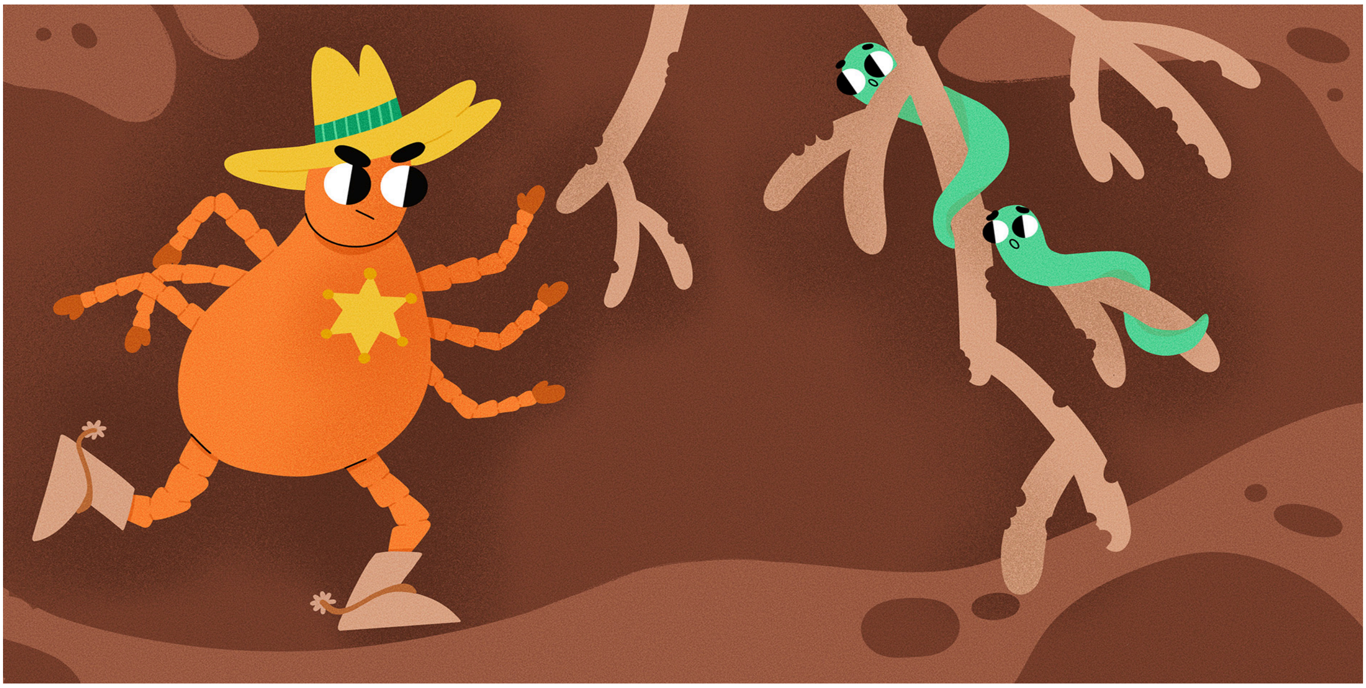
frontiers | Frontiers for Young Minds

BIODIVERSITY
Published: 28 August 2023
doi: 10.3389/frym.2023.1094740



MYSTERIES OF SMALL WORMS AND HOW THEIR ARCH ENEMIES SAVE OUR FOOD

Diana Rueda-Ramírez [*] ***and HU Scientific Writing Class 2022***

Institute of Biology, Ecology Group, Humboldt-Universität zu Berlin, Berlin, Germany

YOUNG REVIEWERS:

HAN
AGE: 15

RANJAI
AGE: 13

RANVIR
AGE: 13

To produce enough food, we must protect our crops from pests that attack plants. Some of these pests are mysterious small worms called nematodes, wandering through the soil. While most nematodes are beneficial to plants, others can destroy whole crops. The most common weapons against destructive nematodes are also harmful to nature. We need more environmentally friendly tools to control these worms. Tiny spider-like creatures called mites are the nematodes' arch enemies. Can mites be used to control nematode populations and protect crops? Scientists did experiments on tomato plants in a greenhouse. They added both harmful and helpful nematodes to check the effect of mites. The experiment showed that mites alone, and in combination with the beneficial nematodes, reduced the damage harmful nematodes caused to the plants. Future studies should determine how we can help mites and friendly nematodes to protect our crops and ensure our food supply!

BIOCONTROL: CONTROLLING PESTS USING OTHER ORGANISMS

Biocontrol, short for biological control, is a method used in farming to protect plants from **pests**. In contrast to chemical control, which includes chemicals like **pesticides**, biocontrol uses living organisms. These organisms are like gardeners: they control the pests, and help us to have healthier plants [1].

In this article, we will explore how tiny spider-like (**arachnids**) creatures called predatory mites can be used to control a plant parasite. Mites live in the soil, in the ocean, in our beds, and even in the lungs of birds! All arachnids, including mites, have special mouth tools called chelicerae and palps, which are used to feed on other organisms [2].

The plant parasite that scientists were trying to control in this study are nematodes. Nematodes are miniature worm-like organisms, and they are some of the most common animals on Earth. Not all nematodes harm plants—some can be quite helpful, too. Just like mites, nematodes live in a wide range of different environments. We find them in the soil, on mountains, and even in vinegar.

WHAT DO SOIL NEMATODES DO?

You may have heard about the important roles earthworms play in soil, but maybe you did not know that other types of worms can also be found in the soil, including nematodes. There are two main types of nematodes in soil: **free-living nematodes** that live freely in the soil and other nematodes that live as **parasite** that damage plants. Some free-living nematodes munch on bacteria, others on fungi, and some even eat other nematodes! Free-living nematodes provide high-quality nutrients to the soil that help plants grow (Read more in this Young Minds article). Root-knot nematodes are a type of parasitic nematodes that attack plants through their roots (Read more in this Young Minds article). These nematodes have only a juvenile stage that is free in the soil and seeks out the roots of plants. When the nematodes find the plant, they dig into the roots and trick the plant into form large, knot-like structures on the roots, called **galls**, where the worms feed [3]. Galls on the roots limit a plant's ability to take up nutrients, which damages plant health over time and can lead to crop failures, costing farmers enormous amounts of money.

HOW TO BOOST PREDATORY MITES IN THE SOIL TO REGULATE THE NUMBER OF ROOT-KNOT NEMATODE?

Nematodes are the most abundant **prey** for predatory mites that live in the soil, as they contain high-quality nutrients. Since root-knot nematodes spend most of their lives within roots, free-living

BIOCONTROL

Short for biological control. The use of friendly bacteria, viruses, fungi, plants, or helpful animals to reduce the number of organisms that might harm our plants, animals, or other important things.

PEST

An organism that is considered destructive or harmful to the health of crops, humans, or other living organisms.

PESTICIDES

Chemicals used to kill, reduce, or control unwanted organisms. These chemicals can be harmful to the environment and can kill harmless or helpful organisms, too.

ARACHNID

A taxonomic group of animals that includes spiders, scorpions, ticks, and mites. They normally have eight legs and characteristic mouth parts: the chelicerae and the palps.

FREE-LIVING NEMATODES

Nematodes (worm-like creatures) that do not depend on other organisms to survive. Instead, they live freely in soil, water and even in decaying leaves or other natural places.

PARASITE

A cheating organism that that lives at the expense of another animal or plant. It takes what it needs to survive, but the host does not benefit and may be harmed.

GALL

A swollen and distorted area on plant roots caused by root-knot nematodes. The nematode causes this growth by injecting special substances into the roots, making them to grow strangely.

PREY

An animal that is hunted or killed by another for food.

nematodes are typically a more reliable food source for mites. How do predatory mites regulate the nematodes? By eating free-living nematodes, predatory mites obtain the nutrients that keep them healthy enough to reproduce a lot, creating even more mites. More predatory mites eat more juveniles of the harmful nematodes before they enter to the roots. Thus, fewer root-knot nematodes would damage the plants and steal their nutrients (Figure 1).

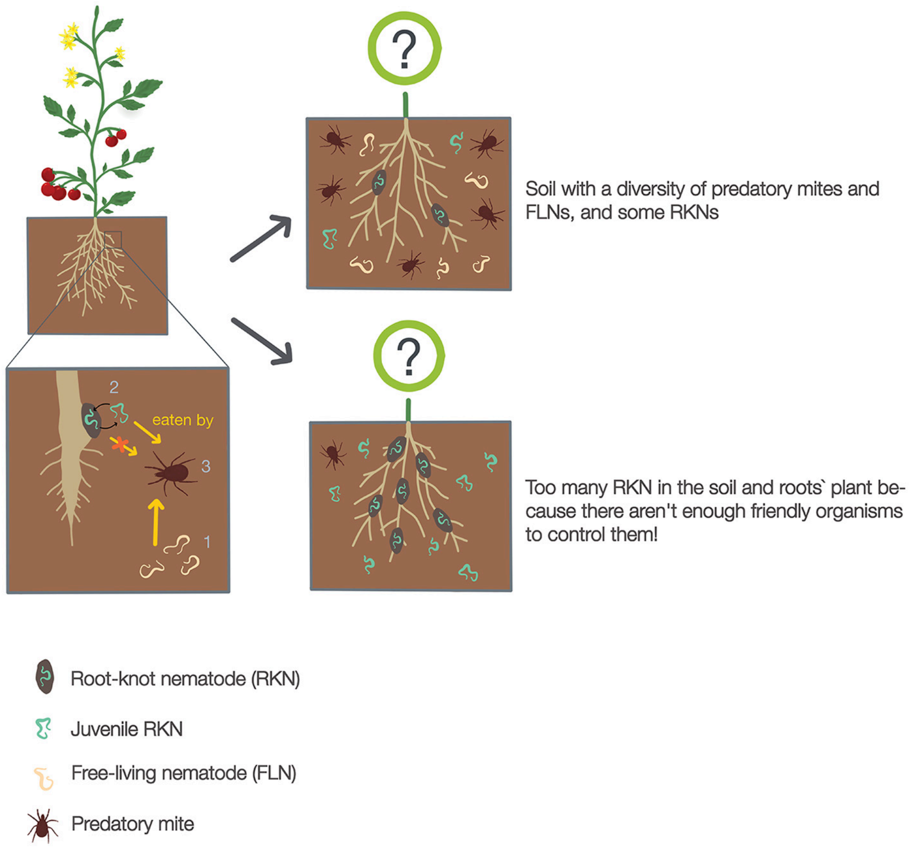


Figure 1

Figure 1

The scientists studied three types of organisms that affect tomato plants. Free-living nematodes (FLNs) live outside the roots. Root-knot nematodes (RKNs) usually live *inside* the roots, but their juvenile (young) stages are found in the soil. Mites eat both the FLNs and the juvenile stage of RKNs. The aim of the experiment was to see how mites, RKNs, and FLNs interact to affect the health of tomato plants (Image credit: Svenja Seifert).

To use predatory mites as biocontrol agents for root-knot nematodes, they will need plenty of food to keep their population stable. So how can predatory mites and free-living nematodes be used to protect tomato plants from root-knot nematodes damage (Figure 1)?

THE EXPERIMENTS

The scientists designed two experiments to evaluate the effects of free-living nematodes and predatory mites on root-knot nematodes control and plant health, using tomato plants grown in pots in a greenhouse. To judge plant health, the scientists looked at the number of galls on the root, roost's area, and nutrients in the leaves. In the first experiment, they collected data after 5 weeks, at the time of flowering.

In the second experiment, the scientists took data after 15 weeks, when the tomatoes were ready to harvest.

For each experiment, the scientists used eight pots. Pot 1 contained root-knot nematodes, free-living nematodes, and predatory mites. Pot 2 contained only nematodes— root-knot nematodes and free-living nematodes. Pot 3 contained mites with free-living nematodes; and pot 4 contained mites with root-knot nematodes (Figure 2). Pot 5 had no organisms and was used as a **control**, to observe how the tomato plant grew without the influence of mites or nematodes. Pots 6–8 contained one species of organism each: root-knot nematodes, free-living nematodes, or mites. With these controls, they ensured that the influence of all animals alone and in combination could be observed. To verify the results, the experiment was repeated 12 times.

CONTROL

A special sample that helps us check if our experiment is going well. They stay unchanged to compare and see how things differ when we test other samples.

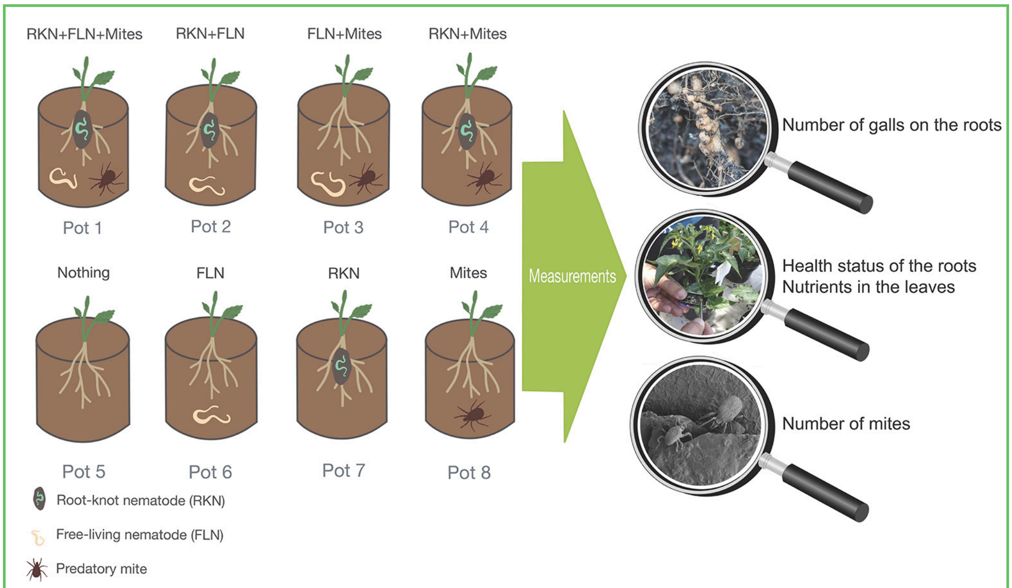


Figure 2

Figure 2

The scientists set up eight tomato plants, each with different treatments (pots 1–8). They collected data using the techniques shown on the right, which included counting the number of galls, measuring the leaves and roots, and counting the mites. This experiment was repeated 12 times (Image credit: Svenja Seifert; Photo credits: Gary Bauchan and Eric Palevsky).

For all pots, the scientists counted the predatory mites and the number of galls and the area on the tomato plants' roots. After the second experiment, they measured the nutrients in the leaves at the time of the tomato harvest. This told them how much the galls were limiting the nutrient uptake of the plants. Moreover, to document feeding, the scientists froze the mites while they were eating and viewed them under a scanning electron microscope.

INTERACTIONS BETWEEN MITES AND NEMATODES

Nematodes and predatory mites live in the same environment and interact with each other in various ways that can be seen as beneficial or harmful, depending on your point of view. When predatory mites eat the root-knot nematodes, this is harmful to the root-knot nematodes but beneficial for the mites and plants. While conducting the experiments the scientists observed how mites eat both nematodes, using their special mouth tools. With the palps they hold and squeeze the nematode and with the chelicerae they perforate the prey and consume their insides (Figure 3B).

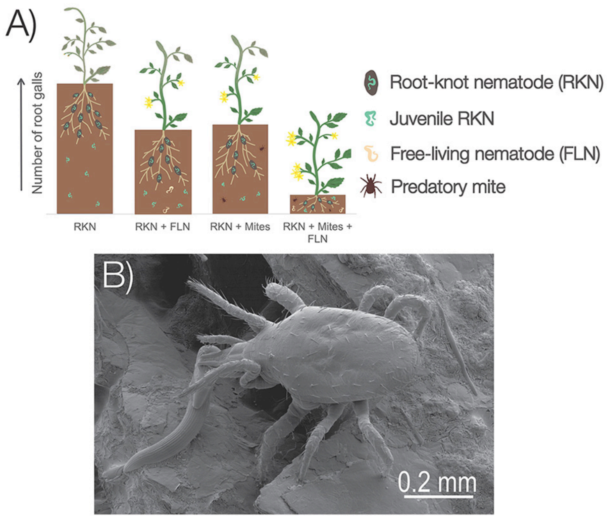


Figure 3

Figure 3

(A) The results of the first experiment showed that, at the flowering stage, the mites alone, and in combination with FLN, reduced the damage caused to the plants by the harmful nematodes. Surprisingly, FLN alone also reduced the damage in a similar way as when mites alone were added (Image credit: Svenja Seifert). **(B)** Scanning electron microscope image of a mite eating a nematode (Photo credit: Gary Bauchan and Eric Palevsky).

The scientists saw that, after 5 weeks, the highest number of predatory mites was found in the soil containing both nematode species. In the soil containing only free-living nematodes, the number of mites was also increased. But when only root-knot nematodes were present, the number of mites remained the same. This means that the predatory mites produced more offspring and increased their numbers when free-living nematodes were present. So, free-living nematodes were good food for the mites! This makes sense because when the predatory mites have a healthy diet, they are fitter and can reproduce more. More predatory mites mean more parasitic nematodes are eaten, leaving fewer root-knot nematodes to harm plant roots!

The results of the second experiment could not prove anything, because unfortunately the mites migrated to pots where the scientists did not place them. This probably happened because the growing mite population did not have enough food and space in their original location. So, another study is needed.

MITES, NEMATODES, AND PLANT HEALTH

The health of most plants in the study was negatively affected by root-knot nematodes. The parasites constantly draw nutrients out of the plant, and roots infected with root-knot nematodes were smaller compared to healthy, non-infected roots.

When predatory mites were present in the soil, the plants' roots showed a higher surface area, meaning they were healthier. The scientists think the mites loosen up the soil as they move around, which provides more space in the soil for the roots to grown and take up nutrients. Roots of plants infected with root-knot nematodes were covered with many galls. The presence of predatory mites reduced the number of galls, but the greatest reduction in galls was seen when mites and free-living nematodes were both present (Figure 3).

Surprisingly, even when free-living nematodes and root-knot nematodes were present without mites, there were fewer galls than with root-knot nematodes alone, and those plants had more nutrients, especially in the leaves. Other scientists found that free-living nematodes help convert nitrogen in the soil into forms that plants can use for their nutrition. With more nutrients available, the plants can grow stronger and balance out for the nutrient loss caused by root-knot nematodes.

WHY ARE THE RESULTS IMPORTANT?

As you already know, root-knot nematodes can harm many plants. Plants infected with root-knot nematodes have root galls and contain fewer of the nutrients needed for growth. Besides tomatoes, root-knot nematodes can harm important crops like beans, bananas, and lettuce. Root-knot nematodes cause enormous harvest losses worldwide, causing farmers to lose lots of money. Controlling root-knot nematodes is important to protect our food supply and support efficient farming.

To reduce damage caused by root-knot nematodes, the typical solution is to use pesticides. While this solution can be effective for controlling root-knot nematodes, it has negative effects on the environment, polluting soil and water, and killing many harmless or even useful organisms. This is why it is important to control root-knot nematodes using biocontrol that does not harm other organisms in the environment.

In this study, scientists tested predatory mites as a biocontrol method for root-knot nematodes. Their results showed a new, natural way to fight root-knot nematodes. Adding free-living nematodes or predatory mites to a plant's soil reduced the damage by root-knot nematodes. Adding both organisms was even better! Adding both free-living nematodes and mites increased the number of predatory mites, which fed on both "good" and "bad" nematodes. The number of galls was reduced, and the amount of nutrients in the plants was improved. Overall, this treatment enhances the plants' fitness. This method shows the potential of conserving predatory mites and free-living nematodes as tools for biological control of plant-parasitic nematodes.

To keep our environment healthy and protect our food, it is necessary to do more research on biocontrol. This research showed that it *is* possible to use predatory mites as biocontrol for nematodes. Biodiversity, stabilizing environmental conditions and diverse food options are important for predators. Increasing the amount of food available for predators increases the number of predators and then more predators eat more prey—boosting biocontrol. In the future, scientists should try to figure out which soil conditions and climates help free-living nematodes and predatory mites to survive and reproduce. The more we can improve the living conditions of these organisms, the better able we will be to fight harmful nematodes and possibly control other soil pests.

ACKNOWLEDGMENTS

To Stefan Mucha, Behavioral Physiology group, and Liliane Ruess, Ecology group, Humboldt-Universität zu Berlin, Germany, for their supervision, guidance and help during the writing of the article. To Svenja Seifert (Humboldt-Universität zu Berlin, Germany) for designing and drawing the figures. To Eric Palevsky, Newe Ya'ar Research Center, Agricultural Research Organization (ARO), Israel, for supporting this initiative, providing the LTSEM photo and reviewing the final text. To Gary Bauchan, Joseph Mowery, and Ronald Ochoa, U.S. Department of Agriculture (USDA), for their help with taking the image of the mite feeding a nematode. To Lynn Carta, U.S. Department of Agriculture (USDA), for providing and identification of nematodes. The HU Scientific Writing Class 2022 is integrated by Sirine Ayoubi, Sarah Bock, Franziska Eberhardt, Charline Gennat, Maria Hermesmeyer, Henriette Hölscher, Randy Ingelmann, Alexander Jähngen, Tristan Jockheck, Felix Kaulbach, Valentine Mewis, Saskia Nieke, Svenja Seifert, Kristin Trepels, Anna Luiza Wende. The writing of the article was supervised by DR-R, M.Sc. Stefan Mucha and Prof. Dr. Liliane Ruess.

ORIGINAL SOURCE ARTICLE

Azevedo, L. H., Moreira, M. F. P., Pereira, G. G., Borges, V., de Moraes, G. J., Inomoto, M. M., et al. 2020. Combined releases of soil predatory mites and provisioning of free-living nematodes for the biological control of root-knot nematodes on "Micro Tom tomato." *Biol. Control* 146:104280. doi: 10.1016/j.biocontrol.2020.104280

REFERENCES

1. Stenberg, J. A., Sundh, I., Becher, P. G., Björkman, C., Dubey, M., Egan, P. A., et al. 2021. When is it biological control? A framework of definitions, mechanisms, and classifications. *J. Pest Sci.* 94:665–76. doi: 10.1007/s10340-021-01354-7

2. Walter, D. E., Proctor, H. C. 2013. *Mites: Ecology, Evolution & Behaviour. Life at a Microscale*. 2nd ed. University of New South Wales Press, Sydney, Australia: Springer Science+Business Media Dordrecht XIV, 494.
3. Jagdale, S., Rao, U., Giri, A. P. 2021. Effectors of root-knot nematodes: an arsenal for successful parasitism. *Front. Plant Sci.* 12:800030. doi: 10.3389/fpls.2021.800030

SUBMITTED: 10 November 2022; **ACCEPTED:** 07 August 2023;
PUBLISHED ONLINE: 28 August 2023.

EDITOR: Becky Louize Thomas, University of London, United Kingdom

SCIENCE MENTORS: Varsha Singh and Pan Zheng

CITATION: Rueda-Ramírez D and HU Scientific Writing Class 2022 (2023) Mysteries of Small Worms and How Their Arch Enemies Save Our Food. Front. Young Minds 11:1094740. doi: 10.3389/frym.2023.1094740

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

HAN, AGE: 15

Han is a secondary school girl living in China. She enjoys outdoor activities and exploring the beauty of nature. She is interested in the subjects of biology and chemistry at school. She cares about the environment and has particular concerns about the impact of human activates to the nature and the environment.

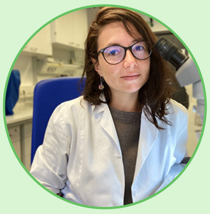
RANJAI, AGE: 13

I like space, fungi, rocks, chemistry, architecture, biology, physics, fortnite, NASA, space telescopes, Rockets, pizza, pasta, chicken (fried, smoked, etc.), sea creatures, Dude perfect, Brave wilderness, history, geography, Rick Riordan books, weapons, archery, Cobra Kai, Beyblade burst, Jurassic park: Camp Cretaceous, Teen titans, Arrow, The Flash, DC, Marvel, Botany, MCU, Dinosaurs, Alan Walker songs, and debating.

RANVIR, AGE: 13

My name is Ranvir and I am in class 7. As hobby I catch snakes to learn about herpetology. I started doing that when I was 8. I used to catch skinks, but I got bored doing that, so I learned a few things about herpetology and went out with some of my friends. After some time, we found our first Microhylid frog. And after half a year we also found our first snake, a Lycodon capucinus! Besides herpetology, I also like doing origami. I also like reading Greek mythology.

AUTHORS



DIANA RUEDA-RAMÍREZ

Soil has always attracted my attention because it is the basis of land-based ecosystems, and very important processes occur in soil, on which all living things depend. When I was looking at soil several years ago, I saw many mites and that is when I became interested in this organism. My main interest is the study of all aspects of soil predatory mites (structure, diversity, ecology, and use for biocontrol of agricultural pests). I now focus on understanding the interactions of mites with other organisms in the soil, such as nematodes, and I am hoping to find ways to conserve these important organisms. *ruedadia@hu-berlin.de

HU SCIENTIFIC WRITING CLASS 2022

We are a group of 15 biology master's degree students at the Humboldt-Universität of Berlin, Germany. Our master's program is called M.Sc. Organismal Biology, Biodiversity and Evolution. Our course, Communicating Science, was supervised by DR-R, M.Sc. Stefan Mucha, and Prof. Dr. Liliane Ruess. In our course, we practiced how to clearly explain science, to share it with a broad audience—like you. We learned how to structure and write a scientific article then rewrote that article for Frontiers for Young Minds—in a way that would interest kids. We hope you like it!