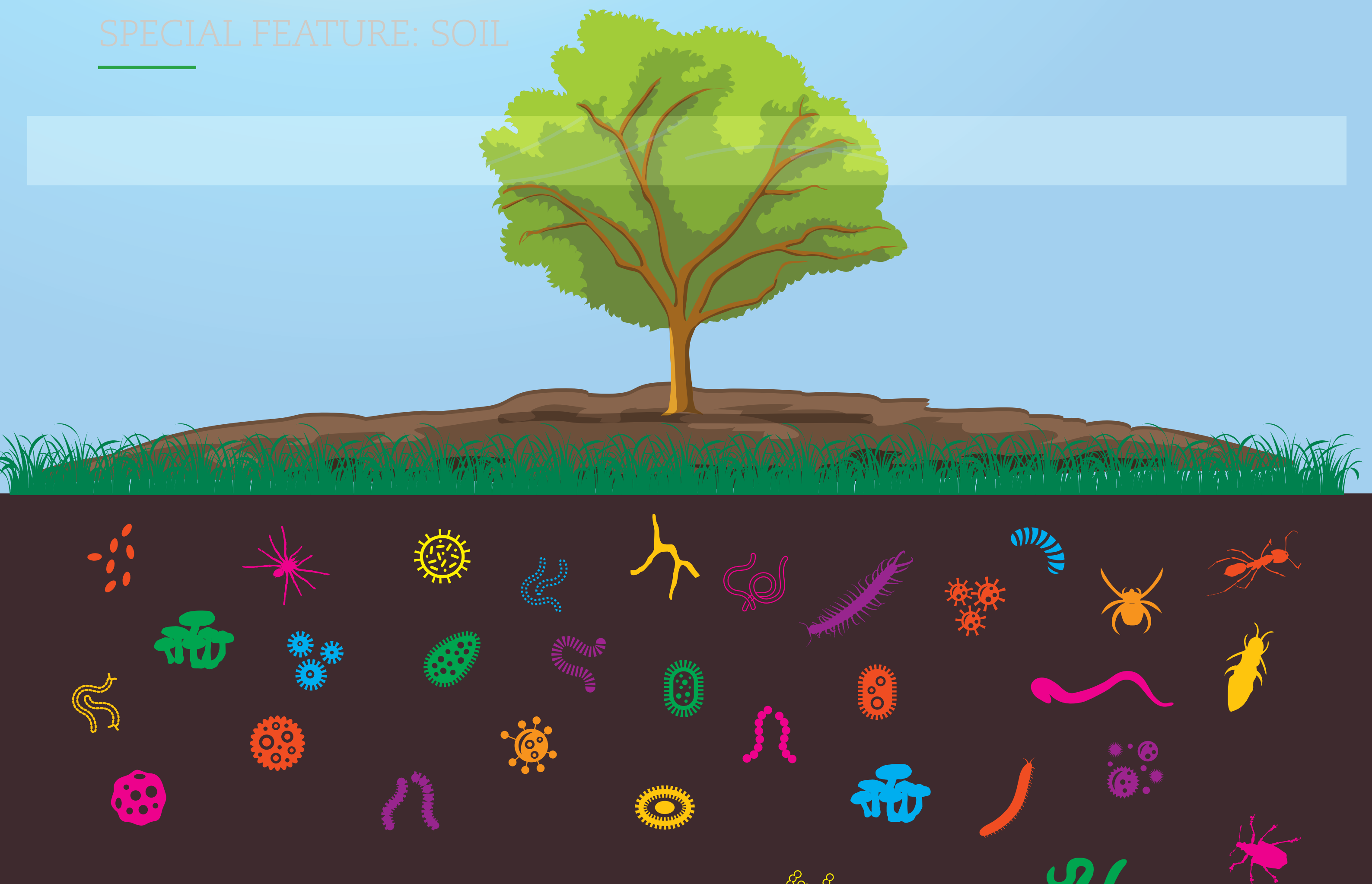

The living soil

Researchers at TEAGASC are investigating the life under our feet with the aim of harnessing soil biology to provide natural-based solutions to global challenges.

Life beneath our feet

Soils are home to a staggering abundance and diversity of living organisms that are integral to the health and productivity of our farming systems. Our soils are teeming with life. Soil ranks among the most biodiverse habitats on the planet, housing greater than a quarter of all living organisms and making it a globally important reservoir of biodiversity. This diversity encompasses an enormous range of organism types, sizes, shapes and lifestyles, which operate at many different scales and occupy a variety of niches within the soil habitat. Soil organisms range from the microscopic (e.g., bacteria, fungi, protozoa and nematodes) to larger mesofauna (e.g., springtails and mites), up to the largest macro- or mega-fauna (e.g., earthworms and ants). Mainly hidden from view, these organisms are often forgotten about, but there is an increasing awareness that this life underpins the majority of processes within soil and is critical for delivering a whole range of vital ecosystem functions. Their importance to the sustainability, resilience and functioning of our farming systems cannot be overstated.

Among the most important of these functions is climate regulation, with soil microbes playing a pivotal role in both generating and mitigating greenhouse gases (GHGs), and their activity largely determining the net balance between the two. They are intrinsic to plant health and establishment: fixing, recycling, and scavenging nutrients for plant growth; providing essential plant vitamins and hormones; suppressing pests, pathogens and disease (**Figure 1**); protecting against plant stress; and, maintaining the soil structure that anchors plants. Complex and extensive below-ground microbial networks act as channels for resources and messaging, facilitating plant–microbial and plant–plant collaboration. Soil biota are known to influence the yield, quality, longevity and even flavour of crops and their products. The rich diversity of organisms within soil provides many of our antibiotics and vaccines.

Given the importance of soil biology to soil functioning, it is clear that to fully understand our soils, and how to manage them, we need to understand and work with this biology. Technological constraints, which have historically hampered investigation of microbial communities (that make up the greatest diversity of soil life), have been largely overcome with the advent of contemporary molecular approaches, offering revolutionary advances in our understanding of soil communities and how they affect agricultural systems. The abundance, diversity and functioning of these organisms are strongly impacted by agricultural practice, so managing our soils in a manner that safeguards and supports these essential members of the farming workforce is key to sustainable agricultural production.

Harnessing soil biology to enhance agricultural sustainability

The central role played by soil biota in nutrient transformations, climate regulation and plant health has placed them at the heart of global challenges around food security and climate change. As international efforts towards carbon neutrality and environmental sustainability intensify, a key focus is on development of climate-resilient agricultural systems that are capable of maintaining food production and farm incomes, while minimising environmental impacts. Teagasc researchers, in association with national and international collaborators, have been assessing the potential to harness knowledge of soil biology towards development of natural-based solutions, underpinned by science, which support the development of sustainable agriculture systems and enhance soil health. For example, as GHGs result from microbial processes, insights into the functioning of microbial communities offer a unique opportunity to mitigate emissions while increasing nitrogen (N) use efficiency. Researchers in Johnstown Castle have shown that the abundance and activity of microbial communities that produce and mitigate GHG nitrous oxide (N_2O) in Irish and international soils are strongly influenced by the pH and phosphorus (P) content of the soils, providing an effective means of reducing N_2O by balancing soil fertility and liming where needed.

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Sustaining crop production against the backdrop of reduced inorganic fertiliser inputs represents a challenge for farmers that soil biology can potentially offer some solutions for. Ongoing research has identified the microbial communities involved in transforming N from organic pools to plant-available forms, and how this is impacted by agricultural management. As we better understand how and when nutrients are made available to plants by soil communities, we can better tailor fertiliser advice to maximise efficiency and reduce losses. The potential of biofertilising microbial inoculants to enhance microbial provision of nutrients within grasslands is currently being tested, and the

FIGURE 1: Bacterial-feeding nematode from grassland soil (image: Israel Ikoyi). Nematodes are important constituents of the soil food web, providing a range of functions, including important roles in nutrient cycling and the suppression of pests and diseases.

role of mycorrhizal fungi in supplying P in limited conditions is also being characterised. Recent results indicate that the diversity of the plant community and the fertilisation strongly impacts on the diversity and function of the microbial community below ground, including how it transforms nutrients. Initial indications suggest that the diversity of the plant community also impacts the complexity of the wider food web and the potential of the soil biology to suppress pests and diseases.

These studies, and many more, provide data that can be incorporated into management advice to enhance soil health and functioning. We still have much to learn about the spectacular array of life that inhabits soil, and the many complex interactions happening therein, but technological advances have allowed us to look more deeply than ever before and have revolutionised our understanding of soil organisms, offering great potential to harness these communities towards providing solutions for our greatest challenges.

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