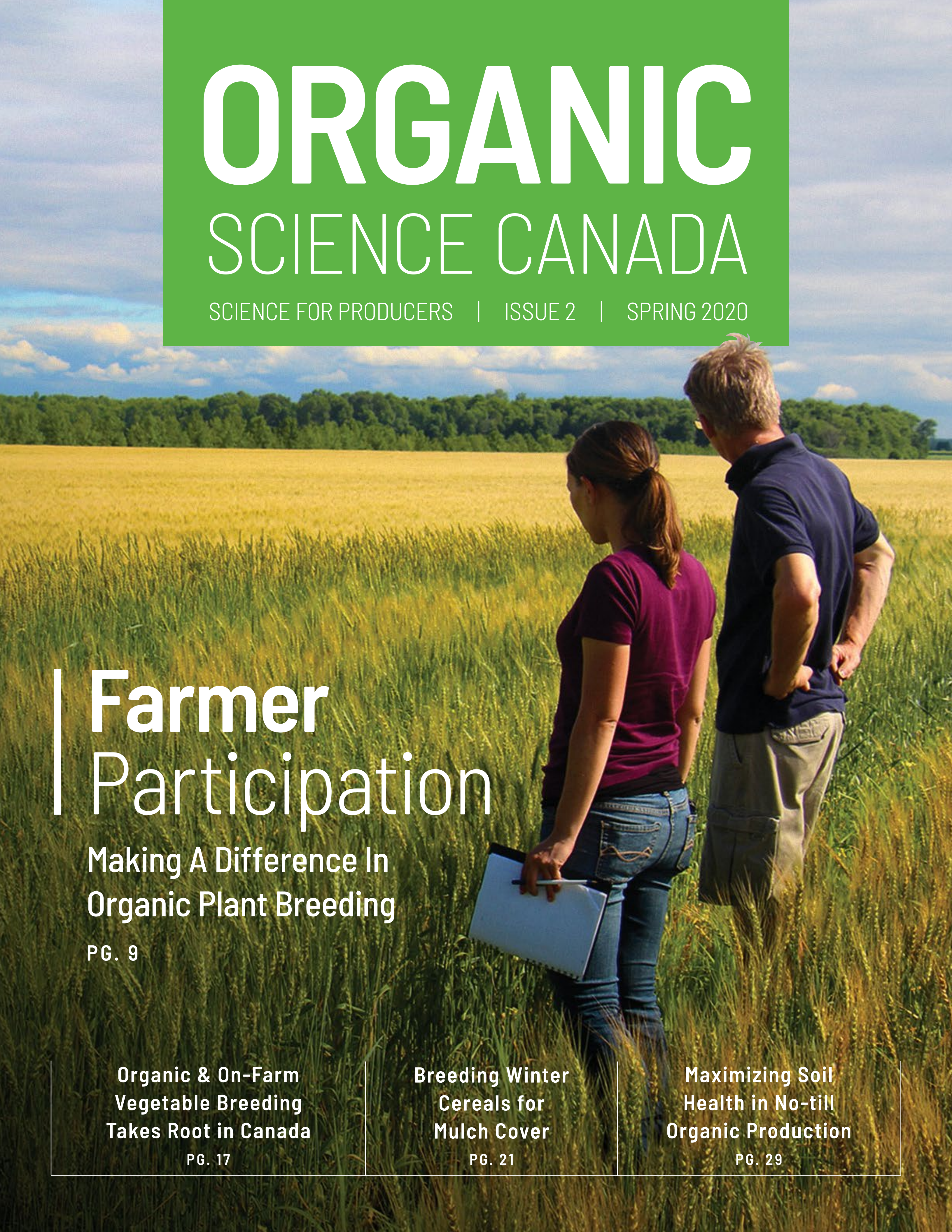
ORGANIC SCIENCE CANADA

SCIENCE FOR PRODUCERS | ISSUE 2 | SPRING 2020



Farmer Participation

Making A Difference In Organic Plant Breeding

PG. 9

Organic & On-Farm Vegetable Breeding Takes Root in Canada

PG. 17

Breeding Winter Cereals for Mulch Cover

PG. 21

Maximizing Soil Health in No-till Organic Production

PG. 29

Introducing Organic Science Canada Magazine

Organic Science Canada magazine is packed with the latest advancements in organic research and innovation from the national Organic Science Cluster (OSC) program. The magazine brings you trends, news and results from across Canada. The scientists who appear in these pages are working hard to improve the sustainability and profitability of organic and low-input agricultural systems.

Organic Science Canada magazine is published by the Organic Federation of Canada (OFC), in cooperation with the Organic Agriculture Center of Canada (OACC).

Created in 2007, the OFC is composed of ten organic associations representing nine provinces and one territory. Collectively, they promote the development of the Canadian organic industry across the country. The Federation is responsible for the maintenance and interpretation of the Canadian Organic Standards and the management of Organic Science Clusters 1, 2, and 3. OFC is based in Montreal.

The OACC was formed in 2001 with a mission to lead and facilitate organic research and education. The Centre plays a key role in national efforts to advance the science of organic agriculture. OACC also supports the training of the next generation of organic professionals. OACC's home base is in Truro, Nova Scotia, at Dalhousie University's Agricultural Campus.

OSC3 (2018-2023) is supported by the AgriScience Program under Agriculture and Agri-Food Canada's Canadian Agricultural Partnership, and by over 70 partners from the agricultural community. OSC3 has 27 research activities under five general themes: field crops, horticulture, pest management, livestock and environment.

FOR MORE INFORMATION:

- www.organicfederation.ca
- www.dal.ca/oacc
- @OrganicAgCanada

organic SCIENCE CLUSTER 3 · OFC FBC · OACC Organic Agriculture Centre of Canada · DALHOUSIE UNIVERSITY

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Above: Tomato plants at the Guelph Center for Urban Organic Agriculture (Photo: Youbin Zheng)

Cover photo: Loic Dewavrin and Michelle Carkner observe a participatory plant breeding wheat crop plot in Les Cedres, QC. (Photo credit: Yann Vergriete)

This magazine may be cited as: Geldart, E., M.E. Graves, N. Boudreau, and A.M. Hammermeister (Editors). 2020. Organic Science Canada. Volume 2. Organic Federation of Canada, Montreal QC and Dalhousie University, Truro NS. 30 pp. www.dal.ca/oacc/osclll

Welcome to Organic Science Canada!

Dear Reader,

The organic agriculture industry in Canada depends on the commitment, experience and wisdom of its organic farmers and on the innovative science of its organic researchers. The Organic Science Cluster, the third version of which began in 2018, represents much of the research energy devoted to organics in Canada. The Cluster is crucial to the health and development of our organic industry.

The Organic Federation of Canada, in collaboration with the Organic Agriculture Center of Canada, is proud to publish the 2020 edition of Organic Science Canada. This issue is devoted to the crop breeding projects, many of which focus on field crops. These projects, which are funded by the Cluster, provide us a glimpse of the impressive variety and scope of organic research taking place across the country.

As an organic mixed farmer from west central Saskatchewan, many of the projects described in this magazine are of direct and strategic importance to our family farm. The research that is described within this issue can help organic farmers make decisions on their farms which ensure sustainability moving forward. We hope that you find this information as valuable as I did, and that you can perhaps begin to implement some of this research on your own farms.

One challenge that researchers are working to tackle is the development of cultivars suitable for organics. Conventional plant breeding programs provide many plant varieties which are grown as organic field crops in Canada, but conventional varieties are not developed under organic management. As a further complication, genetic modification is becoming commonplace in conventional breeding, and those techniques are prohibited under organic production. Researchers are investigating best practices for developing varieties under organic conditions. An articles by MacDonell (pg. 19) describes a crop breeding project which is making selections and developing registered varieties under organic management conditions.

As organic agriculture breeding develops, perhaps it will become possible to grow varieties which are tailored to your precise soil and climatic region, perhaps even to your own farm. Articles by Entz, Kirk and Carkner (pg. 9), Lyon (pg. 17), and Hughes and Dey (pg. 25) are exploring options for participatory plant breeding. Their research describes breeding programs which select under organic conditions and which also involve farmers in the cultivar selection process. The goal is for researchers to work directly with farmers to produce even better cultivars tailored for organic production.

Organic agriculture relies heavily on tillage for seed bed preparation and for weed control. We are often criticized by proponents of zero tillage for the damage this tillage does to soil organic matter and the soil biota. An article by Hammermeister (pg. 21) describes a project which seeks to develop varieties of fall rye and fall triticale which can be used as organic mulches in an organic zero till system. An article by Dr. Carolyn Marshall (pg. 29) describes soil health research which indicates that tillage in an organic production system may not be as damaging as tillage in a conventional production system. In fact, Dr. Marshall's research suggests that tillage in an organic production system may not be any more damaging to the soil than a zero till system.

With a diverse collection of current research in organic agriculture, I am excited to present this edition of Organic Science Canada to you. Acquiring and disseminating new knowledge is the mission that those at the Organic Federation of Canada and the Organic Agriculture Center of Canada are committed to. We are devoted to continuously communicating the ongoing research and research results to you. Future issues of Organic Science Canada will be packed with new knowledge that covers a wide scope of organic agriculture. We hope you like this new and improved magazine issue and that you'll stay tuned for future issues. As always, we are open to feedback and suggestions.

Happy reading!
Sincerely,

James Robbins
President, Organic Federation of Canada

organic SCIENCE CLUSTER 3

$12 Million

TOTAL BUDGET

17%	30%	17%	23%	12%
B.C.	PRAIRIES REGION	ONTARIO	QUEBEC	ATLANTIC REGION

$8m AAFC CONTRIBUTIONS

$4m INDUSTRY CONTRIBUTIONS

79 RESEARCHERS

40 GRAD STUDENTS

74 INDUSTRY PARTNERS

14 AAFC RESEARCH CENTRES

22 UNIVERSITIES

27 RESEARCH PROJECTS IN 5 CATEGORIES

- FIELD CROPS
- HORTICULTURE
- PEST MANAGEMENT
- LIVESTOCK
- ENVIRONMENT

DAL.CA/OACC/OSCIII @ORGANICAGCANADA

Snippets

MARGARET GRAVES
ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY

Scanning carrot leaf samples at the University of Toronto. (Submitted photo)

FARMERS TAKE ON DATA COLLECTION CHALLENGE

My interest was piqued by the "citizen science" part of a recent study. Citizen science is when scientists collaborate with the public to collect information. Researchers can essentially be in many places at once, with the help of some friends.

Drs. Marney Isaac and Adam Martin, at the University of Toronto, are part of the Organic Science Cluster 3-funded work in on-farm participatory vegetable breeding. Farmers across Canada are working with researchers to select the best carrots for their farms. These farmers are the "citizens" who collected samples.

The ten farmers collected three carrot leaves from five varieties, at the end of the growing season. They packed up the fresh leaves and mailed them to Toronto.

Why carrot leaves? It's not what comes to mind when you think of carrots. Despite the fact that carrot top pesto is delicious, nobody is paying a premium for carrot tops… are they?

Larger leaves and stems let the carrots capture more sunlight and get ahead of the weeds. The leaves can tell researchers and farmers a lot about the health of the plant, what it needs and whether its genetics are useful to keep.

I picture the researchers waiting with excitement for the packages, hands outstretched to the mail carrier. Whisking their cargo off to the lab, they analyzed the contents immediately.

They measured functional traits like leaf area, petiole diameter and length, total carbon (C), and total nitrogen (N). These are "functional" because they relate to how the plant functions in its environment; how it photosynthesizes, how it takes up nutrients, how it grows and survives.

The data collection by farmers proved to be successful! Of the 150 leaves shipped from both coasts, from Southern Ontario to much further north, only 14 leaves arrived damaged.

So why do scientists care to collect all these measurements on crops? Well, there are huge databases of functional trait measurements from wild plants of many species, and the data has helped researchers understand big concepts like evolution and the effects of climate change.

Drs. Isaac and Martin are seeking to fill in some gaps in these databases. Noticeably missing is data from the crops that we humans artificially select, cultivate and depend on for food. Modeling how these important plant species will respond to changes in climate and management will help make decisions for the future of agriculture and food. The researchers also expect that the information will circle back, and help the farmer participatory breeders select the best traits for their farms.

Farmers, watch this space. You could be a key player in collecting this powerful data.

Source: Isaac, ME and Martin, AR, 2019. Accumulating crop functional trait data with citizen science. Scientific Reports. Vol. 9, Article 15715. https://doi.org/10.1038/s41598-019-51927-x

Snippets

MARGARET GRAVES
ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY

Tia Loftsgard, Executive Director of COTA, with Martin Entz. (Submitted photo)

TRAILBLAZER DR. MARTIN ENTZ ACKNOWLEDGED BY ORGANIC SECTOR

During Organic Week 2019, the Canada Organic Trade Association (COTA) presented the inaugural Leadership in Organic Science award to University of Manitoba researcher Dr. Martin Entz.

The award recognizes the significant impact of an individual's research, especially when it comes to providing new and improved tools for the organic farming toolkit. This means that the research itself needs to be valuable, and communicated skillfully to the people who can use it.

Dr. Andrew Hammermeister, Director of the Organic Agriculture Centre of Canada (OACC), says "If Dr. Entz isn't worthy, then this award should not exist. His long and excellent track record speaks for itself. His work in organic agriculture includes increasing the integrity of organic in the science community, communicating organic science to farmers, training graduate students, teaching in organic ag, and building collaborations."

To see Dr. Entz's work in action, check out his 2019 Summer Field Walk of the Glenlea Long-term Rotation Study on YouTube (https://youtube.com/watch?v=NZsSTjvsDdE). Launched in 1992, the Glenlea Rotation is Canada's oldest comparison of organic and conventional practices.

For more information about Dr. Entz's research, visit the University of Manitoba's Natural Systems Agriculture website (www.umanitoba.ca/outreach/naturalagriculture/).

ORGANIC GROWS GLOBALLY

FiBL, the Research Institute of Organic Agriculture, based in Europe, and IFOAM-Organics International teamed up to release global organic statistics in The World of Organic Agriculture 2020. The latest edition presents data from 2018 – a record year.

In 2018, there were 2.8 million organic producers worldwide. The global organic market exceeded 100 billion US dollars, with double-digit growth in many countries. And there were 71.5 million hectares of organic land – 2 million more hectares than in 2017.

Source: https://www.organic-world.net/yearbook/yearbook-2020.html

LEAH OVERBYE RECEIVES FIRST SASKORGANICS SCHOLARSHIP

Leah Overbye is the deserving recipient of the very first scholarship awarded by SaskOrganics. Leah is a third year nutrition student at the University of Saskatchewan.

"The farm that I grew up on has been implementing organic practices for four generations," says Leah, "starting with my great-grandpa when he came to Canada from Norway. My family and I are strong advocates for organic agriculture...I believe with individuals continually informing and advocating there will be more people that understand why organic agriculture is so important for individuals and families."

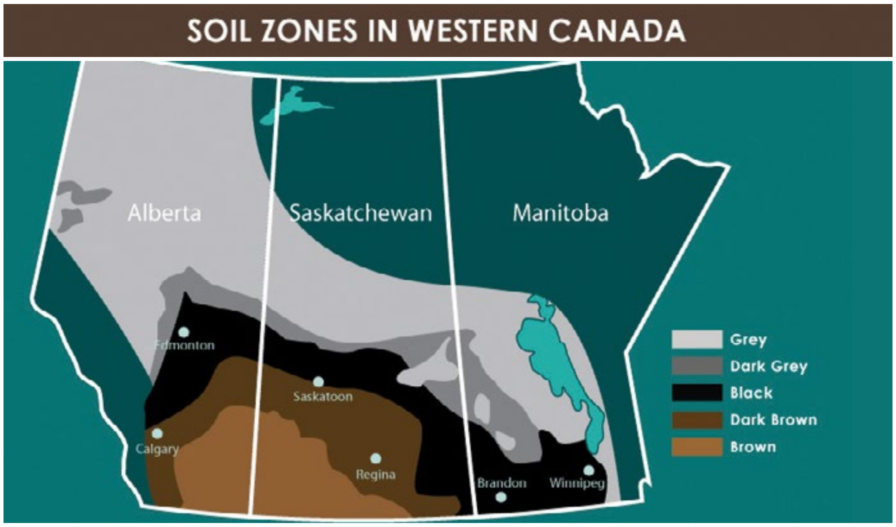
A generous donation from the North West Saskatchewan Organic Producer Group has allowed SaskOrganics to support students in their studies. The goal is to help the next generation pursue their passion for organics. The annual scholarship is valued at $1000, and preference is given to students who grew up on a certified organic farm.

If you are a post-secondary student residing in Saskatchewan who has an interest in organic food, farming, processing, or marketing, keep your eyes open for the next application window of Nov-Dec 2020.

For more information, consult SaskOrganics' website, http://saskorganics.org/education-scholarship/.

Snippets

MARGARET GRAVES
ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY



Used with permission from Western Winter Wheat Initiative, growwinterwheat.ca

REDUCING TILLAGE STILL A CHALLENGE

Organic management in the Prairies has been criticized for relying too heavily on tillage and summerfallow for managing weeds, disease, soil moisture and fertility. Predictably, reducing tillage has proved to be a challenge. The latest experiments haven't yet come up with a clear way over the major hurdles.

Increasing crop rotation diversity (more crops in the rotation) has shown promise as an alternative to intensive tillage and summerfallow. One of Canada's pioneering organic researchers, Agriculture and Agri-Food Canada's Dr. Myriam Fernandez, took on the question. Could diversifying crop rotations under reduced tillage work to help organic farmers to increase their profits and sustainability?

From 2010 to 2016, Dr. Fernandez compared a simple vs diversified rotation with high and low tillage intensity. Together with the Swift Current Advisory Committee of local organic farmers in south-west Saskatchewan, Dr. Fernandez designed a diversified rotation to test her hypothesis.

Simple rotation: Forage pea green manure, spring wheat.

Diversified rotation: Forage pea green manure, oilseed (alternating flax and yellow mustard), pulse (alternating field pea and lentil), spring wheat.

The experiments were done in Swift Current, Saskatchewan, in the Brown soil zone. It's among the driest areas in Canada, but with variable weather. Most years of the study were wetter than the long-term average.

Wet weather in the first years of the trial caused an explosion of perennial thistles, which made the plots quite difficult to manage. In response, the research team increased tillage in all the plots. Wheat yields fell over time, but it wasn't mainly due to the weeds. It had more to do with the soil nitrogen (N) availability going down, especially in the low tillage plots. The end of the trial had the lowest yields overall. It was likely due to the dry weather at that point in the trial.

Soil organic carbon (C) was higher and soil structure was better under low tillage, but it was a tradeoff with yield. The high tillage, simple rotation had the highest and most consistent yields.

Dr. Fernandez explains, "Green manure and crop residue incorporation in the soil with high tillage likely increased microbial activity, which in turn increased residue decomposition and N mineralization."

Among these mixed results, wheat grain protein was one that stood out. The protein concentrations were remarkable, either similar or higher than with conventional wheat, and were not negatively associated with yield.

Reducing tillage did not seem to make organic wheat more resilient, in the face of higher than average soil moisture conditions. To deal with variable weather, tillage will still be an important tool in the organic farmer's toolkit for now.

The work was funded in part by the second Organic Science Cluster, with the Western Grains Research Foundation.

Source:

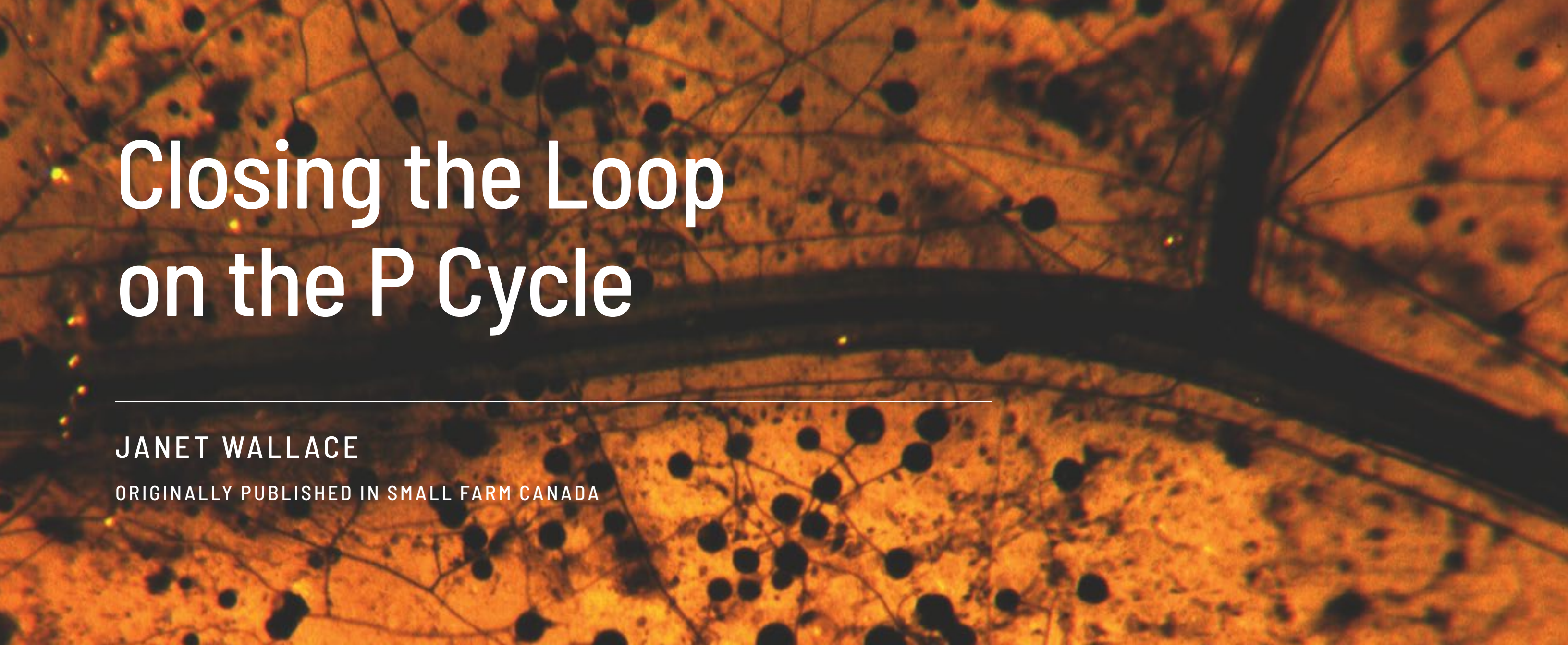
https://dx.doi.org/10.2134/agronj2018.01.0028

https://dx.doi.org/10.2134/agronj2018.01.0029

Closing the Loop on the P Cycle

JANET WALLACE

ORIGINALLY PUBLISHED IN SMALL FARM CANADA



Arbuscular mycorrhizal fungi (AMF) form associations with plants and establish networks that explore micropores for nutrients and water where roots can't go

Phosphorus (P) is needed by plants and often found in the soil -- the challenge is having an adequate and constant supply of phosphorus in a form that plants can use. Canadian scientists have been studying the P cycle on farms, particularly organic farms, for several years. A recently published paper summarizes many of the findings.

First, the researchers discovered that "Crop yields could be maintained at lower than recommended soil test P concentrations." One way to do this is by increasing the availability of the P already in the soil. Farmers can improve a crop's access to P by ensuring there are high levels of soil organic matter and by supporting arbuscular mycorrhizal fungi (AMF). AMF form symbiotic relationships with many plant species, particularly legumes, and enable the plant roots to access more water and nutrients including P. These helpful fungi are harmed by many common farming practices including tillage, application of high rates of soluble P fertilizers, leaving soil bare, and monoculture. Farmers can protect AMF by avoiding these destructive practices and also using diverse crop rotations that include green manures, particularly mixes of cover crops that include legumes.

As mined sources of rock phosphate are being depleted, soil scientists are seeking other sources of phosphorus. Struvite might be the answer. In traditional mixed farms, P was removed from the fields when crops were harvested but much was later returned in the form of livestock bedding mixed with urine (a source of P) and manure.

Struvite is created by precipitation and crystallization of liquids containing urine or other high-P materials. The result is a high-phosphorus substance that can be used as a fertilizer. The original source of the material affects the quality of the struvite. For example, struvite can be made from municipal wastewater but this may contain undesirable chemicals that have also been flushed down the drain. Another alternative is to produce struvite from livestock urine and manure or food processing wastes.

The researchers suggest a multi-faceted approach to P availability is needed. For example, plant breeders might select for crops that form symbiotic relationships with AMF or are more efficient at using P. Many of the practices recommended to improve the availability of P (e.g., complex crop rotations, protecting soil organic matter, keeping soil covered) are generally good soil management practices with many other benefits.

For updates on this work, keep an eye on the Organic Science Cluster 3 project coled by Drs Henry Wilson and Kim Schneider. They are investigating the effects of fertilizing with struvite.

Source: Schneider, KD, et al. 2019. Options for Improved Phosphorus Cycling and Use in Agriculture at the Field and Regional Scales. Journal of Environmental Quality. Vol. 48 No. 5, p. 1247-1264.

https://dl.sciencesocieties.org/publications/jeq/articles/48/5/1247

Farmer Participation is Successfully Improving Organic Crop Breeding

DR. MARTIN ENTZ, UNIVERSITY OF MANITOBA
ANNE KIRK, MANITOBA AGRICULTURE
MICHELLE CARKNER, UNIVERSITY OF MANITOBA

Can organic farmers count on better cultivars for organic production? The short answer is yes, organic farmer selections and participatory breeding often outperform conventional varieties. The success of the farmer selections is clear.

A major part of our research is to test the organic farmer-selected lines and compare them to conventionally bred varieties in an organic production system. We now have multi-year data on the performance of a wide range of farmer-selected lines. All of these experiments are conducted on organic fields, either on research stations or on commercial organic farms.

In our potato work, some farmer selections had higher yield and fewer internal defects than Yukon Gold, a popular variety across Canada. On average, organic farmer selections demonstrated greater early season vigour and less disease than most check varieties, which included Kennebec, Yukon Gold, Agria, Atlantic, Chieftain, and Envol.

The farmer selections are helping AAFC scientists develop potato varieties better suited to organic production, achieving one of original goals of the program. In further recognition, the national potato breeding program of AAFC at Fredericton is advancing the farmer-selected lines in their mainstream breeding program.

Farmers play an important role in developing superior lines of oats for organic production. Farmer selections are being funneled back into the organic oat breeding program of AAFC in Brandon, Manitoba.

Oat breeder Dr Jennifer Mitchell-Fetch has run organic oat breeding program since 2004. In her own organic nursery, she now considers lines from the farmer participatory program. In 2019, the majority of the lines which she decided to advance to the "B" test (which is the series of field tests before the official registration tests) came from the farmer participatory program. This was an exciting result for the farmers and all those involved in the Participatoiry Plant Breeding program (PPB).

Farmer-selected wheat lines have been evaluated in two major studies. The first group of farmer lines were evaluated in 2014 and 2015. While there was significant variation in agronomic performance of different farmer-selected lines, the farmer selections were generally taller, later maturing, more susceptible to lodging and higher yielding than the check cultivars.

The second wheat study evaluated another cohort of farmer breeders involving field experiments at several sites in 2017 and 2019. Results mirror those of the first set of farmer-breeders; that is, farmers are selecting lines that perform better under organic production than most conventionally-bred varieties.

HOW PARTICIPATORY BREEDING WORKS

Developing cultivars for organic production has become a topic of interest in Canada and elsewhere. It is clearly documented that organic production systems experience challenges that differ from conventional systems with different soil nutrient status, soil biology, and weed pressure. A number of carefully conducted studies have confirmed that direct early generation selection under organic management results in genotypes that are better adapted to organic production.

Evolutionary participatory breeding (EPB) takes PPB to another level to emphasize the utilization of natural selection in combination with site-specific farmer selection to segregate early generations of a crop population.

Small-holder production systems and modern potato breeding in the Netherlands have gained significant experience in PPB. For example, as of 2014, 148 active farmer breeders in the Netherlands were involved in EPB with a goal to select for late blight resistance.

The EPB concept has not been widely explored in the Canadian plant breeding context, but a number of factors encouraged us to do so. There was interest in improving crop varieties for organic production, farmers were motivated to become in-

Foster Richardson and Natasha Tymo (Mill Bay, Vancouver Island, BC), farmer-breeders who participated in the selection process of the populations of oat. (Photo credit: Michelle Carkner)

volved in the process, and funding partners were willing to support the work.

The first step in the process was to identify interested farmers: farmers who were willing to grow segregated populations in their organic fields and select superior plants. The farmer network was achieved through close collaboration with the regional coordinators of the Bauta Family Initiative on Canadian Seed Security. The interested farmers were approached by the Program Coordinator with information about what genetic material was available for selection.

The populations that would eventually go out to farmers for selection were created by AAFC scientists and by our program staff at the University of Manitoba. Wheat and oat crosses were made by AAFC scientists based in Manitoba while potato crosses were made by AAFC scientists in New Brunswick.

In one instance, the farmers reached out to us to learn how to make their own cross. They were successful and were able to select from the offspring of a cross they made themselves.

Farmers were then provided with a list of crosses, and this information included which varieties or landraces had been used as parents in the cross. This allowed farmers to choose material that may be best suited to their area and their organic production system. This makes the process similar to sire selection in on-farm beef breeding, which some of the participating farmers were familiar with.

The first phase of the project involved on-farm selection. The second phase involved testing the farmer-selected varieties, and comparing them to conventional varieties developed for conventional production.

Interestingly, lines selected on farms close to the site of field testing performed best in those environments. For example, lines selected by two farmers in Southern Saskatchewan performed best in the experiments at Swift Current test site. We think this may reflect the value of local selection.

The main goals of the Organic Science Cluster PPB project in the next two years is to continue field testing of wheat that will produce a dataset large enough to allow proper multi-generational stability analysis to be conducted. We are also in the process of evaluating the farmer-selected lines for disease resistance and response to water and heat stress.

STEP BY STEP: FARMERS SELECT THE BEST WHEAT AND OATS FOR THEM

We initiated a farmer participatory plant breeding program for wheat in 2011. In 2013 it was expanded to also include oats and potato. By 2019, over 80 farmers from across the country have participated in the program.

The PPB program coordinator arranged to send the seeds to participating farmers in PEI, Manitoba, Saskatchewan and Alberta. Most famers were interested in trying more than one population. Therefore, most farmers received three different second or third generation populations for planting.

Each population contained between 3000 and 5000 wheat or oat seeds, which allowed the farmers to plant an area approximately 20 m2 per population. Populations are planted by hand, with a push garden seeder, or modified grain drills. Row spacing and seeding rates are the same as the farmers would use in commercial production.

We built the program to provide plenty of support for participating farmers: an instruction manual was sent to each farmer, and each farmer received a visit from the program coordinator in the first and second year of the selection program. Farmers were able to contact the program coordinator to ask questions throughout the growing seasons.

The farmers made selections throughout the growing seasons based on their preferences. This included removing undesirable plants from the populations and the identification of desirable plants.

Final selections were made at harvest. Farmers selected approximately 300 spikes or panicles per population. The selected spikes or panicles were sent to the University of Manitoba for threshing and cleaning and returned to the farmers the following spring.

In the case of wheat, when selecting from the same population, farmers produced distinctive crop lines. Differences were observed in disease response, days to maturity, height, lodging and yield. Four farmer-selected lines, PA00-KB-AL, BL26-KS, BJ13-HRE, and BJ08-IG displayed both above average multi-generational stability and high yield. They may be good candidates for future crosses in organic breeding programs.

No further selection was conducted by the research team during the threshing and cleaning process – the farmers' selections were honoured.

The process of field production and selection as well as threshing and cleaning was repeated for three consecutive years for each population. At the end of the three-year selection process, the F6, or 6th generation, was harvested by the participating farmers.

NO SMALL POTATOES HERE

Farmers likewise participated in potato selection, and were supported by the research team in the same way as for wheat and oat selection. The instruction manual for potato breeding was made available online to farmers.

The crosses were made at AAFC Fredericton, NB by Dr. Benoit Bizimungu with some additional crosses made by Dr. Dwayne Falk in Ontario. Parents were chosen based on field performance and disease resistance.

Eight farmers, in New Brunswick and Quebec, received one or two populations of seeding tubers, with approximately 500 tubers per population. During the first year of selection, farmers were instructed to reject 70-90% of the clones (individual plants). One tuber from each of the remaining plants (10-30% of the original population) was saved on farm for planting the following spring. Farmers also had the opportunity to check for storability, as some seed pieces stored better than others

During the second year of on-farm selection, farmers planted the dramatically narrowed populations. They cut potato tubers into four pieces and planted them as a tuber unit, separated by an empty space to avoid mix-up at harvest time. Selection in year two involved removing approximately 50% of the tuber units. After selection, approximately 15-20 plants per population remained for planting in year three. AAFC lent a hand by providing quality analysis and yield testing on a subset of the year two tubers.

During the third year of on-farm selection, tubers harvested from the selected 15-20 plants were planted in larger plots to allow for yield assessment and grading. Again, some of the selected tubers were sent to AAFC for quality analysis and yield testing.

Jim Grieshaber-Otto (Agassiz, BC) a farmer-breeder who participated in the selection process of the populations of wheat. (Photo credit: Michelle Carkner)

THE FUTURE OF FARMER-SELECTED LINES

There are two main options for farmer-selected potato, wheat and oat lines. The first is to use the farmer selections to develop official registered varieties suited to organic production. This is already happening with the farmer-selected oat and potato lines, as we have described. This model of crop breeding mirrors what is being done with potatoes in the Netherlands, where farmer selection is built into the mainstream plant breeding program.

The second option is for farmers to grow their selected lines as landraces for their own markets. This is being done with farmer-selected lines of wheat in Quebec, BC and more recently Manitoba. In this case, farmers can brand their organic grains as "Farmer-Bred" in addition to the organic certification. In accordance with plant breeding regulations, these lines (or landraces) cannot be sold under any variety name and seed of these lines also cannot be sold as a variety.

THE ORGANIC AGRICULTURE RESEARCH STANDARD

NICOLE BOUDREAU
ORGANIC FEDERATION OF CANADA

Did you know that research that claims to be "organic" is expected to comply with the organic standards? While not all research undergoes the full certification process, peer reviewers of science claiming to be organic carefully assess the research methods to make sure they are in compliance. Many researchers will bring land into organic certification or will collaborate with certified producers to bring added integrity to their research.

Sometimes, however, researchers need to compare organic and non-organic practices under the same growing conditions, or perhaps need to use a non-permitted substance to better understand how organic practices are working. In these cases, researchers benefit from an exception to the clause which prohibits parallel production in Canada (simultaneous production or preparation of organic and non-organic crops that are visually indistinguishable). Clause 5.1.4 of the Organic Standard allows an exception:

The exception to this norm, parallel production, is only allowed in the following cases: perennial crops (already planted), agricultural research facilities and production of seed, vegetative propagating materials and transplants. However, the organic standard adds, in clause 5.1.5, that the practice of parallel production must meet certain conditions:

a) The operator shall clearly demonstrate that the identity of the crops so produced can be maintained during their production, harvesting, storage, processing, packaging and marketing;

b) The operator shall maintain verifiable, accurate records of both non-organic and organic produce and product storage, transportation, processing and marketing.

The parallel production waiver facilitates research by allowing researchers to compare yields of organic and non-organic crops on parallel plots.

Organic Oat Research Success Made Possible Through Valuable Participation of Industry Partners

EMMA GELDART

ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY

For over 10 years, researchers through the Organic Science Clusters (OSC) have been seeking answers to the issues that are important to organic famers. From livestock to crop breeding and a wide variety in between, countless hours of time and resources have been focused on furthering organic agriculture across the country. Valuable industry partners across all sectors have helped to ensure that organic science is moving forward in Canada.

Grain Millers Canada Corp., Nature's Path, and the Prairie Oat Growers Association (POGA) are three of the largest contributors to Dr. Jennifer Mitchell Fetch's organic oat breeding work in Organic Science Cluster 3 (OSC3). All three stakeholders value organic research and play an important role in supporting the Cluster.

Beginning in 1986 as a small oat milling company in Oregon, Grain Millers Canada Corp. has now become North America's largest oat ingredient supplier. As the world's largest organic oat ingredient supplier, their interests include whole grain manufacturing and merchandising, organic and conventional consumer food products, and the import and export of commodities.

Today, Grain Millers has production facilities across North America, with their Canadian facilities located in Alberta and Saskatchewan. Research and innovation is an important mandate to Grain Millers, so supporting the OSC's was a natural fit.

"We became aware of the Cluster model when Agriculture and Agri-Food Canada rolled it out with the changes to the ag policy framework," explains Terry Tyson, General Manager of Grain Millers Canada Corp.

> Oats are a main ingredient in our products; we want to support organic farmers in using the most organically suitable varieties.
>
> —Dag Falck, Organic Program Lead, Nature's Path

The Science Cluster model was initiated with the Growing Forward policy framework in 2008. "We were invited to participate when the organic sector made the move to create a Cluster. Advancing the genetics of oat varieties, whether conventional or organic, is in our interests and that of our farmer suppliers."

"We hope to see continuous improvement of yield potential, quality, agronomic factors, and nutritional composition," Terry adds.

In addition to their guidance and generous financial support, Terry helped to recruit an additional partner to support the organic oat research. In 2018, Nature's Path Foods joined the roster.

With a portfolio of nearly 500 organic products, Nature's Path has production facilities across North America with sales spanning 40 countries. The company identifies sustainability as one of its core pillars and their business model is based on sustainable practices through support of charities and eco-friendly initiatives. Supporting oat breeding research is a natural fit for Nature's Path.

"We've been following the Organic Science Cluster research since its inception in 2009," explains Dag Falck, Organic Program Lead at Nature's Path. "We've been providing financial support for three years and now are actively involved in variety identification. Oats are a main ingredient in our products, we want to support organic farmers in using the most organically suitable varieties."

POGA is also a valued supporter of the organic oat breeding project. Formed in 1988, POGA is a voluntary organization of prairie oat growers that was established to promote oat marketing and the interests of oat growers across Western Canada. As research and development is part of their mandate, supporting research was an appropriate choice for POGA.

"POGA's mandate is to support all oat growers in Western Canada, including both conventional and organic," says Shawna Mathieson, Executive Director for POGA. "The demand for organic oats is rising and growers need new varieties to meet that rising need. Therefore, supporting projects like this, along with conventional breeding programs, makes perfect sense. Oat growers rely on funding from outside sources like the government and industry in order to maintain and build breeding programs as well as other research and marketing. Be-

left; Terry Tyson, General Manager, Grain Millers Canada Corp. Right; Dag Falck, Organic Program Lead, Nature's Path Foods (Submitted photos)

ing part of this OSC is a 'win' for everyone from the grower to the end users."

The research is led by Dr. Jennifer Mitchell Fetch of AAFC Brandon and her team. It explores milling quality oat cultivars suitable for organic production in Western Canada, and potentially across Canada. The project comes as a result of organic growers, processors, and consumers continually seeking cultivars developed for their unique systems and needs.

As a result of their previous research under OSC2, two new oat varieties have been registered by Grain Millers and are now commercially available to growers across the Prairies.

"It's gratifying to see the breeding program bear fruit, and we stepped in to register the varieties," Terry explains.

Although Grain Millers, Natures Path and POGA play an important part in organic oat breeding research, they emphasize the supportive nature of their role.

"We've played a role in the post-breeding efforts, but it's important to note that Dr. Jennifer Mitchell Fetch and her team are responsible for the success of the program to date," Terry emphasizes. "We provide our financial support and contributed to defining the goals of the efforts, but the AAFC breeding team is to thank for making the crosses, selecting the right progeny, managing the seed plots and variety trials, and, ultimately, developing the genetics that are starting to deliver on the investment."

With successful oat breeding research to come out of the Clusters to date, the efforts of the research team and support from the industry partners certainly will continue.

"We hope that the oat breeding program will continue to develop oat varieties that are strongly suited for production under organic management," Terry says.

Dag agrees. "Ideally, we will see the development of several new oat varieties with specific traits that are useful to organic low input systems, including yield, and pest, disease, and lodging resistance."

"The real importance is in the question of whether genetic-response differs to growing conditions prevalent in organic production systems," Terry adds. "The importance isn't about optics or marketing- it's about improving cultivars, thereby improving bottom line potential for organic farmers and millers, and maximizing nutrition for consumers."

Organic Science Cluster Supporters

With great appreciation, we would like to acknowledge the following industry partners for their contributions in support of Organic Science Cluster 3.

MONETARY CONTRIBUTIONS

Organic Science Cluster Supporters

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OVER 150 MORE INDIVIDUAL FARMS

Organic and On-Farm Vegetable Breeding Takes Root in Canada

DR. ALEXANDRA LYON

POSTDOCTORAL RESEARCH FELLOW, UBC CENTRE FOR SUSTAINABLE FOOD SYSTEMS

Dr. Alexandra Lyon, University of British Columbia.

It's the first week of January in Vancouver, 11° C with a steady drizzle—the perfect time to plant carrots. As you might suspect, this isn't a normal carrot crop.

This week, my team and I—researchers and students at the University of British Columbia's Centre for Sustainable Food Systems—are planting 120 carrot roots in a heated greenhouse. They will receive 16 hours of light every day from the sun and supplementary greenhouse lighting, growing into lush green plants in the middle of winter.

Growing carrots in the winter is just one step in a recurring cycle of crop production, selection, and seed grow-outs to develop new carrot varieties for organic production through participatory plant breeding.

Developing new varieties is one of the objectives of the Canadian Organic Vegetable Improvement (CANOVI) project. The project emerged from collaborations between UBC's Centre for Sustainable Food Systems, the Bauta Family Initiative of Canadian Seed Security, and grassroots farmer organizations across Canada who support on-farm variety trials that help organic farmers identify promising crop varieties for their regions.

This collaborative work demonstrates that some regionally-adapted varieties offer better traits for organic growers, and that farmers are interested in working with university researchers to do their own breeding and develop improved regional varieties.

The Organic Science Cluster 3 (OSC3) project has enabled our UBC research team to dig further into this work, through funding provided by AAFC's Canadian Agricultural Partnerships program and the Bauta Family Initiative of SeedChange as our industry partner.

An important first step in this research was identifying the crops to focus on. Experience with on-farm variety trials, including farmer meetings and a national survey, gave the team background information on breeding priorities for organic and ecological farmers. Farmers identified carrots as high priority overall, and an important winter storage crop for direct market growers. Farmers were also concerned about relying on only a few hybrid varieties, and unsatisfied with the options for open-pollinated varieties which would offer less expensive seed and the possibility of regional seed saving.

Enter Dr. Phil Simon at the University of Wisconsin, who leads the U.S. Department of Agriculture (USDA) public breeding program for table carrots and has been researching the crop for decades. Since 2016, Dr. Simon has worked with Organic Seed Alliance, a non-profit based in Washington State. There, he has been developing an organic carrot breeding program focused on unique culinary and colour traits, as well as agronomic aspects, such as disease resistance and competitiveness with weeds.

Funding from OSC3 allowed us to build a cross-border collaboration with the U.S.-based research group, bringing seeds from novel carrot populations to Canada and further adapting them to the needs of Canadian organic growers.

Seven experimental carrot populations were grown in the summer of 2018 at the UBC Farm, chosen from hundreds of populations that Dr. Simon maintains as part of the USDA carrot breeding nursery. The U.S. team selected these populations for us based on priority traits for CANOVI participants: vigour, flavour, appearance, nematode and disease resistances, and a cylindrical shape with a rounded tip (called a Nantes shape) that tends to last better in storage.

In October 2018, we held a field day where farmers examined the experimental lines and rated them for flavour and appearance. The roots were stored, carefully trimming the tops to allow for regrowth required for seed production. Roots prepared this way, with the growing point intact, are called stecklings.

These stecklings are what we're planting in the UBC Horticulture Greenhouse on this wintery Vancouver day. Carrot seed

Micaela Colley of Organic Seed Alliance inspects CANOVI carrot breeding lines at the UBC Farm.

production takes two years outdoors, but a heated greenhouse in winter speeds the breeding process to produce seed before the next year's growing season.

We made our first cross in early 2019, creating a multi-parent population that combined some of the best traits from three experimental populations and one commercial variety chosen through farmers' ratings. In summer and fall of 2019, we grew this new population at the UBC Farm and at Forstbauer Family Natural Food Farm, a certified organic farm in Abbotsford, BC.

At harvest time in October 2019, all of the roots were laid on a table and examined by the Organic Seed Alliance researchers and the Forstbauer farm team. Roughly 25% of the roots were selected, based on shape, colour, appearance, and flavour, eliminating any with signs of disease, and stored as stecklings.

Now, in January 2020, we are again planting this population in the greenhouse, where they will flower and cross-pollinate, creating seed that we will plant in late June. This process is the core of evolutionary-participatory plant breeding: creating diversity through an initial cross, then repeatedly selecting the best plants based on farmers' observations in the cultivation system where the variety will be used.

After one to two more cycles of selection to make the population more uniform, our research team will send seed out to a broader range of farms.

The growers will continue to send the best roots back to UBC to be crossed during the winter. By the end of the CANOVI project, we will have several advanced carrot populations, which can be shared with farmer participants for continued selection and eventual use as regionally adapted varieties.

The CANOVI project is also supporting a similar project with red bell peppers. Ontario farmers are collaborating with a public plant breeding program led by Dr. Michael Mazourek at Cornell University, to develop regionally adapted, early-maturing peppers for organic production in Ontario. These carrot and pepper breeding projects will serve as case studies of how collaborative vegetable breeding can be done by communities with minimal infrastructure, planting the seeds of participatory vegetable breeding here in Canada.

FURTHER READING

ubcfarm.ubc.ca/canovi

seedsecurity.ca/canovi

eorganic.info/carrotimprovement/about

www.bcseedtrials.ca/2019/05/15/where-carrots-come-from

Breeding Tailored for Organic Soybean Crops

EDWARD C. MACDONELL, MSC
DALHOUSIE UNIVERSITY

Farmers face their annual dilemma. They select crop cultivars for their farms from sales data provided by the vendor and from performance reports of provincial crop trials.

But do trial results from conventionally managed field sites apply to organic farmers? Generally, the answer is no. What is an organic farmer supposed to do?

Despite a small number of organic soybean growers, around 150 in Ontario, there is a growing market for this product and organic soybeans command a higher price compared to their conventional counterpart. Breeding soybeans for organic systems is an opportunity to close the yield gap between organic and conventional soybean production. For example, fields under organic production can have lower P and K soil budgets than conventional fields, and organic managers also use more labour through mechanical weed control. Selecting robust breeding lines that are better adapted to organic field management will increase product competitiveness in a growing market. Pioneering work is contributing to a greater understanding of soybean breeding for organic production systems.

"Soybeans can be a challenging crop to grow in an organic system, since tools such as herbicides and soluble fertilizers are prohibited," notes Dr. Istvan Rajcan, professor and soybean breeder at the University of Guelph. "Our goal with this project is to provide organic producers with cultivar options that are better suited to their production system."

> Soybeans can be a challenging crop to grow in an organic system, since tools such as herbicides and fertilizers are prohibited.
>
> —Dr. Istvan Rajcan, University of Guelph

Most cultivars used in organic production systems were originally selected within conventional farming systems and selected for attributes that respond to conventional practices. However, a principle of plant breeding is that varieties should be evaluated under conditions that they are expected to encounter on the farm, such as those found on organic farms. Factors such as site fertility and organic weed management techniques provide unique conditions for certain breeding lines to excel over others, which go unnoticed at a conventional test site.

A soybean cultivar is traditionally assessed for important traits such as susceptibility to lodging, seed yield, seed protein and oil content. However, additional traits are important for organic growers that address soil fertility differences and competitiveness with weeds. These traits of interest include plant canopy development, root morphology, and nodule mass. Rapid canopy development can shade out weeds that compete with the crop. In the coming seasons, Dr. Rajcan's team will be using drone technology to measure plant canopy.

The efficiency of the plant's ability to take up nutrients should also be considered. The analysis of the N, P, and K contents in leaf samples will estimate the plant's nutrient use efficiency. Nutrient uptake and assimilation are studied by way of root samples, which explore plants' root volume, root surface and root nodule dry mass.

Dr. Rajcan directs this novel organic soybean breeding project along with retired professor Dr. Ralph Martin and PhD student Xin Lu. Their work builds upon previous research led by Dr. Rajcan and a former MSc student, Torin Boyle. Mr. Boyle's research demonstrated that certain soybean cultivars performed better when grown in an organic production system compared to a conventional system.

Mr. Boyle established a link between cultivar yield performance and root architecture in organic systems: certain cultivars produce root systems that can better access limited nutrients. Therefore, the evaluation of breeding populations in organic production systems can lead to robust soybean cultivars that can be better suited to organic systems.

Dr. Rajcan is conducting two experiments at six sites in Ontario: three under organic and three under conventional management. One experiment consists of an evaluation of 50 soybean cultivars under both management systems. The other experiment consists of two F6 generation breeding populations, which will be evaluated for superior performing lines at organic sites.

In addition to the project's Ontario trials, two organic field sites are under the supervision of Dr. Martin Entz, a professor at the University of Manitoba, where 39 cultivars were grown in 2019. It can take seven to ten generations, after making the initial cross, to get a soybean line to the later stages of a breeding program and ready for commercial release.

The organic and conventional test sites require different crop management practices throughout the test period. At the conventional field sites, herbicides are employed, whereas inter-row cultivation is performed early in the season until V5, the growth stage at which the soybean has five unrolled trifoliate leaves. It is then followed by hand weeding at the organic field sites.

The study will also analyze the DNA from the breeding populations to identify quantitative trait loci (QTLs), which are regions of the soybean genome associated soybean yield in the two production systems. With this information, genetic markers can be developed in the future to guide the selection of parental lines used when breeding for organic production systems.

Dr. Istvan Rajcan, University of Guelph

Breeding Winter Cereals for Mulch Cover Proves Transformational

DR. ANDREW HAMMERMEISTER
DIRECTOR OF THE ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY

Roller-crimper with research plots for winter cereal mulching at AAFC Lethbridge (Photo credit: Agriculture and Agri-Food Canada)

AAFC crop breeders are making a dramatic shift in breeding objectives for fall rye and winter triticale. No longer is the emphasis on crop yield. The breeding program is targeting cover crop characteristics that support weed management and tillage reduction as part of a sustainable cropping system.

This important research could lead to a transformational shift in organic production practices, in the way that the introduction of herbicide resistant crops changed conventional agriculture.

With the support of industry partners, Drs. Raja Ragaputhy (AAFC Lethbridge), Jamie Larsen (AAFC Harrow) and technician Jordan Harvie have established a research program under Organic Science Cluster 3 to develop cultivars of cover crops that are adapted to a roller/crimper production system.

"With the example of rye and triticale, we had to shift our thinking about cultivar development from producing high grain yield to producing early flowering, high biomass, weed suppressing cover crops that suit the organic production system," Dr. Jamie Larsen explains.

TOO MUCH TILLAGE IN ORGANIC AGRICULTURE?

Organic agriculture has long been criticized for relying on tillage for weed control, incorporating cover crops or soil amendments, and seed-bed preparation. While Organic Science Cluster 3 evaluates the impacts of tillage within organic cropping systems, it also supports a project that turns conventional breeding programs upside down.

Intensive and frequent tillage can lead to losses of soil organic matter, degradation of soil structure, higher erosion susceptibility and overall declines in soil quality and health. The impacts of tillage can vary widely depending on the depth, level of disturbance and frequency of tillage. Tillage practices can also vary widely in organic agriculture. For example, ploughs and heavy disks which may invert the soil to a depth of 20+ cm, while rotary hoes disturb only the surface of the soil for weed control, leaving residue and cash crops (if present) in place.

The impacts of tillage can also be mitigated through use of cover crops, crop rotations, and soil building practices such as growing perennial forages. Drs. Caroline Halde (Université Laval) and Derek Lynch (Dalhousie University) are studying the net impacts of tillage within cropping systems on soil health on farms in Quebec through their project within Organic Science Cluster 3.

Some annual weeds rely on soil disturbance to stimulate germination; by tilling the soil, weed seeds are exposed to a flash of light, the seed coat is scratched to allow water penetration, or higher nitrate availability may trigger germination.

Tillage also disrupts the development of mycorrhizal networks that may establish associations with crop plants. The benefits of these associations, such as enhancing water and nutrient uptake, can therefore be lost.

Frequent cultivation within a growing season, even with low disturbance intensity, is a time-consuming and fuel intensive operation for organic farmers. Thus, organic farmers and researchers are still looking for ways to reduce tillage in cropping systems while minimizing weed pressure.

Winter cereal mulch after roller-crimper pass (Photo credit: Agriculture and Agri-Food Canada)

THE SEARCH FOR A NO-TILL ORGANIC SYSTEM

The most extreme form of no-till grain cropping would involve the development perennial cultivars of cereal crops. These perennial crops would eliminate the need for soil disturbance with planting, produce much more root biomass (sequestering carbon) and have a competitive advantage over annual weeds. This system of production would need to establish effective ways of minimizing problems with perennial weeds, deal with a potential dwindling crop stand over several years, and provide adequate nutrients to support an acceptable yield with good quality.

While progress is being made in these breeding and research programs in the U.S. (visit for example The Land Institute), there is limited research occurring in Canada in this production system, and it is still not close to becoming a commercially viable option.

Fall rye has long been recognized as a great option for providing fall/winter cover while also suppressing weeds through its competitiveness and allelopathic effects. Fall rye should be grown at least to heading stage to maximize its weed control benefits. Unfortunately, fall rye has limited value as a food crop and thus growing it to the heading stage results in a low value crop displacing a potentially high value crop.

Enter the Rodale Institute which has introduced paradigm-shifting work to the U.S. and Canada in reduced tillage production systems. They have found that a combination of rolling the crop down while simultaneously crimping, but not cutting the stem, will terminate the plant and leave a flat smooth surface to plant into.

The classic model is to plant soybeans or other pulses in wide rows into the rolled down rye, as the legumes will be able to provide their own nitrogen, while the rye mulch suppresses weeds and slows nitrogen cycling. The catch here is that fall rye must be rolled/crimped no earlier than the late flowering stage which, in many cooler parts of Canada, does not occur until early June. This substantially delays planting of the soybeans which requires heat and a long growing season.

There are two solutions to this: a) select a short season cultivar of soybean and take a considerable yield loss, or b) develop fall cover crops that can be rolled/crimped earlier, either through earlier flowering or without regrowth when crimping at an earlier stage.

> One of the key challenges is producing winter-hardy cultivars of these cover crops with the traits we desire.
>
> —Dr. Raja Ragaputhy (AAFC Lethbridge)

In any case, the cover crop must produce enough biomass to leave a mulch that suppresses weeds. Researchers involved with the Natural Systems Agriculture project at the University of Manitoba suggest that 6-8 t/ha of mulch biomass needs to be in place at the time of cash crop planting.

The challenges are not just limited to early flowering and good crimping characteristics. "One of the key challenges is producing winter-hardy cultivars of these cover crops with the traits we desire. If we have thin or patchy stands of rye or triticale, then weeds are likely to become a problem and the benefits of this system are lost." says Dr. Ragaputhy.

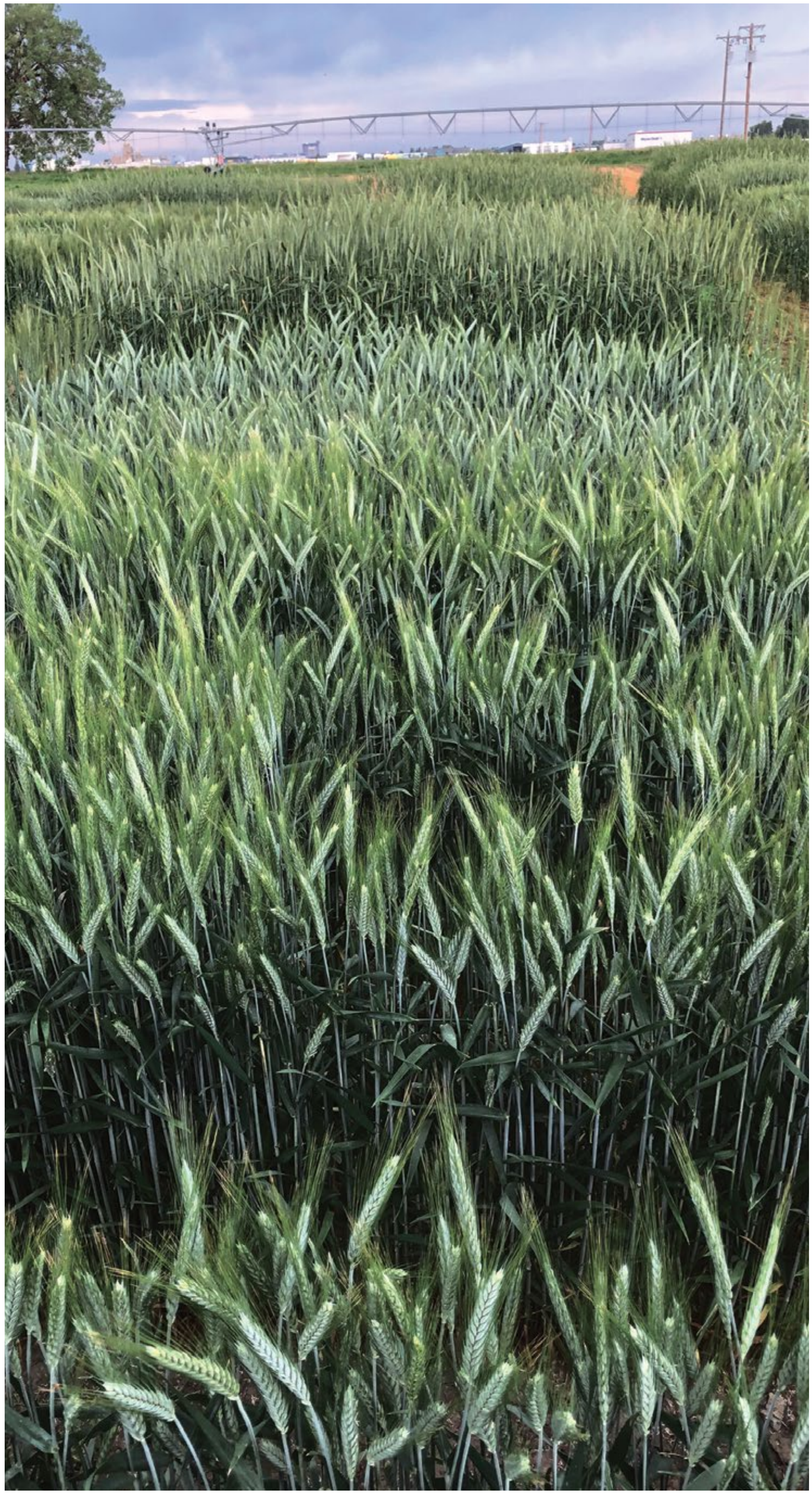
> Existing Canadian cultivars have not been developed for early flowering or roller crimping, but a survey of rye germplasm has shown that there is considerable genetic diversity that we can work with.
>
> —Dr. Jamie Larsen

The breeding program will emphasize early heading, thin stems, and low regrowth potential for better rolling and crimping as well.

"Existing Canadian cultivars have not been developed for early flowering or roller crimping, but a survey of rye germplasm has shown that there is considerable genetic diversity that we can work with." says Dr. Jamie Larsen.

The program will also evaluate triticale as an alternative to fall rye in this system. Winter triticale provides a number of similar benefits as fall rye and may even have some key advantages as explained by Dr. Larsen, "Triticale regularly produces more biomass per unit area than rye (in the prairies). Although the heading date of triticale is slightly later than rye, it is self-pollinated making variety height and flowering date more uniform. The inherent variability in open-pollinated rye, means that flowering can extend over a longer period making termination via roller crimping more difficult."

Organic agriculture sees a future with significantly reduced labour and energy inputs while controlling weeds and increasing soil carbon content. This future will be achieved through collaborations among AAFC, universities, and industry. There is a convergence of breeding programs specifically targeting organic production systems, for yield and pest resistance among our economic crops, and for weed suppression and biomass among our cover crops.



Winter cereal test plots at AAFC Lethbridge are being evaluated for their potential as a mulch in no-till organic farming systems. (Photo credit: AAFC)

Farmers Creating Seeds for Farmers

STEPHANIE HUGHES (PROGRAM MANAGER) AND AABIR DEY (DIRECTOR)
THE BAUTA FAMILY INITIATIVE ON CANADIAN SEED SECURITY

At the University of Alberta, Dr. Martin Entz leads farmers, researchers, and government officials through test plots of dozens of different populations of organic farmer-bred wheat developed through participatory plant breeding.

In the upland farming fields of northern Honduras, smallholder farmers plant dozens and dozens of dry bean varieties every season. Many of these varieties have been developed by Honduran farmers, for Honduran farmers.

One of the most popular bean varieties that are planted in these regions, is a variety called Macuzalito. Macuzalito is a red dry bean, with good yield, moderate earliness and disease tolerance, and excellent flavour and marketability. Macuzalito was developed in 2004, and it was the first variety created through participatory plant breeding in Honduras - a collaborative effort of 53 Honduran farmers and a network of non-profit organizations, and research institutions. Since then, 23 different bean varieties have been developed in collaboration with Honduran farmers.

In Canada, a network of over 75 growers are following in the footsteps of these Honduran farmers and trying to breed new varieties of wheat, oats, potatoes, peppers, and other vegetables for regional, organic farming conditions. These farmers are part of two national organic participatory plant breeding (PPB) programs supported by The Bauta Family Initiative on Canadian Seed Security (a program of SeedChange), the University of Manitoba, and the University of British Columbia. Focusing on crops that are important for Canadian food security, and those that can feasibly be grown for seed in Canada, the project focuses on wheat, oats, potatoes, bell peppers, and carrots, with plans to expand to more crops in the future.

PPB is an established international methodology that puts farmers in the driver's seat for variety development. The principles underpinning PPB are simple: i) farmers should lead the seed selection and development process, and ii) these processes should happen on farms to replicate the conditions in which these seeds will be grown.

However, PPB goes beyond the creation of new varieties for organic farms. It gives organic farmers more control and knowledge of the variety development process.

One of the farmers involved in the program in Manitoba for several years shared the following comment through a survey conducted in 2015: "I think that I am a better selector of plants and seeds. But what I think is really amazing is that there is support for farmers to select for traits that will benefit their own specific farm. Support for specificity of place is the direction in the future – the exact opposite of the current system that uses very few seed varieties regardless of place."

Investing in Canadian PPB is an investment in Canadian farmers, and it is a variety development model the Canadian agricultural community should embrace. This research is not only contributing to the development of varieties that are more suitable to organic systems, but also those that are more adaptive to the challenges of climate change.

Early evaluations of our program's farmer-selected wheat lines show that, when tested under organic management systems, the lines show strong early vigour, disease resistance, more micronutrients, and competitive yield performance when compared to conventionally bred cultivars.

Our collaborative efforts engage farmers as early-generation plant breeders and builds on-farm research capacity. Farmer consultations determine the parent lines for crosses of each crop. Seed from the resulting crop is distributed to farms across the country to be selected by farmers, according to their priorities and needs.

The process of seed selection by farmers is backed by a research and facilitation team at the University of Manitoba, the University of British Columbia, and The Bauta

Family Initiative, who provide coordination, seed distribution and cleaning, and agronomic support to participating farmers. In turn, the researchers gain valuable insights into regional plant breeding priorities for farmers. The performance of farmer-selected lines can then be studied in controlled environments, where comparisons to commercial varieties are carried out.

Farmers have always been the original plant breeders; however, the activity of plant breeding has shifted away from farmers over the past several decades. While this innovative program is novel in Canada, it is part of a robust PPB tradition of farmer-researcher partnerships all over the world. Farmers and researchers pioneered PPB in economically developing countries to help meet the needs of farmers cultivating land that differs significantly from the ideal conditions found on research stations, where many varieties are developed.

> I think that I am a better selector of plants and seeds. But what I think is really amazing is that there is support for farmers to select for traits that will benefit their own specific farm.
>
> —Farmer participatory breeder, Manitoba

Since 2013, The Bauta Family Initiative on Canadian Seed Security has been bringing together the best of what works from SeedChange's international partners such as PPB programs in Honduras and Nepal. With the cutting edge expertise of Canadian researchers and farmers, PPB is a promising research model for the future of Canadian agriculture.

The work is supported by The Bauta Family Initiative on Canadian Seed Security (a program of SeedChange) and Agriculture and Agri-Food Canada's Canadian Agricultural Partnerships Program. Focusing on crops that are important for Canadian food security and those that can feasibly be grown for seed in Canada, the project focuses on wheat, oats, potatoes through the University of Manitoba, and bell peppers, carrots, and other vegetables through the University of British Columbia.

Farmers who wish to be involved in this work, or to find out more about it, can contact the Regional Coordinator for The Bauta Family Initiative in their area. Staff contacts can be found online at www.seedsecurity.ca/team.

Organic Horticulture Research: Where Are We Now?

EMMA GELDART

ORGANIC AGRICULTURE CENTRE OF CANADA, DALHOUSIE UNIVERSITY

Organic greenhouses at the Guelph Center for Urban Organic Agriculture during Organic Science Cluster 2 (2013-2018)

As the demand for organic fruits and vegetables grows amongst Canadian consumers, organic farmwers are eager to improve their production practices. Researchers across the country have been committed to investigating best practices for organic fruit and vegetable growers. So far, the results have been promising.

While the Organic Clusters are cross-sectoral, significant research and development has emerged in the fruit and vegetable sector. The total 15-year OSC investment in organic horticulture research is $12.5 million. This is made up by funding from Agriculture and Agri-Food Canada (AAFC) and about ninety industry partners, who fund individual projects.

"With limited options for inputs in organic agriculture, the most common challenges facing farmers relate to managing soil fertility and dealing with pests," Dr. Hammermeister, director of OACC, explains. "Research activities under the Organic Science Cluster program relating to organic fruit and vegetable production have included sprout seed sanitation, weed management, biological control of insect pests, advanced greenhouse production, and participatory plant breeding programs."

Facilitated through OSC2, Dr. Martine Dorais (Agriculture and Agri-Food Canada- Université Laval), and Dr. Steeve Pépin (Université Laval) looked at fertility and lighting in greenhouses to improve vegetable yields. To meet the Canada Organic Standard, organic greenhouses must have a soil-based growing system. Fertility management in these systems can be a challenge. The work was co-funded by Les Serres Lefort, Inc., and many of the experiments were done onsite.

Dorais and Pépin studied multiple factors within the greenhouses, seeking the perfect combination to produce optimal yields. Fertilization management, the use of biostimulants, and LED intra-canopy lighting were investigated in their multi-year study. They found that there was no difference in nutrient availability or fruit quality when applying solid organic fertilizers every four weeks, compared to weekly application. The scientists determined that less frequent applications of amendments were sufficient due to the high background fertility and microorganisms in the soil. They also found that the use of biostimulants, wollastonite and vermicompost, helped increase crop resilience. Intra-canopy LED supplemental lighting was also found to be beneficial, increasing crop productivity by 20%. Tomato quality, colour, and firmness all improved with the intra-canopy lighting.

Current studies facilitated through OSC3 investigate pest management in horticulture crops. Spotted Wing Drosophila, a type of fruit fly, is a top priority for entomological and agricultural research programs because of its negative impact on global small fruit production. Dr. Juli Carrillo of the University of British Columbia, and Dr. Annabelle Firlej of the Institut de recherche et de développement en agroenvironment (IRDA), are taking a closer look at managing this common and damaging pest. With support from six different industry partners and four research institutions, including Terramera and the BC Berry Councils, their research looks at best practices for managing SWD. Organic berry producers currently have limited tools to manage SWD. Only a few pesticides are registered for organic use, and additional controls can be labour intensive and economically impractical. The objective of Dr. Carillo and Dr. Firlej's research project is to create multiple vectors of control, which will increase the likelihood of developing successful strategies for better SWD management. These results will also be of great benefit to non-organic growers.

Cucumber grown with LED intra-canopy lighting

Spotted Wing Drosophila is a top priority for entomological and agricultural research programs because of its negative impact on global small fruit production.

These cutting-edge projects are just a sample of the scope of the OSC program. The organic horticulture research and development goes far beyond pest management and greenhouse lighting. Dr. Hammermeister is enthusiastic about the impact of the Clusters.

"The Organic Science Clusters have not only produced results that are relevant and impactful to stakeholders within the organic sector, they have also helped to train dozens of students to become new professionals with agro-ecological training," he says.

Thirty-four horticulture projects have already been completed under OSC1 and 2, and ten are currently underway in OSC3. Organic fruit and vegetable producers can expect continued research and promising results in the years to come.

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Maximizing Soil Health in No-till Organic Production

DR. CAROLYN MARSHALL
DALHOUSIE UNIVERSITY

Surprise! We found no change in soil organic matter when comparing the incorporation of a green manure by full-inversion tillage versus a no-till method over the subsequent three years of an organic crop rotation. This result was surprising given the differences between the two systems, and the benefits of no-till systems shown in other research.

As part of Organic Science Cluster 2 (OSC2), Dr. Derek Lynch with myself, as a then PhD student, investigated how no-till termination of green manure impacts soil health.

We followed soil carbon in a four-year organic grain rotation. A mixture of hairy vetch and oat were used as a full season green manure, which was terminated either by full-inversion tillage, or using a crop roller as a no-till termination. In the no-till treatment, a heavy layer of mulch remained on the soil surface compared to the bare, highly disturbed soil of the tilled green manure.

Tillage in organic agriculture provides multiple services. It provides weed control and incorporates amendments, such as green manure residue or compost, which provide fertility to the following crop. However, tillage can be degrading to soil, resulting in loss of organic matter. It has also been shown to decrease microbial biomass and enzyme activity. This has led to criticism of organic agriculture for being degrading to soil health.

No-till or minimum till agriculture has been adopted as a best soil management practice. It has found success in conventional systems by building organic matter and reducing erosion. Minimizing tillage is one of the three pillars of conservation agriculture supported by the Food and Agriculture Organization of the United Nations, and one of the five core principles of regenerative agriculture supported by a new initiative from General Mills.

However, caution should be exercised in applying the results of research done in conventional production systems to organic agriculture. Organic and conventional systems often look very different. Many research studies comparing soil health in organic versus conventional systems shows no detrimental effect or even a slight improvement in the organic systems regardless of tillage levels.

This is not the only research to have shown soil health benefits under organic agriculture when tillage is used. A possible explanation could be the organic matter being added in organic systems, such as the green manure biomass used in the above study. This could provide a 'buffer' against the detrimental effects of tillage, by creating larger pools of soil carbon, and making the soil more resilient to disturbance.

I would also point out that there are two other pillars to conservation agriculture that organic agriculture does very well; using diverse crop rotations and keeping the soil covered, whether that's with a cover crop or just some weeds! Soil health is not held up by just one pillar.

There is a new and growing body of research questioning some of the claims made about no-till agriculture. Flaws in measuring, such as not accounting for changes in bulk density caused by tillage, could be leading to over estimation of soil carbon stocks under no-till management. The shallow sampling depth of many studies also means we are not seeing the full picture. Carbon at deeper soil depths can form a large percentage of soil carbon stocks, and doesn't necessarily have the same response to tillage as surface soil carbon.

While full adoption of no-till management in organic production may not be the final answer on soil health in organic production, there are other benefits to reducing tillage, such as reduced fuel costs. There are also many options for reducing soil disturbance without becoming fully no-till, such as moving to chisel till, which research has shown has less impact on soil degradation.

Current research funded by Organic Science Cluster 3 (OSC3) continues this theme and will add more insight into the impacts of tillage in organic production. Drs. Derek Lynch and Caroline Halde are investigating how tillage intensity impacts soil carbon and soil health on organic farms in Quebec as part of Activity 27: Soil health in organic tillage-based systems.

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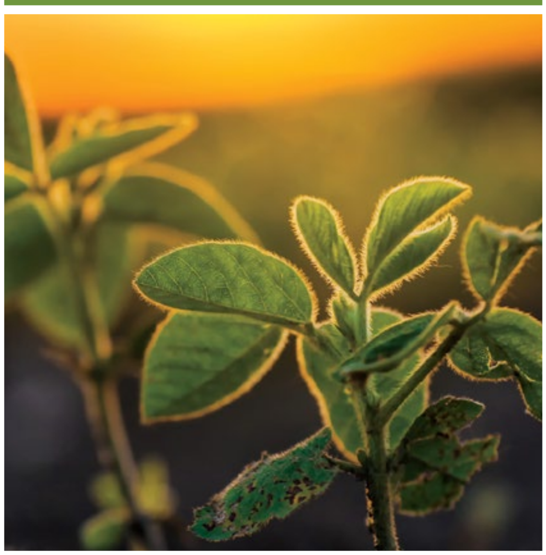

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