CATCH P IF YOU CAN

THE STORY OF FARMERS & PHOSPHORUS

By Tanya Brouwers

Phosphorus stimulates root growth, promotes the maturity of crops, and stimulates seed production. When soils are low in phosphorus, crop yields suffer and, ultimately, so does the farmer's bankbook.

Phosphorus (P) is one of the most challenging nutrients for both plants and farmers to use. Of all the phosphorus deep in fertile fields, only a fraction exists in a solubilized, plant-available form.

Except under ideal conditions, phosphorus, (including applications of expensive rock phosphate) will bind tightly to soil particles of aluminum, iron and calcium and then be unavailable to plants.

AMF attach themselves to plant roots in exchange for a supply of carbohydrates.

Phosphorus is most available in perfectly moist and warm soil, ideally a slightly acidic, sandy loam. Even if available forms of P are plentiful but refuse to move, plants outside of 'the zone' are out of luck.

It is interesting that some organic farmers operating at less than optimal soil phosphorus levels continue to report excellent crop yields. Scientists tell us that the largely unexplored soil microbial community has a large part to play in this anomaly, providing plants with phosphorus that was previously assumed unavailable.

The following group of researchers, in partnership with the Organic Science Cluster (OSC), are going one step further. To help organic farmers use this elusive element more effectively and efficiently, they are attempting to identify, capture and harness the phosphorus-solubilizing power of soil microorganisms.

AMF attached to a root.

> **Canadian topsoil** contains anywhere from 100 to 2500 kg/ha of phosphorus. Of that total, only a fraction, sometimes less than one percent, is in a solubilized form that is available to the crop.

AMF, P and plants: A symbiotic love affair – Chantal Hamel

There are three basic ways plants access available phosphorus in the soil. Some plants, like canola, have very fine root hairs that extract phosphorus from the immediate vicinity of their highly developed root system. Others, like lupins, manufacture a sticky root coating that binds soil and nutrients tightly to their root surface.

Dr. Chantal Hamel, a research scientist at Agriculture and Agri-Food Canada in Saskatchewan, is fascinated with a third group of plants—those that have relationships with the soil organisms known as arbuscular mycorrhizal fungi or AMF.

AMF attach themselves to the roots of host plants. In exchange for a supply of carbohydrates, AMF multiply and spread out through the soil. They form expansive hyphal networks somewhat reminiscent of highways or, as Hamel puts it, "pipes."

"These networks (or pipes) take up phosphorus that is far away from the plant," notes Hamel. "They package it in little vestibules and keep it plant-available." Then the host plants can "suck on these pipes, much like a straw."

Not all plants, however, form relationships with AMF. Of those that do, some are more dependent on these organisms than others for nutrient uptake. This is worth considering when planning a crop rotation.

Crops that support AMF include corn, wheat, barley, most grasses and all pulses except white lupin. Wheat, however, is much less dependent on AMF than corn, so wheat could potentially follow a crop like canola without a significant drop in yield. Soybeans, on the other hand, would be a better choice to precede corn.

Members of the brassica family, like canola, radish, mustard, cabbages and kale, are ***not*** mycorrhizal hosts. Consider this when designing crop rotations with plants that require the phosphorus benefits of mycorrhizal fungi.

Dr. Chantal Hamel.

Wild lupins, unlike white lupins, support AMF populations.

AMF populations can be reduced by:

- environmental factors,
- agricultural interference,
- excessively dry conditions,
- cold soils,
- too much moisture,
- overfertilization with phosphorus, and
- excessive tillage.

"AMF live in about the first 25 cm of soil, so you need to till shallowly," says Hamel. "Tilling to 10 cm will not have too much effect but if you go to 20 cm with a plow, you will have more of an impact on AMF networks."

Inoculation of seeds or soil with AMF are options where soils exhibit minimal populations. In 2010, Hamel and her team of researchers inoculated several wheat test plots with the Premier Tech product, MYKE PRO. One of the outcomes was the early maturation of wheat. This year, they will re-inoculate test soils to determine the effect on yield.

AMF are sensitive to environmental factors and agricultural interference.

Looking to the future, Hamel is excited to be working on a long-term project to breed wheat varieties that form effective relationships with the most productive AMF populations.

"What we've found is that not all AMF are the same. There is a big difference in their effectiveness," says Hamel.

Some, for example, form large networks. Others are easily parasitized or diseased. Some groups perform poorly in dry soils. Still others more efficiently capture phosphorus; in soils where plant-available phosphorus is limited, this characteristic might be the most desirable of all.

Hamel admits, however, that a fully functional wheat/AMF combination is still over a decade away. Until then, she is happy to continue her work exploring the life and times of arbuscular mycorrhizal fungi: just one member of the complicated community down in the dirt.

Rhizobacteria: Resolving replant disorder – Louise Nelson,* Molly Thurston* and Gerry Neilson**

In B.C.'s Okanagan Valley, tree fruit and real estate are two of the big businesses. The price of land is anywhere from sixty to a hundred thousand dollars per acre, and the cost of orchard establishment is around ten thousand dollars an acre. So, a typical loss of ten to twenty percent of a farmer's newly replanted fruit trees is hard to swallow.

OSC researchers Thurston, Dr. Nelson and Dr. Neilson set out to determine the cause of (and potential solution to) this financially devastating problem.

During their initial investigation, the scientists noticed that applications of soluble phosphorus to young trees led to greater vigour and canopy size, disease resistance, and increased yield in subsequent years.

"Phosphorus is really important in the development of the root system," states Thurston. "When trees arrive from the nursery, there are some primary roots but the tiny feeder roots need to be developed. And that's where phosphorus comes in—it stimulates their growth."

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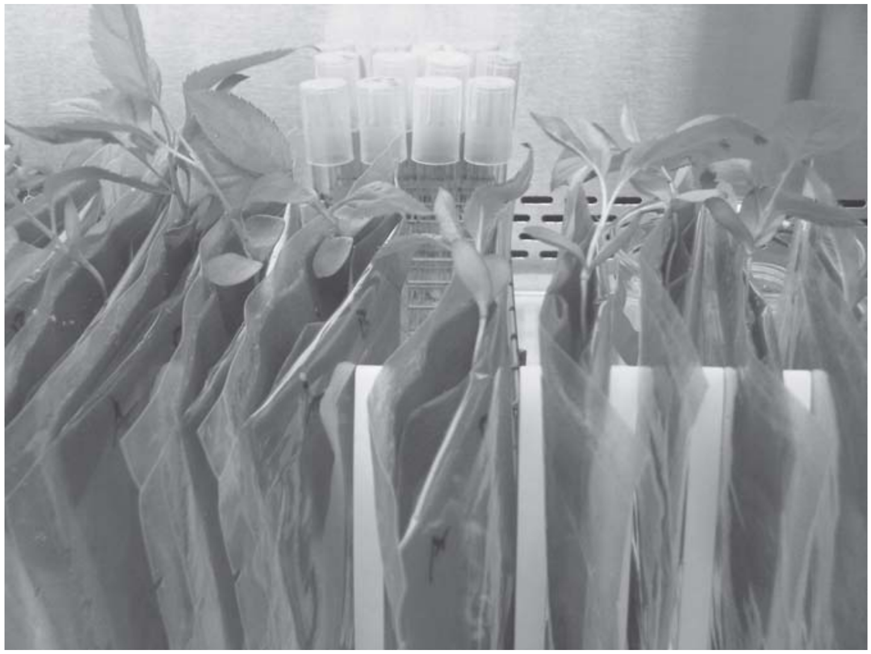


Growth pouches filled with a liquid medium, soil bacteria, insoluble phosphorus and apple seedlings.

Some predict that rock phosphate will all but disappear in roughly thirty years if extraction rates continue as they are today.

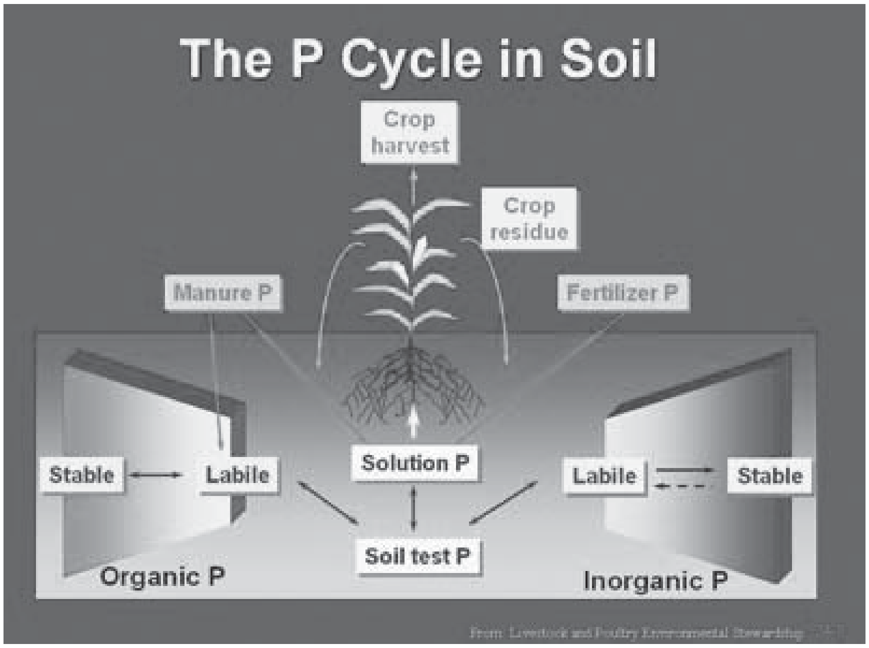
These little feeder roots help the plant access nutrients in the soil. Without them, the tree becomes "malnourished" and, just like a human body that lacks sufficient vitamins and minerals, the tree becomes sick.

In organic production, however, soluble phosphorus fertilizers are not permitted. "The rock phosphate or bone meal that we use doesn't flow to the tree roots. You may apply it to the planting hole but it's just going to stay there." She adds, "You might as well take your money and flush it down the toilet."

That's where bacteria come in. In the soil, some bacteria join up with plant roots and form a coating around them. The bacteria then release organic acids into the rhizosphere (area nearest the root), and lower the soil pH. The result? The rock phosphate or any phosphorus bound to soil particles in the rhizosphere is solubilized and becomes immediately available to the plant.

For researchers, the obvious next step was to gather and harvest these productive rhizo-

Rhizo- or 'root' bacteria release organic acids that acidify the area around a plant's roots. This acidification solubilizes phosphorus and makes it available to the plant.



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bacteria. Thankfully, Louise Nelson, in her previous position at the University of Saskatchewan, had collected more than 100 species of soil bacteria from the root zones of legumes. They had been selected for, among other things, their anti-fungal properties, their plant growth properties and their abilities to tolerate cold. Now in B.C., they are being tested for their phosphorus-solubilizing properties.

Starting with one hundred species of bacteria, Petri dishes and two forms of insoluble phosphorus, the researchers narrowed down the numbers to five of the best performers. These five went into growth pouches filled with a liquid medium, more insoluble phosphorus and apple seedlings. The results are exciting.

"We're seeing some interesting data," says Thurston. The data are "indicating that the combination of the bacteria and the rock phosphate is giving more root tips. We're excited about that because it supports the idea that having extra phosphorus available stimulates root growth."

The next stop is the field. Last summer, Thurston inoculated the roots of apple seedlings in solutions containing three of the bacteria. She planted the seedlings into holes containing six different P treatments including bone meal, rock phosphate and a control. Then she had to wait.

"I'm really excited to see what progresses over the next year," Thurston says. "My focus this spring and summer will be on trying to collect growth data on both the root systems and the trees themselves."

So, when will this technology become a viable option for farmers everywhere? Nelson predicts it will be at least another five years. In that time, the bacteria must be packaged in a useful form and, according to national regulations, must be tested for human and ecological safety.

"In the meantime, there's lots of work to be done," muses Nelson.

"That's a good thing," laughs Thurston. "It keeps us busy."

The future: Thirty years and beyond

Not only is soil phosphorus frustratingly elusive, it is also frighteningly finite. Some predict that rock phosphate, the lifeline of many organic farmers, will have all but disappeared in roughly thirty years if extraction rates continue as they are today.

Even the large pools of phosphorus in Canadian agricultural soils are at risk of total depletion. As long as organic and conventional farms continue to remove more phosphorus than is returned, including that removed by the action of soil organisms, it is forecast that the pools will drain in as little as 200 years.

The combination of bacteria and rock phosphate is producing more root tips.

What is required is a closure of the phosphorus loop. Especially on large-scale grain operations, a massive amount of a field's phosphorus heads straight off the farm and into the cities. From there it is, quite literally, dumped down the drain.

Cutting edge agricultural products that use struvite (phosphate extracted from wastewater) have the potential to return phosphorus to the fields from a city's waste treatment plant. However, products of this kind have not received approval for organic applications. Consequently, a majority of phosphorus on organic farms continues its trip on a one-way ticket.

"Things are running out really quickly," admits Thurston. She discusses the important role of soil bacteria in sustainability and points out, "If we use what we're applying more efficiently, and have less waste or less accumulation in the soil, I think that will be a good thing."

She's right. Until the country-city connection is effectively fused, the role of soil organisms in the efficient extraction of soil phosphorus will be the key to both Canada's organic agricultural success and its long-term food security.

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