The Eternal Rye and earthworms:
A case study for long-term effects on
agricultural intensification

C. Huber[1], P. Euteneuer*[2], H. Wagentristl[2], R. Neugschwandtner[1], L. Sturm[1], K. R. Butt[3]

[1] University of Natural Resources and Life Science, Vienna; Department of Crop Science, Institute of Agronomy, Tulln, Austria
[2] University of Natural Resources and Life Science, Vienna; Department of Crop Science, Experimental Farm, Gross-Enzersdorf, Austria
[3] University of Central Lancashire, School of Natural Science, Preston, United Kingdom

Corresponding author:
pia.euteneuer@boku.ac.at

Introduction

In arable fields, **earthworm abundance declines** with the level of intensification, due to soil **disturbance or decreasing food** (Briones and Schmidt, 2017; Euteneuer et al., 2020). In this context, ploughing and bare fallow are major drivers for the decease of earthworm populations, but the impact of fertiliser addition is not yet sufficiently addressed. Therefore, the earthworm population of the **"Eternal Rye", a 116-year field trial** with three fertiliser regimes and two cropping sequences was investigated in 2020 and 2021.

Figure 1: The Eternal Rye in April 2022 in Gross-Enzersdorf at the experimental farm of the University of Natural Resources and Life Sciences, Vienna. The winter rye and spring barley in the crop rotation treatment in the three fertiliser treatments. Farmyard manure (FYM).

Results and discussion

Results show that **only fertiliser addition had an impact** on earthworm populations with the **highest abundance in plots of FYM, followed by mineral fertiliser and unfertilised** (Figure 2A). The most abundant species was *Allolobophora chlorotica* under FYM and mineral fertiliser, followed by small numbers of *Aporrectodea caliginosa*, *Aporrectodea rosea* and *Lumbricus terrestris* (Figure 2B). Interestingly**, *L. terrestris* was observed mostly in FYM** and Edwards and Lofty (1982) reported similar from the continuous wheat trial Broadbalk (instigated in 1843). Additionally, Stroud (2016) found in 2015 in Broadbalk, 0.3 and 0.13 middens of *L. terrestris* m^{-2} in FYM and mineral fertiliser, respectively. Similar results regarding total earthworm abundance and cropping sequence were seen in a 50-year trial in Lithuania when a cropping sequence of rye, oat (*Avena sativa*) and bare fallow did not differ when compared to rye in monoculture (Bogužas et al., 2022).

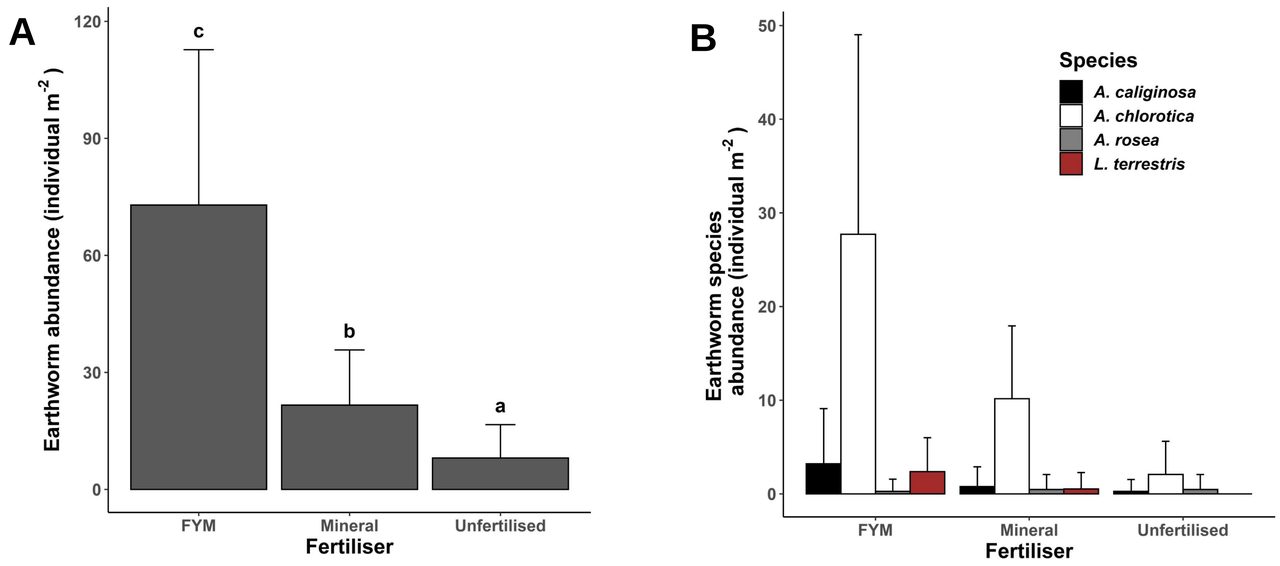

Figure 2: A) Total earthworm abundance, B) number of earthworm species within three fertiliser regimes (unfertilised; mineral fertiliser; farmyard manure (FYM)). Treatments having no letter in common are significantly different (2-way LMM; Tukey; $P < 0.05$).

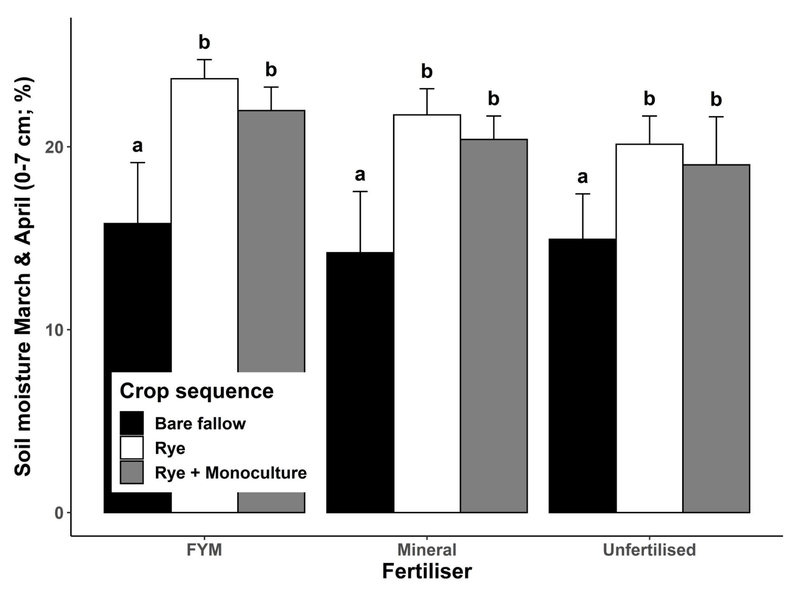

Figure 3: The overall % topsoil moisture (0-7 cm) in March and April (2020;2021) in cropping sequence winter rye in rotation (Rye), bare fallow in rotation (Bare fallow) and rye in monoculture (Rye + Monoculture). Cropping sequences having no letter in common are significantly different (2-way LMM; Tukey; $P < 0.05$).

Material and Methods

The Eternal Rye was **instigated in 1906** at the experimental farm of the University of Natural Resources and Life Science, Vienna (Austria). The field experiment is two-factorial with cropping sequences **crop rotation** (Winter rye (*Secale cereale*) – Spring barley (*Hordeum vulgare*) – Bare fallow) **or continuous cropping of winter rye**, and fertiliser treatments **farmyard manure (FYM), mineral fertiliser or unfertilised** (Figure 1). **Straw was removed** every year after harvest and **plots were ploughed** before sowing of rye in late October. Earthworms were investigated only under rye (crop rotation rye or continuous rye) and bare fallow in April 2020 and 2021 by hand searching of soil monoliths (20 × 20 × 30 cm).

In contrast to earthworm data**, soil moisture** in the Eternal Rye in spring was **only affected by cropping sequences** with driest soil (% moisture) under bare fallow (Figure 3). Hence, **the impact of FYM** on earthworms in the Eternal Rye is based on the soil nutrition status and the **availability of food rather than soil moisture**.

Conclusion

The Eternal Rye and similar long-term trials such as Broadbalk may be **a glimpse into the future** for long-term effects to **biodiversity in intensified agriculture** with simplified crop rotation and without FYM.

References

Bogužas, V., Skinulienė, L., Butkevičienė, L.M., Steponavičienė, V., Petrauskas, E., Maršalkienė, N., 2022. The Effect of Monoculture, Crop Rotation Combinations, and Continuous Bare Fallow on Soil CO2 Emissions, Earthworms, and Productivity of Winter Rye after a 50-Year Period. Plants 11, 431. https://doi.org/10.3390/plants11030431

Briones, M.J.I., Schmidt, O., 2017. Conventional tillage decreases the abundance and biomass of earthworms and alters their community structure in a global meta-analysis. Glob. Change Biol. 23, 4396–4419. https://doi.org/10.1111/gcb.13744

Edwards, C.A., Lofty, J.R., 1982. Nitrogenous fertilizers and earthworm populations in agricultural soils. Soil Biol. Biochem. 14, 515–521. https://doi.org/10.1016/0038-0717(82)90112-2

Euteneuer, P., Wagentristl, H., Steinkellner, S., Fuchs, M., Zaller, J.G., Piepho, H.-P., Butt, K.R., 2020. Contrasting effects of cover crops on earthworms: Results from field monitoring and laboratory experiments on growth, reproduction and food choice. Eur. J. Soil Biol. 100, 103225. https://doi.org/10.1016/j.ejsobi.2020.103225

Stroud, J.L., 2016. Population collapse of *Lumbricus terrestris* in conventional arable cultivations and response to straw applications. Appl. Soil Ecol. 4, 72-75. https://doi.org/10.1016/j.apsoil.2016.08.002