The real dirt

The ground beneath our feet is more complex than most of us would think — and understanding and working with that complexity is a key to sustainable agriculture

BY GORD LEATHERS

Grain farmers are no strangers to dirt — in fact it's the very foundation of their businesses.

Western Canadian farmland came of age under a carpet of native plants and its riches are still evident in the heavy black tone of the topsoil. Black soil speaks of organic matter and it tells us how healthy that soil is.

"Soil organic matter describes all of the life in the soil so it's at the heart of the soil's ability to function," says University of Manitoba crop ecologist Martin Entz. "Other than that you're just farming in a sandbox and you have to add everything. But in Canada we're dealing with the best temperate region soils in the world."

The first settlers could certainly tell you that. Plunge a spade into the odd remaining corner of undisturbed Prairie sod, upend it and grab that clump of black dirt with both hands and watch the nutty granules crumble when you shake them from the tangle of roots that's held them in place for 10,000 years. If you could look even closer at those crumbs of soil, if you could actually see right into the angles and corners you'd see that it's alive. Soil teems with a staggering variety of living things. Charles Darwin noticed this too and, after several years of watching soil, he published The Formation of Vegetable Mould Through the Action of Worms with Observations on their Habits.

"Charles Darwin's last and least-known book was not particularly controversial," according to the University of Washington's David Montgomery in his book Dirt, The Erosion of Civilizations. "Darwin's book explores how the earth beneath our feet cycles through the bodies of worms and how worms shaped the English countryside."

Darwin was onto something. He suspected the importance of those lowly earthworms to the nature and character of the soil in which they lived. They feed on the organic matter, the decaying plants that litter a field and pull it down under the surface where it mixes with the mineral soil. Soil minerals were also ingested by the worms and they ground them through their guts and bathed them with digestive enzymes before excreting them in their castings.

One square metre of land can have anywhere between 30 to 300 worms so you can get a staggering amount of work done by huge numbers of earthworms over an entire acre. They can leave upwards of 16,000 pounds of castings on an acre of soil annually and Darwin calculated that they could build up to a quarter of an inch of topsoil per year. In addition, worm castings are rich in bacteria, organic matter and exchangeable nutrients. Darwin saw what earthworms do and it may seem curious that a seemingly insignificant, and even maligned organism, could take so much credit.

Then again, we tend to malign soil itself, and most people only see it as "dirt" that appears unbidden on the kitchen floor. That completely underscores what they would see if they really took the time to look. Within that "dirt" is a booming, bustling metropolis of millions of different organisms working together in a chaotically co-ordinated ecosystem as complex as any other on the planet. This is bringing a new agricultural problem to light. As we simplify the old grassland with under-rotated monocultures above ground, we're in danger of oversimplifying the soil ecosystems below ground too.

"We need the complexity of relationships from microorganisms, earthworms, decomposers, you name it," states Steve Gliessman of the University of California. "They're all so critical for maintaining that dynamic equilibrium, that stability of the system over time. When the below ground becomes a monoculture, that's when we're in trouble."

To understand any system you have to break it down into its different parts and before we can appreciate what we're losing we should take a look at what should be there. The foundation of any ecosystem whether it's farm field, forest or pasture, is an energy conversion system that harnesses sunlight and stores it in the bonds of organic molecules. We have to bolt carbon, hydrogen and oxygen together to make sugar and that's the job of the primary producers, the plants.

"Everything starts with plants, the solar collectors," explains University of Manitoba soil scientist Mario Tenuta. "These are the factories that bring energy into the system through plant residues. It's the supermarket."

Underground

We've all seen what goes on above ground. As the plants grow they extend a structural stem on which they hang leaves, the solar panels that house the chloroplasts. That's where the energy conversion takes place and the resulting sugars are burned as a fuel by the plant as it makes tissue and build structure. We usually can't see the roots so we don't often think about the rhizosphere, the zone where roots meet soil, and this is where the energy from the sun is injected into the mineral matrix.

"The excretion of readily decomposable compounds such as amino acids as well as the sloughing of root tissue stimulate the microflora to a high intensity of action."

Nyle C. Brady said that in his classic text book The Nature and Property of Soils and, in the usual understated academic way, he described one of the most important ecological relationships on the planet. That all-important zone where the roots hit the dirt is where the living meets the dead and brings it to life.

"The supermarket that I mentioned is the roots," Tenuta said. "As we get closer to the root the number of organisms tends to increase. For instance, the number of bacteria per volume of soil starts skyrockets but as we move further from the root it drops dramatically."

Bacteria and fungi are the next level in the soil's food chain. Much like the grazers that feed on grassland plants above ground, they feed on the same bounty below. In this way energy from sunlight finds its way into the soil.

Since there are so many different kinds of bacteria and fungi it's impossible to talk about one single role played by either. Certain species of bacteria live in special nodules grown on the roots of some plants where they break apart nitrogen atoms and make amino acids with them. Other forms of bacteria help decompose plant tissue and break it down into simpler compounds that other organisms can use. They both aid in that grand recycling process that keeps life going.

It's the same with fungi. Most of them are decomposers that help keep nutrients moving through the system. Since they can't make their own sugars through photosynthesis they have to find it in other organisms, breaking down their tissues, releasing and absorbing their nutrients and, becoming food for the next level in the chain, the predators, a dizzying array of single celled protozoa, rotifers and nematode worms.

"Nematodes feed on a wide variety of things like fungi and bacteria so fixed nitrogen and other nutrients can be cycled back into the soil through their feces," Tenuta said. "Now this release of nutrients will be picked up by other organisms or it will be picked up by plants. Not only that, there are even higher trophic relationships built on other things that feed on those predators."

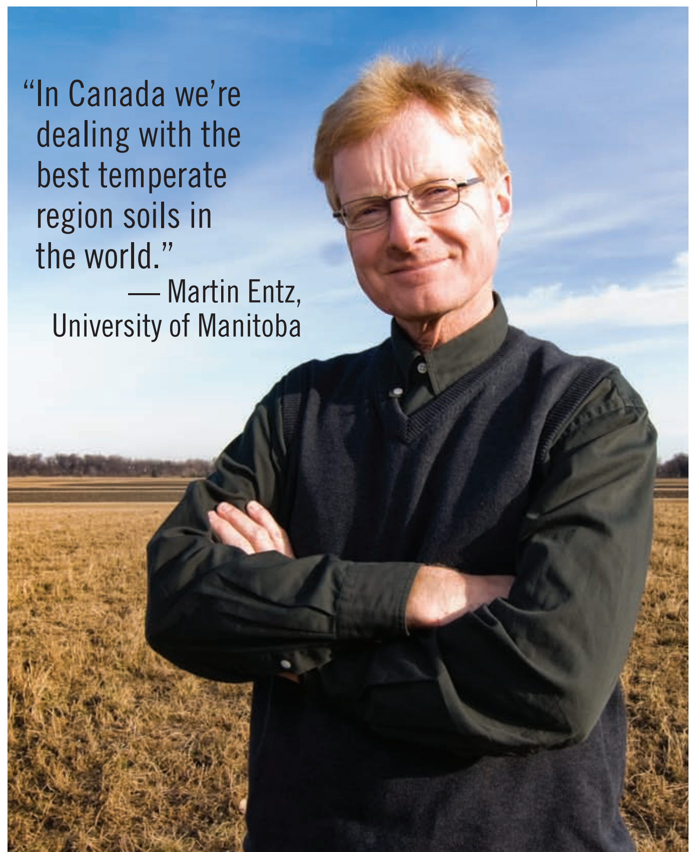
It's absolutely critical that this happens. When the soil nematodes and arthropods such as mites and springtails really go to work on plants, detritus and other organisms it has two effects. The first is the increased amount of processing that goes on because of their piercing and chewing which opens up the soil material for more processing by more organisms. The second is the release of nutrients through their wastes and this is sent around the loop again.

Complexity

This whole system is self regulated and the fine tuning has been going on for several million years. Through the complex interplay of millions of different organisms living within the shifting layers of the food web the populations of all those soil denizens are kept in check and nutrients are kept in motion. The problem is that, through cultivation, we may be losing that biodiversity.

"If we increase the numbers of bacteria and fungi and there's nothing to prey on them anymore they start tying up nutrients," Tenuta explained. "The nutrients aren't released because they're not being fed upon by these nematodes and protozoa and so forth."

There are other dynamics at work here too. Fungus is a dirty word to a lot of people and farmers are no exception. A lot of nasty crop diseases are fungal and we have quite an array of fungicides that we use to keep them in check. But this reduces the number of different soil fungi and this might not be in the crop's best interest either.



"Every fungus has some kind of an ecological role and it's when there're too many of one kind that they become a disease," according to Gliessman. "We've verified this in some of our below ground studies of systems where there are a lot of different fungi present. We've found that, even though the disease organism is there, the expression of the disease is not."

Some fungi are also highly beneficial. For example, some species of fungus actually catch and eat harmful nematodes. We're also well aware now of the role of mycorrhizal fungi that grow within plant roots where they act as a root extension and collect water and nutrients from further afield.

Soil really is the living, breathing skin of the planet and its crucial to all biological systems whether they're natural or cultural. We've learned a lot about soil chemistry and it's given us great insight into how we can increase production through the use of fertilizers. We're starting to learn more about soil biology and this may give us greater insight into how we can set a healthy community of organisms to work. ■