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Soil Science Challenge Grants Program

The University of Melbourne

Soil fauna and nutrient transformation of agricultural soil: project summary

Project period: June 2022 to June 2025

Introduction

Soil fauna is a vital part of healthy soils. They help break down plant material, recycle nutrients and support the microbes that keep soil productive. Together, these processes improve crop growth and support sustainable farming. Despite their importance, soil fauna has received much less attention than other parts of the soil ecosystem. This has limited our understanding of how they contribute to healthy soil. This first-of-its-kind Australian project investigated the diversity, distribution and ecological roles of soil fauna across major farming systems, including wheat, sugarcane, cotton and grazing pastures.

The project included 3 main areas of research.

1) **Understanding what shapes soil fauna communities**
   Researchers studied more than 400 sites to identify the environmental and management factors that influence soil fauna. The results showed that climate and soil chemistry are the strongest drivers of soil fauna communities. Farming practices also play an important role, leaving long-term effects on nutrient availability and soil biodiversity.

2) **Exploring interactions between soil fauna and microbes**
   This research examined soil faunal and microbial interactions. The study found that introducing beneficial soil fauna can:

   - improve nitrogen cycling
   - reduce plant-parasitic nematodes
   - rebuild damaged soil food webs.

   Researchers also developed the Nematode Soil Health index, a practical tool that converts complex ecological information into indicators that can be used to assess soil health.

3) **Measuring how soil fauna contributes to nutrient cycling**
   This research measured how soil fauna influence nitrogen and phosphorus cycling under different pH levels and management practices. The results showed that applying lime reduced soil disturbance and maintained nutrient balance, leading to improved biological nutrient cycling and greater soil resilience.

Findings

The research confirmed that soil fauna, particularly nematode food webs, play an important role in cycling nitrogen and phosphorus. However, how effectively they perform these functions depends on soil pH and how the soil is managed. The project identified critical soil pH levels where biological nutrient cycling becomes much more effective.

The research also found that:

- reduced soil disturbance through practices such as no-till farming helps protect the complex soil food webs needed for efficient nutrient cycling
- fertiliser inputs should match the soil's biological capacity to reduce nutrient losses and improve nutrient use efficiency.

Overall, the findings support a whole of system approach to soil management. Combining chemical amendments, such as lime, with farming practices that protect soil biology, including conservation tillage and organic amendments, will help maintain a healthy soil ecosystem. When soil chemistry and soil biology are managed together, farmers can make better use of the natural nutrient cycling provided by soil fauna and microbes. This can improve crop productivity while also building healthier, more resilient soil. These findings provide valuable evidence for developing practical management guidelines that improve fertiliser efficiency, increase phosphorus use in acid soil and rebuild healthy soil food webs across farming systems in Australia and beyond.

Publications

This project has published the following papers with additional papers currently in preparation or in review. This section will be updated once additional papers are published.

Ghaderi, R, Hayden, HL, Jayaramaiah, RH, Hu, HW & He, JZ 2025, An innovative framework fosters practical application of nematode-based indices in soil health assessment, *European Journal of Soil Science*, vol. 76, no. 4, e70149, DOI:10.1111/ejss.70149

Ghaderi, R, Hayden, HL, Colombi, E, Jayaramaiah, RH, Hu, HW & He, JZ 2025, Soil faunal community transfers nutrient cycling functionality and plant-parasitic nematode suppression from different depths of a natural soil to an agricultural soil, *Applied Soil Ecology*, vol. 207, 105933, DOI:10.1016/j.apsoil.2025.105933

Ghaderi, R, Hayden, HL, Jayaramaiah, RH, Nguyen, TBA & He, JZ 2025, Fungal Networks Constrain Microfauna-Stimulated Nitrogen Mineralisation in a Soil Microcosm Experiment, *Journal of Sustainable Agriculture and Environment*, vol. 4, no. 3, e70081, DOI:10.1002/sae2.70081

Ghaderi, R, Hayden, HL, Nguyen, TBA & He, JZ 2025, Towards a standardised protocol for estimating nematode-based indices in ecological studies: extraction step, *Nematology*, vol. 27, no. 8, pp. 905–921, DOI:10.1163/15685411-bja10429

Ghaderi, R, Nielsen, UN & He, JZ 2026, Transforming morphology into ecology: functional trait-based estimation of biomass and carbon budget in predatory nematodes (Nematoda: Mononchida), *Applied Soil Ecology*, vol. 217, 106605, DOI:10.1016/j.apsoil.2025.106605

Ghaderi, R, Nielsen, UN, Jayaramaiah, RH, Hayden, HL & He, JZ 2025, Linking morpho-taxonomy to ecosystem functions: trait-based estimation of biomass and potential carbon budget in omnivore nematodes, *Ecological Informatics*, vol. 90, 103309, DOI:10.1016/j.ecoinf.2025.103309

Hayden, HL, Ghaderi, R, Trollip, CR, Hu, HW & He, JZ 2025, Advancing the use of metabarcoding-derived nematode-based indices (NBIs) as soil health bioindicators in agricultural and natural environments, *Soil Biology & Biochemistry*, vol. 205, 109772, DOI:10.1016/j.soilbio.2025.109772

He, Z-\Y, Hu, HW, Wu, K, Bi, L, Na, S, Weatherley, A, Nash, M & He, JZ 2024, An optimised molecular-based method for ecological study of tardigrades in soils, *Soil Biology & Biochemistry*, vol. 199, 109597, DOI:10.1016/j.soilbio.2024.109597

He, ZY, Hu, HW, Nguyen, TBA, Chen, QL, Weatherley, A, Nash, M, Bi, L, Wu, K & He, JZ 2024, Distribution of soil tardigrades as revealed by molecular identification across a large-scale area of Australia, *Soil Biology & Biochemistry*, vol. 196, 109506. DOI:10.1016/j.soilbio.2024.109506

Jayaramaiah, RH, Ghaderi, R, Nguyen, TBA, Na, S, Kedharnath, P, Lenin, A, Stephen, A, Hayden, HL, He, ZY, Hu, HW, Xu, W, Egidi, E, Hoyle, F, Murphy, DV & He, JZ 2026, Uncovering the functional roles of soil fauna in nitrogen cycling and agricultural sustainability, *Geoderma*, vol. 468, 117777, DOI:10.1016/j.geoderma.2026.117777

Na, S, Hayden, HL, He, JZ, He, ZY, Ghaderi, R, Bi, L & Hu, HW 2025, Bacterivorous nematodes drive ammonification and bacterial community growth in a strongly acidic soil, *Journal of Sustainable Agriculture and Environment*, vol. 4, no. 1, e70057, DOI:10.1002/sae2.70057

More information

Learn more about the Soil Science Challenge Grants Program.

Contact the project lead, Professor Jim He.

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We acknowledge the continuous connection of First Nations Traditional Owners and Custodians to the lands, seas and waters of Australia. We recognise their care for and cultivation of Country. We pay respect to Elders past and present, and recognise their knowledge and contribution to the productivity, innovation and sustainability of Australia's agriculture, fisheries and forestry industries.