To what extent do soil micro-arthropods facilitate organic matter breakdown in an arable field soil? – Implications on specific protection goal setting for soil risk assessment of plant protection products

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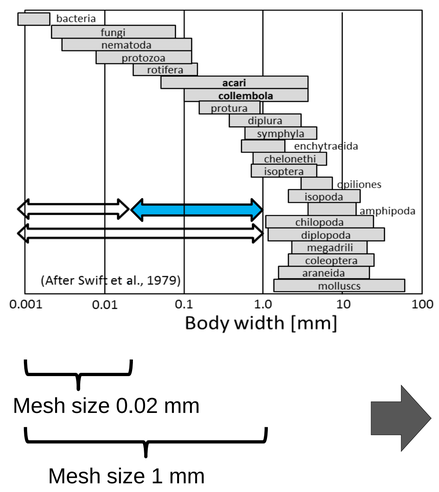
Introduction

To directly link the protection goals related to ecosystem services (e.g. nutrient cycling) with the in-field soil risk assessment of plant protection products it is suggested to take functional test systems into consideration. This project aims to determine the contribution of soil micro-arthropods (Collembola and Acari) and micro-organisms to the functional endpoint of organic matter breakdown and nutrient cycling. A realistic quantification of soil mesofauna contribution to ´organic matter breakdown` in arable field soils can help to better interpret results from structural data in light of Ecosystem Services. The determination of soil mesofauna driven organic matter degradation and the simultaneous monitoring of the soil micro-arthropod abundances allow to assess the functional relevance of effects on soil micro-arthropods differing in magnitude, affected taxa, and duration. Hence, the results can contribute to the definition of specific protection goals for the risk assessment of plant protection products. Only a few validated functional tests methods are available and were considered suitable in the past for being used in the risk assessment, e.g. the litterbag test. For enhancing the toolbox of test systems it is assessed whether the minicontainer test could represent a suitable alternative functional test system for being used in the risk assessment of plant protection products.

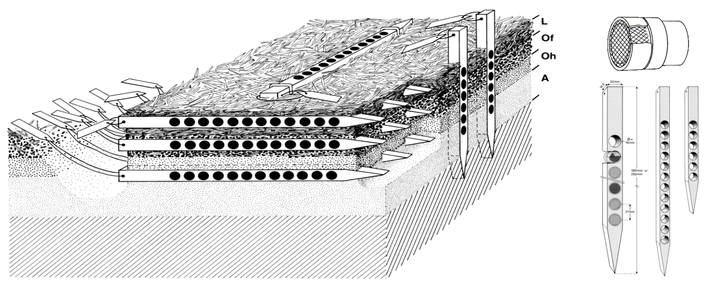
Materials and Methods

Field trial design

- 10 x 10 m plots on an arable field site
- **Treatment groups** (n=4 plots per group)
  - -C: Control
  - -M1: 0.6 kg Methamidophos/ha
  - -M2: 3 kg Methamidophos/ha
  - -L1: 2.5 kg Lindane/ha
  - -L2: 7.5 kg Lindane/ha
- **Minicontainer tests with two different substrates**
  - -Lucerne stems
    → 2 consecutive sets, each running for 3 months
  - -Cereal leaves, 6 months
- **Structural data:**
  Abundances of Collembola and Acari in soil (0-5 cm)
  → 6 soil cores per plot
  → Extraction via MacFadyen
  → Taxonomic identification to species level, if possible
- **Sampling dates:**
  14 d, 1, 2, 3, and 6 months



Minicontainer test (Eisenbeis, 1998)



Source:
EISENBEIS, G. (1998), Praxis der Naturwissenschaften Biologie 47 (4): 15-21

-Determine organic matter degradation at mesh sizes of **0.02 mm** (micro-organisms) and **1 mm** (micro-organisms + mesofauna)
→Determine contribution of **soil mesofauna (mainly Collembola/Acari)** to organic matter breakdown
-4 bars exposed per plot (one bar/sampling) at 5 cm soil depth, each bar with 12 containers per bar (6 container/mesh size/bar)
-Allows a more differentiated view on the process of organic matter breakdown compared to the litterbag test

Results

Abundances of total Collembola and Acari:

- All insecticide treatments caused initial reductions in soil micro-arthropod abundances
- Methamidophos (M1 and M2) reduced abundances of Collembola by 53.4% and 67.2% and Acari by 47.6% and 61.3%, respectively. Collembola recovered to a level of 70% and 75% of control, Acari showed still significant differences compared to control after 6 months
- Lindane (L1 and L2) reduced abundances of Collembola by 80.6% and 86.9% and Acari by 74.8% and 84.8%, respectively
- Six months after application Total abundances of Collembola and Acari did not show recovery in the Lindane treatment groups

Minicontainer:

- Increasing degradation of organic matter with time, lucerne stem residues degrade faster than cereal leaf residues
- The degradation of lucerne stem residues in the 1 mm mesh sized minicontainer is only slightly higher than in minicontainer with 0.02 mm mesh size
- No effects of insecticides on degradation of organic matter by micro-organisms observed
- Insecticide application did not significantly reduce organic matter degradation, even though there was a clear effect on mesofauna abundance
- Overall, the contribution of soil mesofauna to organic matter breakdown is low, it is strongly driven my microbial degradation

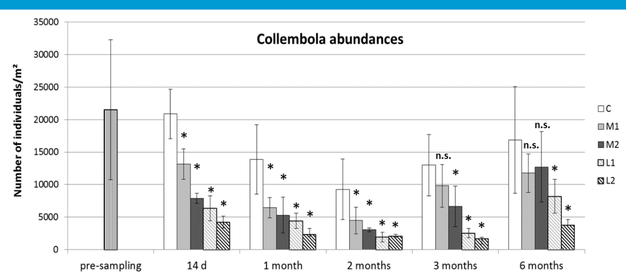


Figure 1: Total Collembola abundances (mean number of individuals/m² ± SD; n=4 (plots); at pre-sampling n=20 (soil cores)) at different sampling dates in the control and the insecticide treatment groups (C=Control; M1=low rate Methamidophos; M2=high rate Methamidophos; L1=low rate Lindane; L2=high rate Lindane); * indicates a significant difference compared to the control (two-sample Student t-test with p=0.05); n.s.= not significant

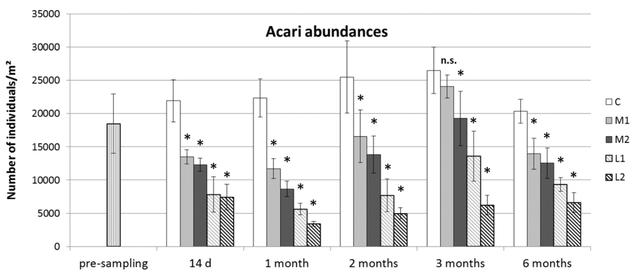
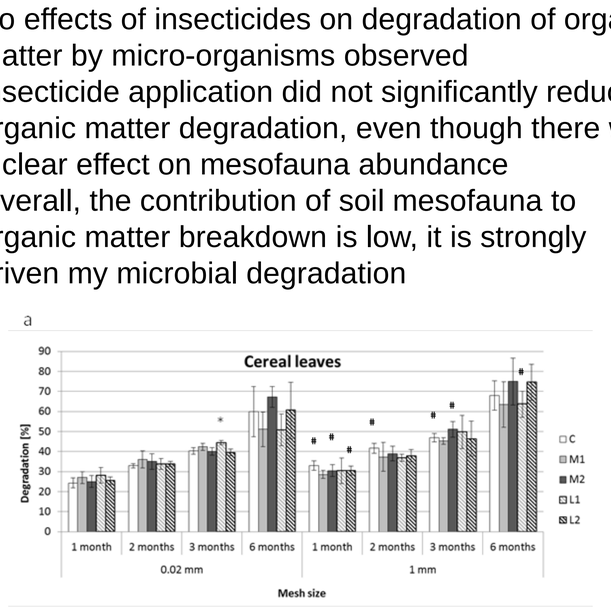


**Figure 2: Total Acari abundances (mean number of individuals/m² ± SD; n=4 (plots); at pre-sampling n=20 (soil cores)) at different sampling dates in the control and the insecticide treatment groups (C=Control; M1=low rate Methamidophos; M2=high rate Methamidophos; L1=low rate Lindane; L2=high rate Lindane);
* indicates a significant difference compared to the control (two-sample Student t-test with p=0.05); n.s.= not significant**



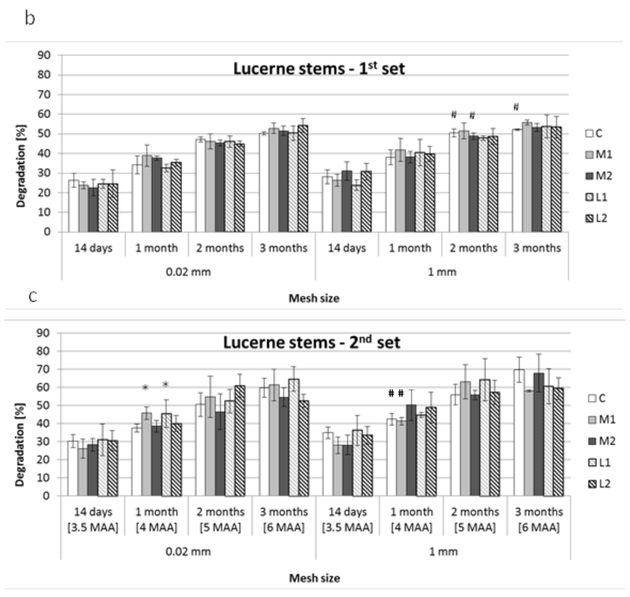


Figure 3 a, b, c: Degradation [%; mean value with SD; n=4] of different organic material (cereal leaves (a) and lucerne stems (b and c, 1st and 2nd set, respectively)) in the minicontainers with 0.02 mm and 1 mm mesh size in soil at a certain time after burying or after application [MAA; month after application]. Treatment groups: C=Control; M1=low rate Methamidophos; M2=high rate Methamidophos; L1=low rate Lindane; L2=high rate Lindane; * indicates statistically significant differences of the insecticide treatments from the control, # indicates a statistically significant difference of the degradation in the 1 mm mesh size compared to the 0.02 mm mesh size (both, two-sample Student t-test, two sided, p=0.05)

Discussion

The minicontainer test shows consistent and reproducible results between the different substrates, mesh sizes tested, and seasons considered. The results indicate that the process of organic matter degradation is dominated by soil microbes. Soil mesofauna contributed only to minor extend to organic matter degradation. Thus, the minicontainer test did not show any significant effects of insecticides on organic matter degradation although abundances of Collembola and Acari were heavily reduced by the insecticide applications. The contribution of soil micro-arthropods to organic matter degradation in this arable field was lower compared to forest ecosystems as shown by Frouz et al. (2015). This might be due to differing quality of organic matter and/or mesofauna community in the different ecosystems.

Conclusions

Effects of plant protection products on soil micro-arthropods should be put into overall functional perspective. The contribution of Collembola and Acari to organic matter degradation might be expected to be low in agricultural soils. Thus, the relevance of structural endpoints on soil micro-arthropods (population and community level) within an in-field soil risk assessment for plant protection products which focus on maintenance of soil fertility (protection of soil functions) is questionable.
An in-field soil risk assessment of plant protection products should focus on functional endpoints as these allow to directly link the risk assessment with protection goals derived from Ecosystem Services (i.e. organic matter degradation, nutrient cycling). Focusing on structural data (e.g. abundances of soil micro-arthropod populations – single species evaluation) seems to have no direct implications on the function ´nutrient cycling` in soil.
The minicontainer test can represent a suitable alternative functional test system for the risk assessment of plant protection products, allowing a more differentiated view on organic matter degradation in soil.

References

Eisenbeis G., Lenz, R., Heiber, T. (1999): Organic residue decomposition: The minicontainer-system a multifunctional tool in decomposition studies. – Environmental Science and Pollution Research 6 (4): 220-224.

Frouz J., Roubíčková A., Heděnec P. & Tajovský K. (2015): Do soil fauna really hasten litter decomposition? A meta-analysis of enclosure studies. – European Journal of Soil Biology 68: 18-24.