That was the basis for the project “Development of Biologicals as Low Input, Sustainable Production Practices for Fuel and Residue/Food Production”. This study aims to develop biological inputs for Canadian crop production, including microbial strains and biostimulants such as flavonoids, and isolate novel plant-growth-promoting microbes from Canadian crop and uncultivated plants.

“Terrestrial plants began to evolve and spread across the landscape almost half a billion years ago,” said Dr. Donald L. Smith, Distinguished James McGill Professor, Plant Science Department, McGill University. “Moving out of an aqueous environment posed some significant challenges for plants, including acquisition of nutrients and water, and responses to more widely varying environmental conditions. Part of the response was evolution of a root system, but plants also developed chronic and intimate relationships with microbes.”

These relationships are mutually beneficial and carefully regulated. Science now recognizes that plants have an associated microbiome, the phytomicrobiome, just as humans have a microbiome that is critical to their wellbeing (microbiome refers to all the microorganisms and their genetic material that are found associated with a larger organism.) This relationship means that anything which benefits the plant is also advantageous for the phytomicrobiome.

“The most studied beneficial plant-microbe relationship is the nitrogen fixing symbiosis between rhizobia (soil bacteria regularly associated with plant roots) and legumes,” said Dr. Smith. “Because of this relationship, crops like soybean do not require nitrogen fertilizer.”

That is significant, as production of nitrogen fertilizer requires a significant amount of fossil fuel. As well, 1-2% of the nitrogen fertilizer applied to agricultural systems is converted into nitrous oxide, a greenhouse gas which is over 300 times more effective at heat trapping than carbon dioxide. Finally, nitrogen fertilizer can also become a ground and surface water contaminant and pose a health hazard.

Nitrogen needs
Legume crops do not require nitrogen fertilizer and leave nitrogen behind (in stem and leaf residues) for following crops. This reduces the amount of nitrogen that a following crop requires and substantially lowers overall nitrogen fertilizer application to crop production systems.

“Elements of the phytomicrobiome and their associated plants regulate each other in extremely intimate and meaningful ways. Again, the best studied system is the legume-rhizobia relationship. When the symbiosis is established, the legume plants emit isoflavonoid signal compounds into the soil. When the correct rhizobia encounter these, they move up the concentration gradient, toward the legume roots.”

At the same time, the isoflavonoid plant-to-microbe signals activate a set of genes within the rhizobial cells that code for the production of microbe-to-plant signals (LCOs). This allows the plant to recognize the rhizobia as a “friend” rather than a foe, and to switch on a bank of genes within the legume that sets up the beneficial infection process and the eventual formation of root nodules.

As growers well know, root nodules are sophisticated structures that form on legume roots to house the rhizobial cells, and in which the rhizobia fix nitrogen from the atmosphere and supply it to the plant. In some systems, simple application of the correct LCOs will trigger formation of fully differentiated, but empty of rhizobia, nodules. Nitrogen fixation involves taking nitrogen from the atmosphere and making it available to the plant. Legumes are valued in agriculture because they do not require nitrogen fertilizer and because they are very high in protein, the class of molecules that contains most of the nitrogen in living organisms.
A stimulating subject

"More recently, it has been shown that LCOs also act as general plant growth stimulators, and that they do this to a much greater degree when plants are stressed. Allowing the microbe to encourage good growth of the plant under stressful conditions, to the benefit of the microbe, also benefits humans if the plant in question is a crop plant."

This issue of stress is a timely one to say the least. As climate change continues, field crops will be subjected to stressful conditions more frequently and the levels of stress will be more extreme. Thus, the application of microbe-to-plant signals has the potential to be a very low-input, sustainable mechanism to help plants deal with climate change. In the process, this mechanism can help the Canadian crop production sector to continue prospering and producing secure food supplies, as challenging conditions become more prevalent.

Fewer fossil fuels

"In addition, where crops are being grown to produce advanced biofuels, or crop residues are being used for this purpose, these biologicals can help reduce human reliance on fossil fuels, and therefore reduce the total level of climate change going forward. Crop plants, such as switch grass or hybrid poplar, are being produced increasingly on marginal lands. The conditions that make these lands marginal make it likely that the plants grown on these lands will also be more stressed, more often. Given the ability of phytomicrobiome member-to-plant signal compounds to overcome plant stress, these biological signals, or the microbes themselves, could play a major role in increasing the productivity of marginal lands."

Thus, beneficial plant-microbe relationships can not only increase plant productivity through things like nutrient provision, but also play a role in mitigating climate change effects, enhancing agricultural sustainability and reducing Canadian greenhouse gas emissions.

"We know there is a substantial phytomicrobiome associated with every plant, which regulates the plant and is being regulated by the plant," said Dr. Smith. "There are several examples that demonstrate the vast potential of the phytomicrobiome to serve as a source of extremely effective, very inexpensive and environmentally friendly crop production inputs. With further research, these inputs can become as important to crop production in the 21st century as chemical inputs were in the 20th century. Key research findings in this area have occurred in Canada, putting us in a leadership role in transforming the food and fuel production industries into low input, sustainable systems. Now is the time to further strengthen this leadership position."

Making this research all the more urgent is the grim reality of agriculture today: The world is at risk of running out of food.

"We are developing solutions to reduce climate change, improve yield and reduce biotic and abiotic stresses," said Robert Lee, president of AgroWorld Precision Agriculture Inc. and co-investigator on this project. "In doing so, we end up with very healthy plants, more nutrients and minerals, higher yields and healthier soil for the next crop to feed a rapidly growing population."

As with any successful research, this project relies on collaborators to make it possible; Dr. Smith is grateful to all of them: Biomass Canada Cluster (https://biomass.biofuelnet.ca/), Agriculture and Agri-Food Canada, and industry partners. The total value of the Biomass Canada Cluster is $12.3 million over 5 years (2018-2023), with funds from both AAFC and industry partners (about $4 million).

For more information on this project, please contact:

Dr. Donald L. Smith
Ph: 514-398-7866
Email: donald.smith@mcgill.ca
Distinguished James McGill Professor,
Plant Science Department, McGill University

Publication of this article has been made possible by the Biomass Canada Cluster. The Biomass Canada Cluster is managed by BioFuelNet Canada and is funded through the Canadian Agricultural Partnership’s, AgriScience Program.