Studies on earthworm populations in orchards

P. Scheewe[1], U. Arnold, S. Rußig and R. Drewes Alvarez

Abstract

Earthworms are a major component of soil fauna and they can play important roles in agroecosystems. There activity influences biological, physical and chemical procedures in soil. One aspect which is especially important in orchards is their feeding and burrowing activities of leaves. As a consequence the primary infection potential of diseases with overwintering spores on leaves, for example of Venturia inaequalis *(Cooke) Wint. causing apple scab, will be lower.*

Overall earthworm abundence is a useful bio-indicator for soil-fertility. The spectrum of species belonging to the different morpho-ecological groupings – epigeic species, endogeic species, anecics species – gives further information.

There are different methods for the estimation of earthworm populations. The mustard extract method combined with hand-sorting used in this study has the advantage not to pollute the soil with chemicals and the earthworms stay alive. The species were determined according to the glass-tube-method for live determination.

The aim of the study was to get a survey of the method, the spectrum of species and the abundance of earthworms depending on the position in the orchard meaning rows and between rows or in relation to other aspects like undergrowth. Orchards at five different locations were included.

Eight earthworm species were found belonging to anecics, endogeic or epigeic grouping. Differences between earthworm populations depending on the position of the orchard could be seen as a tendency in some orchards with lesser earthworms in the driving track. But the investigation of driving tracks was limited due to suppressed soil which did not allow taking of probes with the mustard extract method.

Keywords: earthworm, mustard extract method, organic, integrated orchards

Introduction

Already Darwin documented the activities of earthworms and published his oberservations 1881 in his book „The formation of vegetable mould, through the action of worms“. Worms prepare the ground for the growth of plants, they mingle particles together or they drag dead leaves and other parts of plants as food (Darwin 1881). Scheu (2003) reviewed several studies on earthworm-plant interaction. In 79% of the studies shoot biomass of plants increased in the presence of earthworms. Altogether their activity influences biological, physical and chemical procedures in soil. This includes soil pores for water and air through their burrowing activities or the formation of stable aggregates (Edwards & Bohlen, 1996). The burrows also function as flowpathways for nutrient transport and also for pesticides (Edwards *et al.* 1993, Pätzold & Brümmer, 2004). One aspect which is especially important in orchards is their feeding and burrowing activities of leaves. As a consequence the primary infection potential of several diseases with overwintering spores

[1] University of Applied Science (HTW) Dresden Fakultät Landbau/Landespflege, Pillnitzer Platz 2, D-01326 Dresden, Emails: Petra Scheewe: scheewe@pillnitz.htw-dresden.de, Ulrike Arnold: Arnold.Ulrike@web.de, Renée Drewes-Alvarez: alvarez@pillnitz.htw-dresden.de

on leaves, for example of *Venturia inaequalis* (Cooke) Wint. which causes apple scab, will be lower (Kennel & Niklas, 1980; Raw, 1962). There are some investigations of earthworm populations, abundance and biomass in orchards but due to different sampling methods the results are not always comparable (Raw, 1962, Jamar et al., 2008, Hauser & Pfiffner, 1997, Niklas et al., 1979). Earthworms are, compared to other soil organisms, easier to investigate and so they are interesting for ecological investigations on one side and on the other side they may be of interest for detecting of soil-pollution including heavy-metals (Niklas & Kennel, 1978, Rathkens & von der Trenck, 2007).

The focus of this study was on the spectrum of species to be found in different orchards and on the distribution of the earthworms depending on the position in the orchard meaning rows and between rows or in relation to other aspects like undergrowth.

Material and Methods

The investigations were done in different apple orchards mananged organically or integrated. All orchards are located in Saxony in the fruit growing area near Dresden or on northern Saxony. The management and the conditions of the orchards were different so only different aspects on one location were compared.

Location 1: The apple orchard was on the experimental field of the Universitiy of Applied Science in Dresden-Pillnitz. The trees were planted in 2005. The influence of different undergrowth in sandwich-system or treatment in the row and probes between the rows were compared. Weed control in the rows was done mechanically (Sandy). The soil is para-brown soil and soil type is sandy loam. Location 2 is close to location 1 on the fields of the Saxon State Ministry of the Environment and Agriculture in Dresden-Pillnitz. Compared were a cultivated organic apple orchard planted in 2004 with 'Gala' and a cleared (spring 2008) former (since 1998) organically managed apple orchard. The soil is the same as in location one. Location 3: Three orchards were in Sornzig (Northern Saxony), two orchards with apple planted in 1996 and one orchard with sour cherries planted in 2006 and all were managed organically. The apple orchards were close to each other but one is in an altogether better condition according to growth and yield than the other without any obvious reason. They are later referred to as “good” and “not good” orchard. The soil is loess loam. The fourth location was south of Dresden near Pirna. The orchard was was grown with 26 year old apple 'Boskoop‘ and managed integrated. The rows were treated with herbizides. The soil is loamy sand. In the south-west of Dresden in Theisewitz was the fifth location with different apple varieties and managed organically. Soil type is loam.

In all orchards Funguran (Kupferoxychlorid) was used in different quantities over the last years. The integrated managed orchards used herbizide in the rows and in the organically managed orchards soil cultivation in the rows was done mechanically. Between the rows it was mulched.

For earthworm extraction a combination of the mustard extract method and hand sorting was used, with five replications for each orchard and position. Samples were taken between the begining of June until the end of July 2008. Before extraction the vegetation was cut of to prevent the earthworms to hide and soil temperature (depth about 18 cm) was measured. A metal frame (50 cm x 50 cm) was inserted about 3 cm in the soil. 60 g mustard powder not deoiled (Kroppenstedter Ölmühle) was suspended in 10 l water. This repellent was poured in three portions on the soil in the frame. With very dry and compressed soils mainly between the rows in the driving tracks it sometimes took very long tome for the mustard suspension to drain. The driven out earthworms were collected.

After that a soil block of 25x25x20 cm was dug out put on a white foil and all remaining active or inactive earthworms were sorted out. The earthworms were collected in a jar together with wet earth and preserved in a cooling bag. For determing the abundence and biomass earthworms were washed with clear water until no soil was left. They were carefully dried with a filter paper and weighted. For identification of the living worms the narrow glastube method described by Thielemann (1986) was used in a modified form. The identification was done under a light microscop (Zeiss Stemi 2000-C) using a cold light illumination (Schott KL 200). Adult earthworms were identified to species level and juveniles were identified to the genus using the keys of Christian & Zicsi (1999) and Schaefer (2006). After identification earthworms were put back in the open land.

For statistical analysis of abundance and biomass the mean of the 5 replications was used. Number of individuals was extrapolated to one squaremeter. As the data were not normally distributed the Mann-and-Whitney Test (pairwise comparison) was used for statistical analysis with p=0,05.

Results

Over all locations eight different earthworm species were found. These were the epigeic species *Lumbricus castaneus* Savigny, *Lumbricus rubellus* Hoffmeister and *Esenia (Allolobophora) parva* Eisen, the endogeic species *Allolobophora caliginosa* Savigny, *Allolobophora rosea* Savigny and *Octolasion cyaneum* Savigny and the anecic species *Lumbricus terr*estris L. and *Allolobophora longa* Ude. There was little difference in the number of species between the orchards. The portions of juvenile earthworms over all probes and species were between 47% and 92%. The relation between adults and juvenils of the genus *Lumbricus* was 27% to 73%, of the genus *Allolobophora* 17% to 83% and of *Octolasion* 36% to 64%. Soil temperature was in minimum 13,9°C and maximum 21,7°C with a mean temperature of 18,0°C. Rainfall was quite low during May and June 2008 at all locations. At the first half of July there was a rainy period. This might be important for the results of location 5 where the investigation was done in July about 14 days after the beginning of the rainy period. Comparing number and biomass of earthworms in three different orchards in the rows and between rows there could be found no significant differences (figure 1 to 3). Noticeabel was the much higher number of individuals in the orchard at location 5. At location 4 a probe was taken in the driving track. Here the number and biomass of earthworms was significant lower than at the other positions. The percentage of juveniles was with 92% much higher than 77% in the row and 71% between the rows at this location. Neighbouring apple orchards were compared, one of them not developing very well. There were no significant differences in number and biomass of earthworms. But there was a tendency in the apple orchard "not so good" with a lower biomass indicating to more smaller individuals (figure 4) though the percentage of juveniles was with 86% not much different from the other orchard with 80%. In figure 5 a cleared apple orchard and a cultivated apple orchard are compared. There were no differences. But the clearing was done in spring 2008 so only a few weeks before the beginning of the studies. Interesting is the tendency to a higher biomass in the cleared orchard. This may be due to the much lower percentage (47%) of juveniles compared to the cultivated orchard with 73% juveniles. Figure 6 shows the results of location 1. Comparing the the different undergrowth in the row or between the row the covering with xylit was different. Xylit is a residue of browncoal mining consisting of plant material not completely converted to coal. The number of individuals and the biomass was significant lower than in the other parts except in the driving track. Having a closer look at the percent individuals of *Lumbricus terrestris* of all adults over all locations differences could be seen. The percentage was between 0% in the row of sour cherries in location 3 and 100% at location 4 in the driving track, but this was one individuum.

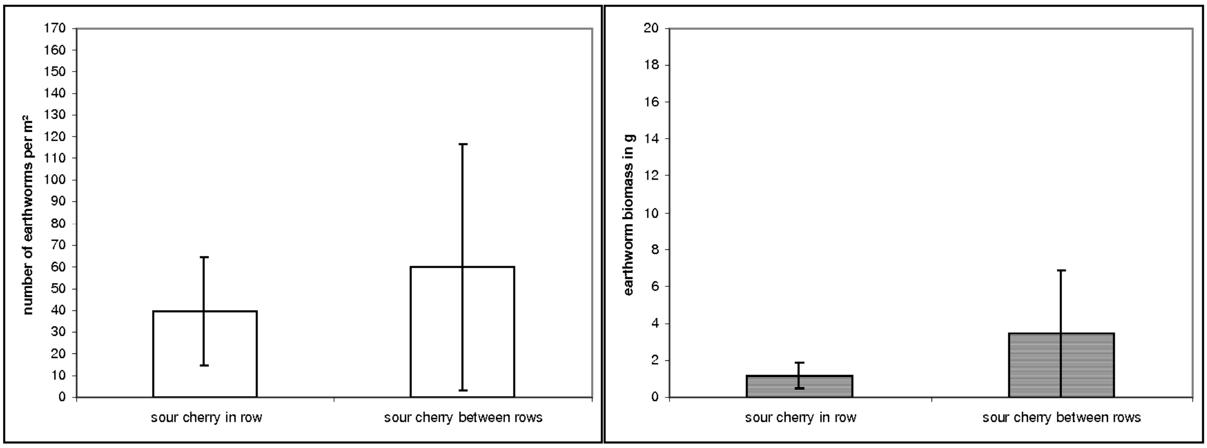

Figure 1: Location 3 Sornzig left: Mean number of earthworms per squaremeter (n=5) in rows; right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; no significant differences with the Mann-and-Whitney Test (p=0,05).

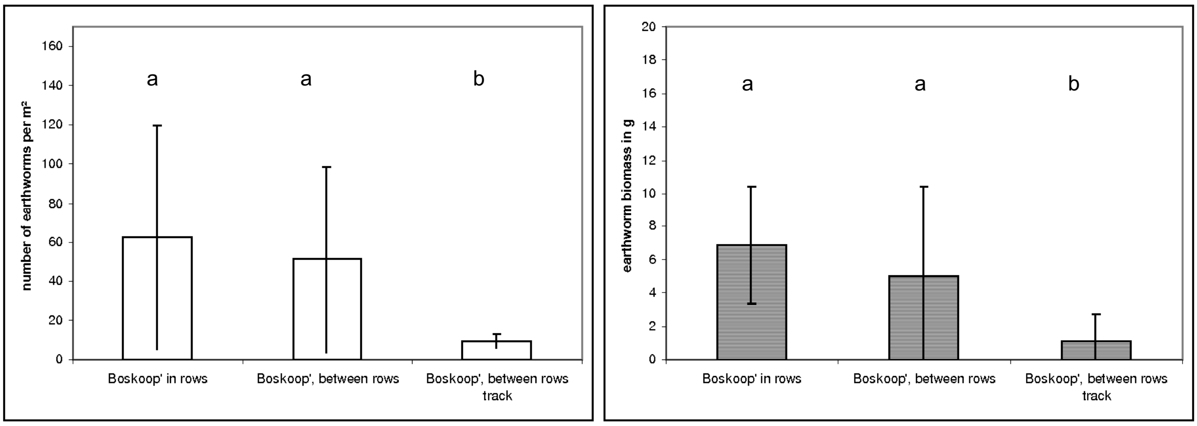

Figure 2: Location 4 near Pirna left: Mean number of earthworms per squaremeter (n=5) right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; different letters meaning significant differences with the Mann-and-Whitney Test (p=0,05).

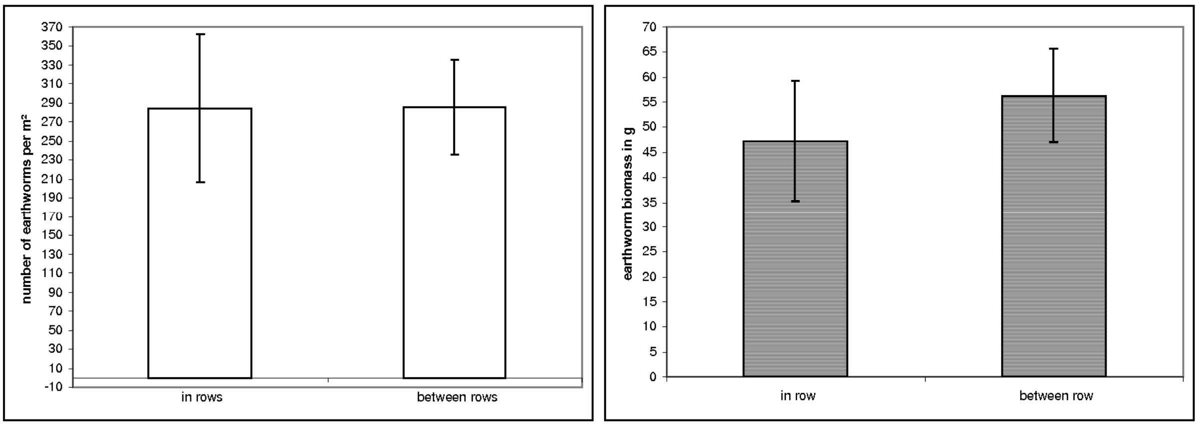

Figure 3: Location 5 near Theisewith left: Mean number of earthworms per squaremeter (n=5) right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; no significant differences were found with the Mann-and-Whitney Test (p=0,05).

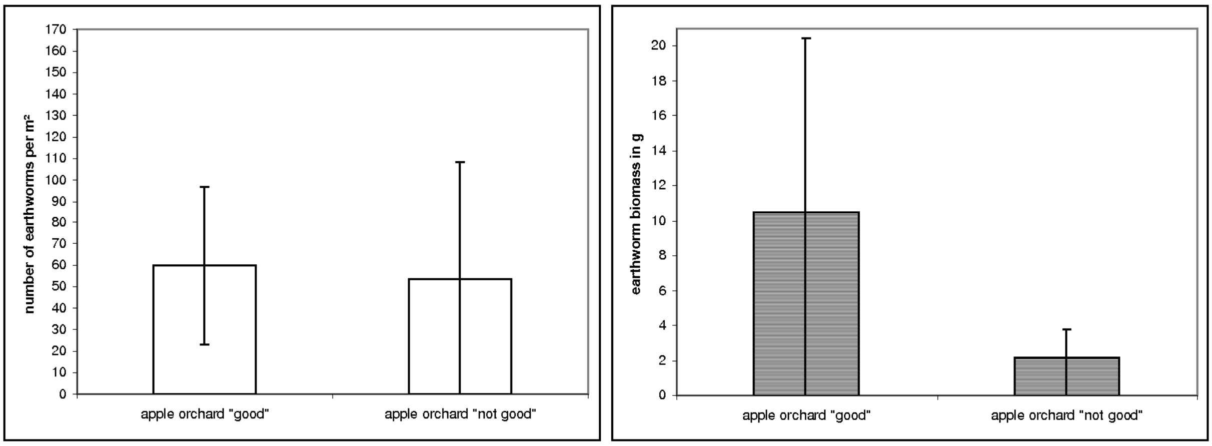

Figure 4: Comparison of two apple orchards at Location 3 Sornzig left: Mean number of earthworms per squaremeter (n=5) right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; no significant differences were found with the Mann-and-Whitney Test (p=0,05); “good” and “not good” in growth and yield compared to each other.

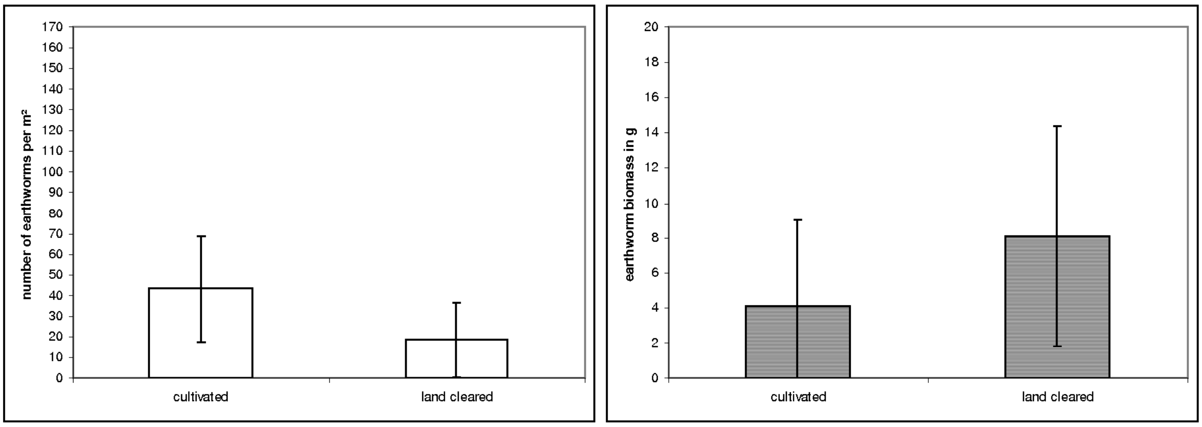

Figure 5: Comparison of a cultivated and a 2008 cleared apple orchard at location 2 Pillnitz left: Mean number of earthworms per squaremeter (n=5) right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; no significant differences were found with the Mann-and-Whitney Test (p=0,05).

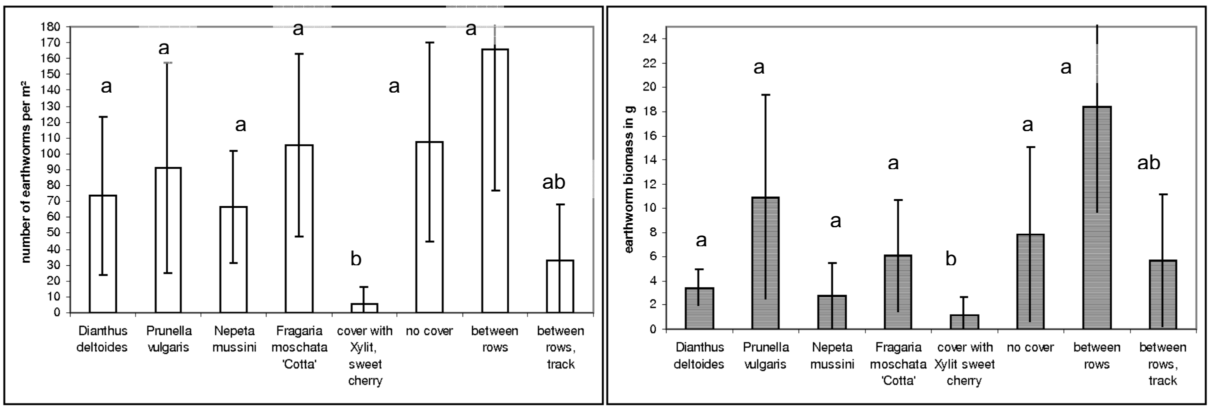

Figure 6: Comparison of different treatment in row and between rows at ocation 1 in Pillnitz left: Mean number of earthworms per squaremeter (n=5) right: earthworm biomass in rows, mean of data for extraction and handsorting; bars are marking the standard deviation; different letters meaning significant differences with the Mann-and-Whitney Test (p=0,05).

At location 3 the numbers were with 10% also low in the row. Interesting were the differences at location 2 with 89% in the cleared orchard and 25% in the cultivated orchard and the results at location 3 with 67% in the apple orchard with better growing and yield compared to only 25% in the nearby apple orchard with poor growth and yield. For nearly all positions at all locations a great variation between the 5 replications for one trial was noticeable.

Discussion

It is common to classify earthworms in three different morpho-ecological groups. Endogeic species live mainly in the upper mineral soil with horizontal burrows. Anecics species dig vertical burrows up to 3 m deep. They draw leaves from the ground into the burrows. Epigeic species live mainly on the soil in the litter and do not dig (Edwards & Bohlen, 1996). Over all orchards eight species were found. This is comparable with other authors who found nine species (Niklas et al., 1979, Hauser & Pfiffner, 1997). Some species were only found in very low numbers and not in all sites like the epigeic *L. castaneus* with one individual in an organic orchard though according to Schaefer (2006) this species is to be found in moist soils frequently. *L. rubellus,* another epigeic species, was only found in organic orchards. Investigations in 2009 confirm this result. Because of their ecology they should be more sensible to the input of fertilizer or pesticides than the endogeic species and they need litter on the soil.

As Earthworm populations are influenced by different environmental factors like moisture, temperature, pH, soil type, organic matter or tillage it is difficult to seperate the effects. One important factor is the soil moisture. Though there are differences in tolerating low soil moisture between species and different strategies for coping with dry soil conditions, prolonged droughts decrease number of earthworm markedly and it may take long time for the population to recover (Edwards & Bohlen, 1996). The high absolut numbers of earthworms at location 5 compared to the other locations may be due to a longer rainy period before sampling. The other reason may have been a higher organic matter probably due to a less intensiv cultivation during the past years.

Altogether there are some studies where the abundance of earthworms was higher in different organic systems (Jamar et al., 2008, Pfiffner, 1993) but not in all cases (Bauchhenß, 2003). The dominating species of the adults was in most cases *L. terrestris.* This is according to the results of Niklas et al. (1979). The tracks between the rows had a low abundance. This might be due to the the suppression of the soil making it difficult for burrowing or in combination a disturbed infiltration of water in soil. This is known for arable land (Laring & Schrader, 2003). In accordance with this is the problem at the time of sampling where it was partly neither possible to use the mustard extract method nor to dig between the rows in the middle and in the track due to the suppressed or dry soil. In further investigation it would be useful to to measure other parameters like soil moisture or organic substance.

Comparing the number and biomass with other studies is difficult because of the use of different sampling methods. Depending on the method the results for different ecological groups are different (Emmerling, 1995). Ehrmann et al. (2007) suggest a method for recording and evaluation earthworm populations.

Taking this and other results and the discussion about the role of earthworms in the soil ecosystem it would be useful to include orchards in programms for long term observations or to start long term observations at all. This could be a chance to find out about changes in populations of earthworms, meaning species, number of individuals and biomass due to climatic changes and management.

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