seven months after ploughing). Results of contribution margin analysis showed no consistent trend referring to tillage measures. Two fields, which performed well under CT, showed a financial surplus (+24% and +13%) when managed with ORT. At the same time one field, performing poorly under CT, generated financial deficits (-10%) under ORT. Overall ORT had immediate positive effects on earthworm populations. Furthermore, this management scheme might have positive effects on the economic outcomes of organic crop rotations if overall growing conditions are sufficient. Along with methods usually applied to investigate earthworm performance, we checked whether the number of surface casts could help estimate earthworm performance. It became apparent that the number of surface casts cannot be used as a general predictor of earthworm performance. The number of individuals of *Lumbricus terrestris*, the number of anecic individuals and the total earthworm biomass can be estimated the most reliable by counting surface casts.



## 1. Introduction

The reduction of tillage intensity, including methods for reducing tillage depth to no-till systems, has been a topic in conventional farming research for many years now and some researchers postulate reduced tillage to be the next agricultural revolution (Krauss et al., 2010). In recent decades it also became a topic in European organic farming research (Mäder and Berner, 2012).

In organic farming, reduced tillage without ploughing can reduce erosion, enhance macroporosity, and promote microbial activity and carbon storage (Peigné et al., 2007). It is also associated with less run-off and leaching of nutrients, reduced fuel use, and faster tillage (Peigné et al., 2007). However, Peigné et al. (2007)

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emphasize possible disadvantages, including greater pressure from grass weeds; less suitability than ploughing for poorly drained, unstable soils or high rainfall areas; restricted N availability and restricted choice of crops. Of the expected drawbacks listed, increasing weed pressure under reduced tillage measures is the most discussed (Krauss et al., 2010; Mäder and Berner, 2012; Metzke et al., 2007). Additionally, in long-term experiments, a change of weed community structure to the dominance of perennial species including competitive grasses has been determined (Peigné et al., 2007). Therefore Metzke et al. (2007) see a conflict of interest between setting aside the plough to promote, e.g., habitat conditions for soil biota (Pfiffner and Mäder, 1997) and intensive ploughing for weed control.

This is where the main line of conflict is drawn when dealing with reduced tillage or no-till systems in organic farming: the promotion of desirable ecosystem services on the one hand versus the risk of increased weed pressure which may consequently cause losses in yields, on the other hand. However, there is an ongoing debate concerning potential drawbacks of reduced tillage and consequent possible reduction of yields. In light of this discussion some attention has been paid to strategies of occasional reduced tillage (ORT) and occasional direct seeding, which means applying methods of reduced tillage/direct seeding only in combination with selected crops (Massucati, 2013). According to Carter (1994) this management scheme, which he calls rotational tillage, can maintain an adequate weed-control and can also have positive influence on sustainable soil management (e.g., prevention of soil compaction, plant disease control) in humid regions when compared to permanent reduced tillage.

In agricultural cropping systems reduced tillage without ploughing (i.e., non-turning soil management) generally favours soil biodiversity and especially earthworms (Carr et al., 2013; van Capelle et al., 2012). At the same time it needs to be kept in mind that species may react differently to the same management measures. In some studies for example the abundance of *Aporrectodea caliginosa* increased when a plough was used for soil cultivation (Peigné et al., 2009; Pelosi et al., 2014). However, according to van Capelle et al. (2012) the overall positive effect of reduced tillage on earthworms is due to interacting effects of reduced injuries, decreased exposure to predators at the soil surface, microclimate changes and an increased availability of organic matter providing a convenient food source in the upper soil layers. Especially for anecic species the reduced destruction of their vertical burrows is supposed to be important. Earthworms function as ecosystem engineers positively changing soil chemical, physical, and biological properties. The positive effects of earthworms on nutrient turn-over and transfer, for bio-aggregation of soil particles and on a porous soil structure that positively influences root growth and water infiltration (Kautz et al., 2013) are beneficial in all farming systems. But these ecosystem services are important in sustaining soil fertility and stabilizing crop rotation yields especially in low input farming. Farmers try to benefit from these services by applying reduced tillage in organic farming (Metzke et al., 2007). This targeted support of ecosystem services to improve cultivation conditions is what Kuntz et al. (2013) call eco-intensification.

Like in our study earthworms are regularly used as bioindicators, e.g. for management changes or soil contamination (Fründ et al., 2011). This is because today much is already known about earthworm behaviour and ecology, and because earthworms can be detected in the field by the naked eye. Nevertheless, there are also some reasons against using earthworms as bioindicators. Generally, methods combining application of specific expellants with hand-sorting of soil are used to study the performance of earthworm communities (Čoja et al., 2008). These methods are time consuming, labour-intensive and require expert knowledge. Alternatively, the activity of earthworm communities can be estimated by counting and mapping soil surface markings of earthworms, like casts and burrow openings (Ehrmann, 2003). Fründ (2010) proposed the use of surface markings of earthworms as a first step when evaluating soil conditions.

In the present case study under on-farm conditions we tested the following hypotheses: In organic crop rotations occasional reduced tillage (ORT) (i) rapidly promotes biomass, abundance and species richness (referred to as performance in the following) of earthworm communities and (ii) generates a financial surplus for farmers. Additionally we checked whether the counting of surface casts is a reliable method to predict the performance of earthworm communities.

## 2. Material and methods

### 2.1. Study site

The experimental farm in Trenthorst has been managed under the EU Organic Standards 2092/91 and 834/2007 since 2001 and is

**Table 1**
Crop rotations, amount of chargeable N-application and soil conditions at the three experimental fields. Each field belonging to one farming system serving the needs of one group of farming animals (dairy, ruminant II, pig).

| Farming system | Dairy | Ruminant II | Pig |
|---|---|---|---|
| Crop rotation | clover-grass<br>clover-grass<br>maize<br>winter wheat<br>field bean/oat<br>triticale | clover-grass<br>maize<br>winter wheat<br>field pea/spring barley<br>triticale | clover-grass<br>clover-grass<br>spring barley<br>field pea/false flax<br>winter barley<br>field bean<br>triticale |
| Chargeable amount of N (kg ha$^{-1}$) | | | |
| 2012 | 72 | 53 | 105 |
| 2013 | 22 | 27 | 25 |
| pH | 6.8 | 6.5 | 6.5 |
| Nutrient content (mg 100 g$^{-1}$) | | | |
| P | 5.7 | 7.4 | 6.0 |
| K | 9.5 | 17.5 | 13.4 |
| Mg | 9.3 | 12.5 | 12.8 |
| Texture (%) | | | |
| Clay (< 2 μm) | 17 | 20 | 21 |
| Silt (2–50 μm) | 35 | 38 | 38 |
| Sand (50–2000 μm) | 46 | 40 | 40 |