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Plant Gene Resources of Canada (PGRC) marked its 50th anniversary on October 1st, 2020

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On October 1, 2020 it was exactly 50 years since Agriculture and Agri-Food Canada (AAFC) formally established a genebank on that date in 1970. Plant Gene Resources of Canada (PGRC) started in Ottawa with staff consisting of Roland Loiselle as Plant Genetic Resources Officer and two technical support members. Since then, PGRC has functioned as the Canadian national genebank for plant genetic resources for food and agriculture. The collection developed a focus on cereals and their crop wild relatives and grew to more than 110,000 accessions. In 1998, PGRC moved its main location for seed germplasm to the AAFC Research and Development Centre in Saskatoon, Saskatchewan. Two other Centres of AAFC became involved in the national Canadian plant germplasm system: The Canadian Clonal Genebank (CCGB) located in Harrow, Ontario, and the Canadian Potato Genetic Resources (CPGR) located in Fredericton, New Brunswick.

PGRC had planned to mark its 50th anniversary with 150 invited participants during a two-day symposium and workshop to be held in August 2020 at Saskatoon. In May 2020, it became obvious that these plans had to be abandoned and instead a virtual event was held on October 1, 2020 (Figure 1).

The virtual event had a very diverse and compact agenda stretching over five hours. There were 16 invited speakers and they represented not only AAFC, but national genebanks, research, plant breeding and non-governmental organizations. They came from seven countries across the globe: Canada, USA, Russian Federation, Senegal, Sweden, Germany, Ghana and Italy. Some close cooperators of PGRC could not speak at the event but left contributions on the event website. Such contributions were made by the national genebanks of Australia and Ukraine. A total of 393 participants attended the virtual event. They included Canadians as well as participants of 26 other countries: Albania, Australia, Chile, China, Denmark, Estonia, Germany, India, Italy, Japan, Jordan, Mexico, Morocco, Netherlands, Norway, Portugal, Romania, Russia, Senegal, South Africa, Tanzania, Spain, Switzerland, Ukraine, United Kingdom and USA. Anissa Lybaert, Associate Director Canadian Biological Collections at AAFC, chaired the event which had four thematic sections.

***Figure 1**: Screen-shot made during the virtual event "50 Years Plant Gene Resources of Canada".*

Section 1 - Agriculture and Agri-Food Canada (AAFC) and Plant Gene Resources of Canada (PGRC)"

The first section was opened by Felicitas Katepa-Mupondwa who greeted the participants from the Saskatoon Research and Development Centre. She emphasized that PGRC works on many crops that were introduced to Canada and are now planted on land that has been inhabited by indigenous people for millennia. AAFC was further represented by Annette Gibbons, Javier Gracia-Garza and Benoit Girard who all confirmed the commitment of AAFC to the conservation and utilization of plant genetic resources for food and agriculture. They emphasized the necessity for a multilateral approach to the efforts of conservations and sustainable use of plant genetic resources in the national and international context by being inclusive and by supporting the International Treaty on Plant Genetic Resources for Food and Agriculture. It was clearly expressed that genetic resources preserved by PGRC were a national asset of global relevance. Furthermore, the importance of the process of reconciliation with indigenous people was articulated and how that relates to plant genetic resources they have used and continue to use.

Following these departmental presentations, Michèle Marcotte provided context by explaining the role of AAFC's Science and Technology Branch Biodiversity and Bioresources Sector Strategy. This strategy guides the work at several AAFC Research and Development Centres that maintain

genebanks for plant, animal, fungal, microbial and plant virus collections, as well as the work of the large AAFC reference collections including specimens of herbaria, insects and invertebrates. The Canadian Biological Collections Division, headed by Anissa Lybaert, oversees the operation of many of these collections.

In Brad Fraleigh's presentation, he explained that initiating a national genebank in Canada was an outcome of active participation by Canadians in the "*FAO – IBP* Conference on Exploration, Utilization and Conservation of Plant Gene Resources" held in Rome in 1967. The term "plant genetic resources" was coined at this meeting. Many countries realized then that the genetic diversity of cultivated plants was indeed a resource that needed enhanced efforts to ensure its conservation for plant breeding and established genebanks. He elaborated how engaged Canada was from the very beginning at the FAO Commission on Genetic Resources and reported the critical role Canada had in negotiating the International Treaty on Plant Genetic Resources for Food and Agriculture which entered into force in 2004.

Axel Diederichsen, curator of PGRC, spoke about the major efforts made by PGRC in Saskatoon since 1998 in regeneration, characterization and evaluation of large parts of the PGRC collections. This was often done in close cooperation with plant breeders and pathologists at the University of Saskatchewan. During the last 20 years, PGRC annually distributed about 6000 accessions to clients in 67 countries supporting research, plant breeding and education. About 75% of the request were by Canadian clients. The major impact of dedicated support staff and student help was emphasized. He also pointed at the enormous importance of fruit genetic resources native to Canada, and how these plants relate to indigenous people and reconciliation efforts with these groups.

The final presentation in this section was done by Benoit Bizimungu from the Canadian Potato Genetic Resources. He gave an overview of the in vitro conservation methods, and various characterization and evaluation methods of the more than 180 clones of potato germplasm preserved in Fredericton by the Canadian Potato Genetic Resources as part of the national genebank network.

Section 2 - Genebanks and plant genetic resources

In this section, four national genebanks presented their activities, sometimes with linkages to the Canadian PGRC. First, Igor Loskutov shared historic insights in the past and present work of the famous N.I. Vavilov Institute for Plant Genetic Resources in St. Petersburg, Russia. He reported that N.I Vavilov visited Canada twice and elaborated how important international collaboration across continents had already been in the end of the 19th century. He pointed at examples where such cooperation is still strong between the two countries, for example in oats.

Peter Bretting from the US then explained the large and well-functioning National Plant Germplasm System of the Agricultural Research Service at the United States Department of Agriculture. In recent years, it annually supplied about 250,000 germplasm samples to clients of which 30% were outside the US. The importance of training future genebank staff was emphasized by him and associated initiatives were explained.

Fernando De La Torre Sanchez introduced the

Mexican genebank and described the results of close interaction with indigenous and local communities. This is particularly important in Mexico when it comes to plant genetic resources. An example is the so-called *milpa* system. This intercropping system includes many species. Only three of them, maize, bean and squash form the corresponding intercropping known as the three sister crops in Canada and the US. The cooperation among Mexico, the US and Canada in genetic resources was also explained.

Lise Lykke Steffensen from the regional genebank of the five Nordic Countries Denmark, Finland, Iceland, Norway and Sweden provided a presentation in the form of a professionally done video recording. In this video, she spoke about how important it is to preserve genetic resources for marginal production areas with specific environments as they can be found in the Nordic countries and which are shared across the circumpolar region of the world.

Finally, Cheikh Alassane Fall shared the achievements that have been made in Senegal in the diversification of agriculture through plant breeding and pointed at the challenges that exist in the *ex situ* conservation of plant genetic resources.

Section 3 - International context for plant genetic resources for food and agriculture

Three key international organizations were represented in this section. Kent Nnadozie, Secretary of the International Treaty on Plant Genetic Resources, explained that plant genetic resources for food and agriculture are a global public good at the heart of the Plant Treaty. He pointed at the interdependency among countries and at the Multilateral System for Access and Benefit-sharing as a key element of the Treaty.

Stefano Diulgheroff from the Secretariat of the Commission on Genetic Resources at FAO illustrated how genebanks and their *ex situ* conservation relates to the Sustainable Development Goals of the United Nations. He also pointed at challenges that occur for genebanks in maintaining collections that were assembled without sufficient planning for their conservation.

Hannes Dempewolf from the Crop Diversity Trust named three global pillars for the world's plant genetic resources for food and agriculture. For the first pillar, he described the importance of the genebanks within the International Agricultural Research Centres which are part of the Treaty's MLS. Annually, they distribute about 72,000 germplasm accessions to many countries. The relevance of national genebanks as a second pillar is evident through their proximity to users within a country. The Svalbard Global Seed Vault was presented as the third pillar in the global efforts of *ex situ* conservations by offering safe storage for security back-up seed samples for genebanks from all over the world.

Section 4 - Work with plant genetic resources for food and agriculture

Canadian partners that have interacted numerous times with PGRC in recent years presented their activities. Yong-Bi Fu from AAFC explained which wide variety of crops and crop wild relatives he has investigated using molecular methods. He elaborated on the long term perspectives and challenges for the future of genebanks.

Katy Navabi gave a presentation on the mission of the still young organization DivSeek International Network. This organization has a secretariat in Canada and started a series of freely accessible on-line seminars. DivSeek aims at strengthening links between modern genotyping and phenotyping initiatives on one side, and the needs of genebanks and plant breeders or other genebank clients on the other side.

Randy Kutcher from the University of Saskatchewan showed that large germplasm screenings for disease resistance based on field observations remain an essential tool to detect and utilize relevant genetic diversity. He has conducted major evaluations of the PGRC genebank collections of wheat, oat and flax.

Helen Booker from the University of Guelph gave examples of using PGRC germplasm in a flax breeding program starting from a core collection and using classical and molecular methods as well as screenings for chemical seed qualities.

The final presenter was Jane Rabinowicz from Seed Change / Sème l'avenir Canada. She explained that each farm is a genebank. She showed progress that has been made in diversification and new initiatives in participatory plant breeding over the last 40 years in 12 countries and since 2012 also in Canada. She pointed at the great importance to have fruitful cooperation between the formal sector such as national genebanks or research at universities and the informal non-governmental sector including civil society organizations.

Despite a loaded program there was room for discussion and questions were answered during breaks and at the end. The event allowed PGRC to invite many engaged speakers and an interested audience that all shared the enthusiasm that comes from working with such a fascinating and important matter as the genetic diversity of our cultivated plants.

A conference website with additional presentations that where sent from the Ukrainian National Centre for Plant Genetic Resources at Kharkiv and from the Australian National Genebank System can be accessed here: https://collab-ext.agr.gc.ca/sites/si-si/PGRC-RPC/SitePages/Home.aspx. For a password to access to this website please contact Kelsey Morrison (Kelsey.morrison@agr.gc.ca).
The recordings of all presentations are also accessible here:

Section 1:
https://www.youtube.com/watch?v=3LHlOt8yabY&feature=emb_logo

Sections 2 and 3:
https://www.youtube.com/watch?v=AZoTE8vjuPM&feature=emb_logo

Section 4:
https://www.youtube.com/watch?v=HVZwpUvcWLI&feature=emb_logo

Acknowledgements
The well prepared contributions of all speakers made this a great event. All went smoothly due to very professional support by many AAFC and PGRC colleagues with special efforts made by Kelsey Morrison and Erl Svendsen.

Heritage Potatoes - Our story

Harold Gill and Annie Martin - Rigaud, Quebec

It is February 14th, and the temperature has been in the mid minus 20's °C or roughly 5 below zero °F.

Since early January, and like many of you, my wife Annie and I are once again under (Covid) restrictions, and curfew. This is the new reality we all live. It's been a test of love for many families and yes, we're getting used to each other and, our home is large enough for us to exist side by side. Indeed we each have a floor we could live on if it ever came to that. Our love for the outdoors keeps us sane and healthy and where we are located we are surrounded by a lovely growth of maple forest which our neighbor uses to produce syrup each spring. We are blessed. A little outdoor enjoyment, be it cross country skiing or snow shoeing, and before we know it, spring will be here. Garden planning is also a sure fired, feel-good recipe to distract from the pandemic, and our long cold Canadian winter.

Our interest in potatoes, or more specifically heritage potatoes, grew from reading a Small Farms Canada article in the winter of 2018-19. At the end of the article, I had spotted a small invitation from Agriculture and Agri-Food Canada's potato gene bank program to participate in a continuing potato gene study. It was mid-winter (like now), freezing cold (like now), and all we were thinking about was our garden (like now). So, I wrote to them for more information.

Our emails were answered quickly and personally, and we were offered a choice of tubers or seed crop, to plant in late spring/early summer. The specific four heritage clones we chose were not singled out for any reason other than a little research of our own on both taste and colour. The varieties of tubers we chose were Slovenian, Banana, German Butterball and Congo. They all have unique flavours and friends from other countries have shared their recipes for several traditional potato dishes.
We cut up and planted 12 little potatoes in mid-June 2019, and cared for them as children do with their first seed experiments (Figure 1). Seeing and understanding how plants grow is a miracle at any age (Figure 2). This case was no exception. Keeping the plants happy produces a good harvest and we watched the plants emerge, the leaves unfold and reach up, and then develop their beautiful flowers. From our harvest, we put aside enough to plant again last summer. The potato garden expanded, and produced close to100 pounds. In itself that's a decent return from 12 potatoes.

2021 is year three for our potato field. I say 'field 'but understand our 'field 'is 400 sf. What we call our 'farm', is more a mid-sized sub-urban lot quickly undergoing a horticultural upheaval as more and more lawn and grass is replaced with gardens of veggies and sustainable plantings (Figure 1). In my wife's words, "grass is overrated".

Neither of us ever grew potatoes before, but we have embraced our new discovery and continue to learn and improve. We learned our planted rows really should have some additional space

for the plants to grow into, as well as for us to work in. We learned that enjoying our harvest can start right after the potato plant commences flowering. For this summer, we have constructed a fifty gallon compost tea maker, we will be watering all our plantings using water that we have processed through a mix of ready compost that we believe should contribute to suitable microhabitats for microfauna and microorganisms. That along with the plants natural development should compete against pathogens, and enrich the soil. It's all new and it's all wonderful. We have set our hopes for good future results. Our veggies are really for us and our families, yet the enjoyment of harvesting our own production comes full circle with our goals of sustainability.

We're still enjoying our harvest immensely. I store the crop in our unheated garage, in large aired Tupperware in burlap and resting on pine shavings. Ah the life of a potato. Of course they have no idea of their destiny. (More going into my soup this afternoon).

Annie is in her third and last year now of online courses leading to a horticulture certificate. At the same time she's following a two year program in farm management. Currently, she's studying while I write this little article and maybe later this afternoon we'll head out for ski through the woods. Then home to dream of gardens.

Figure 1: Establishment of home garden trial

Figure 2: Crop growth

Figure 3: Potato harvest

Heritage potato varieties grown at the Upper Canada Village living history museum

Phil Hosick, Lead Horticulturalist, Morrisburg, Ontario

Whether it be the tantalizing aroma of homefries wafting from Louck's summer kitchen, the golden crispy potato cakes sizzling in the bake-oven at the modest tenant farm, or the purple marbles of roasted perfection, served to the Fall Fair dignitaries at Cook's Tavern, the *humble spud*, contributes heartily to the historical ambience of Upper Canada Village in Morrisburg Ontario.

Julian Whittam, Coordinator of Interpretation at the village stresses the importance and relevance of our gardens and field crops to the visiting public.

> *"In the case of a museum like Upper Canada Village, its mandate to preserve and present the heritage of Eastern Ontario extends past material history such as antiques and original buildings to include living matter. Even if some of the items in our living collection are the descendants of a genitor from the 19th century, they have the same status as physical artefacts which are a unique item which has survived through time. This is true for our horticultural collections that reproduce vegetatively, including our heritage tubers and potatoes. Though there are special challenges associated with managing living collections in museums, the benefits of contributing to the preservation of heritage plants and animals and being able to educate and inform the public about them make it a worth-while endeavour."*

The village has been growing Forty Fold, Early Rose and Garnet Chili potatoes for many years (Fig.1 &2) . The potatoes grown are utilized in the domestic unit cooking demonstrations on site, using recipes and cooking practices from 1866, the year the village portrays. Time-period-correct crops, help to produce authentic cuisine. The ladies swear that the modern varieties are lacking compared to some of these old gems.

Garnet Chili potatoes were first bred in Utica, New York, by the Reverend Chauncy E. Goodrich, who obtained Chilean seed stock in an effort to produce a strain somewhat resistant to the global blight of the late 1840's. This small round pink potato was to become the forefather of most of the varieties grown in the nineteenth century.

One of these descendants was the Early Rose, introduced by B.K. Bliss & Sons of New York in 1861. The American Agriculturist (April 1870, 123) said it very plainly: *"We have seen nothing equal to Early Rose for garden culture."*

In April 2016, we requested a few tubers of additional heirloom varieties that the National Potato Gene Resources repository in Fredericton had on offer. The repository provides in-vitro plantlets and mini-tubers for breeding, research and heritage preservation. As a historical village/living museum we fall under research, training and heritage preservation. We grow historic varieties for the public to see the genetic diversity and horticultural practices involved in growing a replication garden of 150 years ago.

We received mini-tubers of: Irish Cains Rocks, Irish Cobbler, Pink Fir Apple, Angela Mahoneys Blue and Lumpers. In addition there were tiny plantlets of Skerry Blue growing in test tubes.

Figure 1: The potato patch at Louck's Garden

The Irish varieties, while they may or may not have been grown in our area are a great segue for discussion with visitors on the Potato Famine and the resulting tide of Irish emigrants who arrived on Canadian soil to start their lives anew in the fertile lands of Upper Canada.
All of the new acquisitions flourished and we were able to get a large enough sample of each to grow a short row at the village in our heirloom gardens the following season. Since then we have been keeping our best seed potatoes of each variety and replanting each spring. These demonstrate the varieties to the public who come to admire and learn about heirloom gardens.

Figure 2: Phil Hosick tending the taters at Dressmaker's Vegetable Garden.

Visitors love to see the difference in the plant growth and variety of flower colours. Harvesting day is always a great day for the public to witness what actually has been growing under those tops all season. They especially love the wonderful odd shapes and colours, and the diversity from our modern day varieties. Picture the wonder in a child's eyes, as they tug on a plant and plentiful tubers come to light! As well we display during our fall fair days, a peck of representative tubers of each variety (Fig. 3). These in turn are replanted the following spring.

Figure 3: Fall Fair tent, setting up potatoes for display and competition.

We rely heavily on hand written diaries to provide documentation for what is appropriate for inclusion and display within our village. Over the past winter, research of primary documents has yielded more concrete evidence of the importance of the potato crop in early Ontario history.

Usually local diaries are very spare in their detail. For example "*planted potatoes today*" seems a typical terse entry. However during transcription of the Scottish farmer, John Ferguson's diaries, 1871-1880, held in trust by the Rural Diaries Archive at the University of Guelph, the following wonderful entry comes to light:

> *"SATURDAY, May 18, 1872 Was hauling manure from horse stable yard and spreading in potato drills. Planted ½ bushel of each Early White & Early Goodrich, 2½ bush. of Early Rose, 3½ bush. Gleasons, and 5 bush. of Garnet Chilis, total 12 bush. in 15 drills 42 rods long, the potatoes were all cut into two or more pieces before planting."* John Ferguson, diarist, Brampton, Ontario

Later, the following entry:

> *Wednesday, May 3, 1876. Spent forenoon at job of planting potatoes, putting 10 bush "Early Rose" & 1/2 bush "Garnet Chili" on 2/3 of an acre. Plowed them in….*

A second diarist, whose diary is also available at RDA, U of G, Benjamin Reesor, a Mennonite farmer from Markham, Ontario records the following:

> *Oct 10, 1873 - Dug Potatoes in turnip field they were planted the 27th & 28th days of June. The Harrison & Garnet Chili kinds with a very fine crop*

A few years later:

> *Oct 22, 1877 Took in Chili Potatoes 48 bags*

> *Oct 24, 1877 G. finished drawing sheep dung on west side of spring wheat stubble then we took in Rose Potatoes 20 Bags*

It is so gratifying to find specific varieties listed and cultivation practices and techniques so clearly set out.

We have ordered a few more old varieties for the village for spring of 2021, and are so looking forward to adding them to our living artefacts in the horticultural collections. These include: Prince Albert, Burbank, White Rose, Green Mountain, Black Mignion (The Cup), Early Ohio, Yam, Myatt's Ashleaf and Beauty of Hebron. These are all varieties which hail from the Confederation timeframe, and most have received mention in either diaries or seed catalogues of the era and area.

Thank you to the National Potato Gene Resources' contribution to our living history museum. We look forward with great anticipation to our expanded offering of varieties, the interpretive value they will provide and the stories they will generate.

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https://ruraldiaries.lib.uoguelph.ca/home

Ferguson, John Harrington, Dairies 1868-1883, Chinguacousy, Brampton, Ontario, Scottish Farmer, *This Licensed Material is provided by the Archives of Ontario in addition to Peel Art Gallery, Museum and Archives.*

Reesor, Benjamin, Diaries 1871-1911, Markham, Ontario, Mennonite Farmer, *diaries held at Markham Museum.*

Exploring the hidden agronomic and quality traits of mutagenized diploid potato genetic resources

Bourlaye Fofana and Ashok Somalraju, Charlottetown Research and Development Centre, Agriculture and Agri-Food Canada

We have developed a pre-breeding diploid potato germplasm collection with increased genetic variability through a chemical mutagenesis approach, with as an ultimate goal of use in breeding programs and understanding plant metabolic and biological processes. Genetic variations in plant germplasm are critical to plant breeding and genetic conservation programs. These variations known as mutations occur naturally at a slow pace during plant evolution in the environment. When the natural variations are limited in breeding materials, plant geneticists mimic natural evolution by inducing changes in the genetic code using physical or chemical agents. After domestication, current potato cultivars have been developed using relatively limited genetic pool. As a consequence, the cultivated potato has a narrow genetic diversity despite its large and complex genetic make-up, making the genetic studies tedious. In contrast, a high genetic diversity remains in the secondary gene pool of wild species related to cultivated potatoes. Most of these wild relative species have a smaller genome size, having only half size of the cultivated potato's genome. Genetically, wild diploid potato species are easy to work with and can be used in breeding to develop normal cultivated potato and also be grown on their own as potato varieties. However, while wild potato species may carry good agronomic and disease resistance characteristics, they can also contain anti-nutrition factors, difficult to remove through conventional crossing.

After the mutagenesis experiments with the chemical agent (EMS), a large variation in the plant, flower, and tuber characteristics of treated plants was observed compared with their non-treated counterparts. Along the normal plant characteristics, abnormal plant characteristics including twisted stems, partial and/or complete yellow of leaves and stems, as well as weak-stemmed plants with vine-like growth habit were also observed. Changes in the flower color, tuber color, shape, size and yield characteristics were also found in the treated potatoes as compared to the untreated potatoes, evidencing putative induced mutations (Fig 1 and 2).

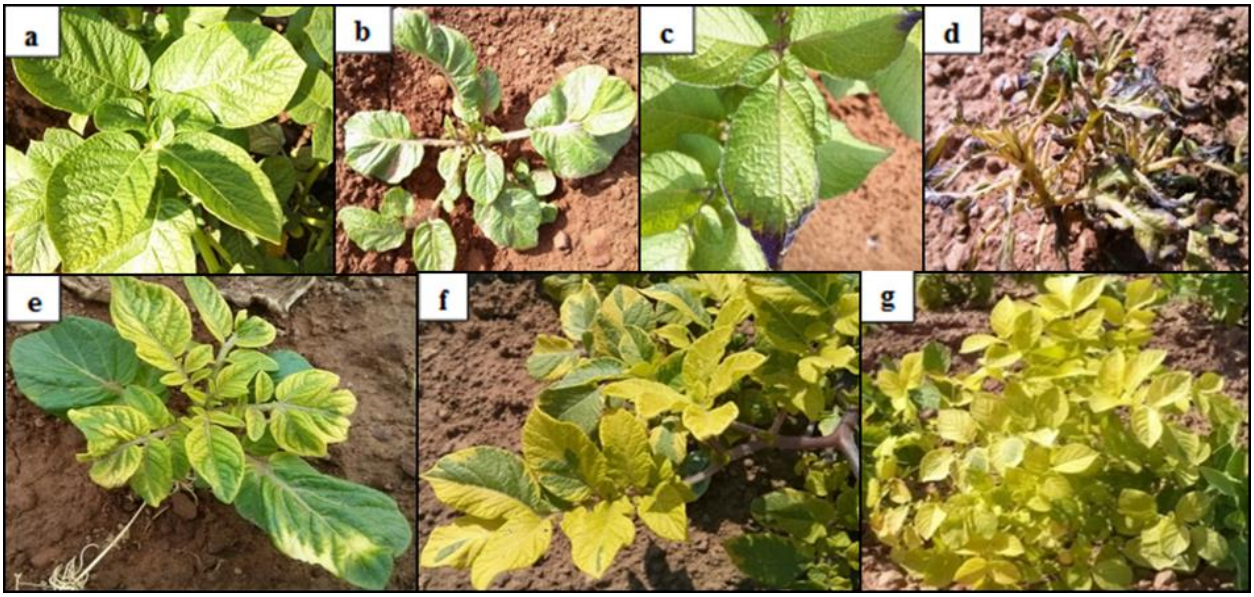

Figure 1. Leaf morpho-variants observed in the EMS-treated lines as observed in the field. ***(a)*** *normal leaf;* ***(b)*** *incomplete (half) leaf;* ***(c)*** *purple leaf tip with needle shape;* ***(d)*** *deformed leaf with only midrib;* ***(e, f)*** *partially chlorotic mutants;* ***(g)*** *completely chlorotic mutant.*

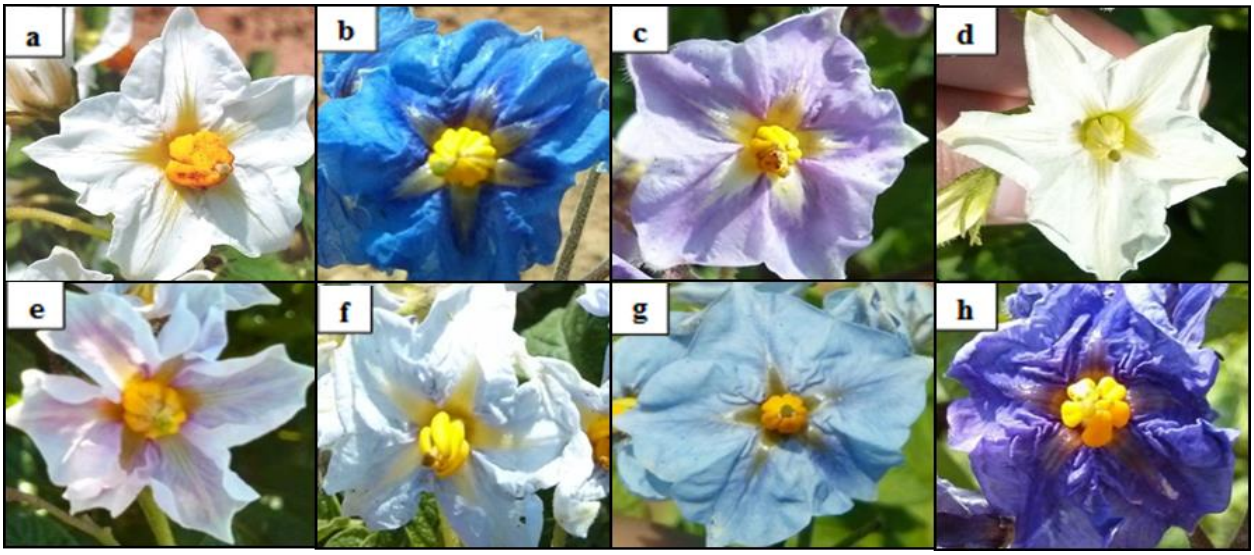

Figure 2. Floral color variations observed between non-EMS treated controls (a, b, c) and EMS-treated potato lines (a-h) in the field.

Figure 3. Variations in tuber shape, color and interior quality of 12 diploid mutants and 2 wild type lines in comparison with cultivars Norland, Goldrush and Russet Burbank.

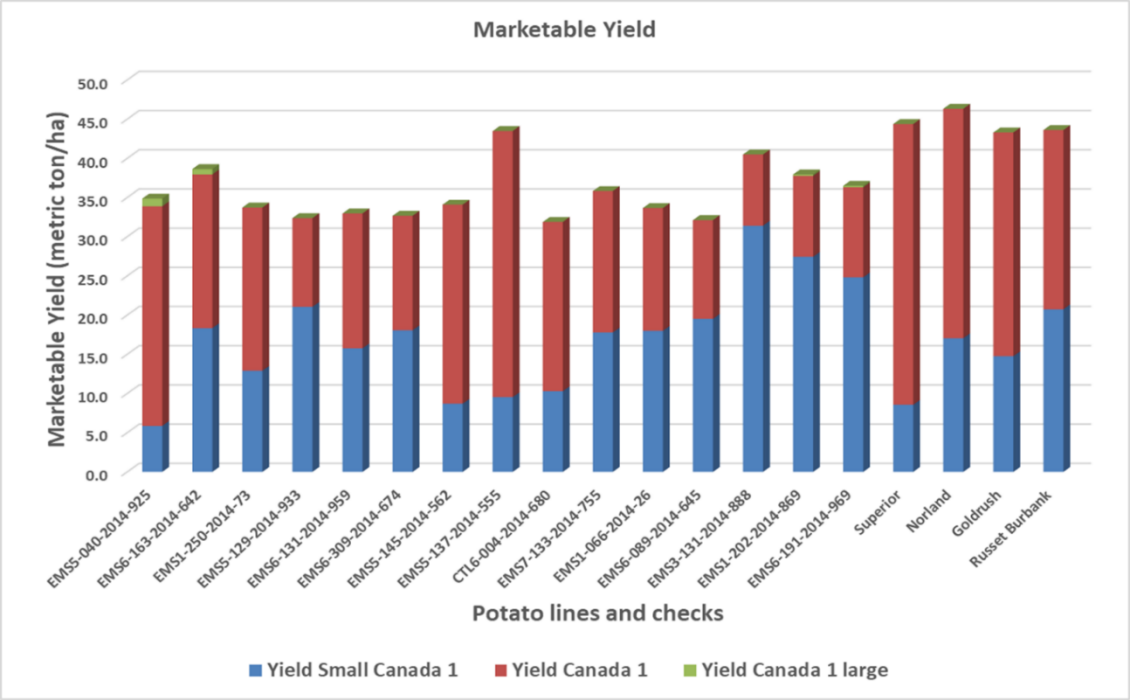

Figure 4. Variations of yield potential and grading characteristics of 14 diploid mutants and 1 non-mutant diploid line in comparison with cultivars Superior, Norland, Goldrush and Russet Burbank.

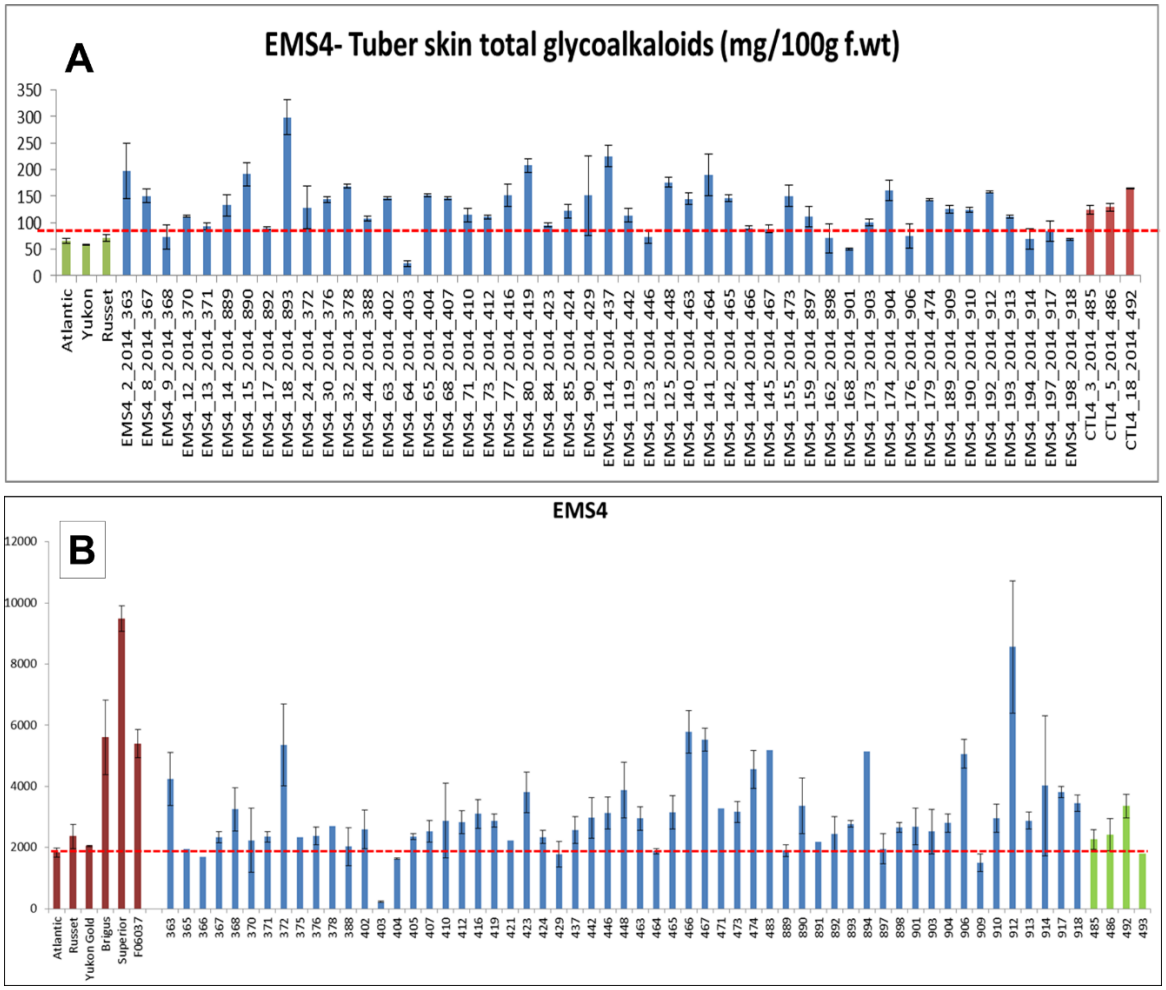

Figure 5. Variations in SGA (A) and Asparagine (B) contents. Subset of 48 and 57 putative mutant lines among the 246 mutagenized potato lines phenotyped are shown, respectively for SGA and Asparagine.

Several lines have been selected and undergone through yield trial and quality evaluation and many promising lines showed consistent good quality and yield potential over years (Fig 3, 4).

Steroidal glycoalkaloids (SGAs) and acrylamide formation in potato products can be hazards to humans when their contents are higher than tolerated thresholds. We characterized 246 putative mutant lines for SGA and Asparagine, an amino acid serving as precursor for acrylamide formation. A total of 13% and 14% of the lines showed Asparagine and SGA contents, respectively, compared to the non-mutant controls and commercial varieties (Fig 5).

Based on the partial genotypic and phenotypic data, the collection represents a premium genetic resource carrying high allelic variants and many hidden agronomic traits yet to be fully evaluated and uncover for cultivar development.

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Gene discovery and editing to enhance multiple disease resistance in potato

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Atoms evolved into genes and produced single cell organisms about three billion years ago. Since then they have evolved into several organisms, including plants and microbial pathogens. Humans have been domesticating plants for more than 10 000 years and over years they have selected the best survivors and high yielding plants for further cultivation. The discovery of hybridization, as occurs in nature, enabled humans to produce dwarf plants that facilitated mechanical harvest and plant response to fertilizers to increase yields; these led to the first green revolution, with large scale farms and monoculture, which in turn led to epidemics of several diseases. The changing climate leads to the appearance of new pathogens. Diseases significantly reduce yield and some require regular application of fungicides to manage them, leading to environmental degradation. The marker assisted selection (MAS) in breeding has produced hundreds of potato cultivars. Some of the cultivars have high yields but low in disease resistance, which either at advanced stage of breeding or after several years of cultivation are eliminated.

Innate immune response in plants: Innate immunity in plants, or disease resistance, is complex and controlled by hierarchies of genes, including regulatory genes, such as immune receptors, MAP kinase, phytohormone biosynthetic, transcription factors that regulate the downstream protein coding and metabolite biosynthetic genes, which produce proteins and metabolites that are antimicrobial or deposited to reinforce the walls of cells around the pathogen invaded cell(s), thus containing the pathogen spread to a small spot rather than a blight (http://dx.doi.org/10.1080/07352689.2016.1148980; http://dx.doi.org/10.1071/FP16028). Based on forward genetics, using resistant genotypes developed by AAFC or others and commercial cultivars, following mock and pathogen inoculation, we have identified several resistance related metabolites (http://DOI.org/10.1007/s11105-017-1043-1; http://doi.org/10.1007/s11105-013-0665-1; https://doi.org/10.1071/FP14177). Based on reverse genetics, we have silenced (VIGS) some of these metabolite biosynthetic genes and proved the mechanisms of resistance

(http://DOI.org/10.1093/jxb/erv434; http://doi.org/10.1007/s10142-013-0358-8). In wheat we have proved that the R genes to biosynthesize even one metabolite are not localized in one QTL or chromosome, rather they are often in different chromosomes; a marker may or may not be associated with the respective trait (https://doi.org/10.1016/j.plantsci.2021.110820).

Genetic Diversity and Composition of R genes in potato cultivars: Potato is diploid, however, most of the cultivars grown in North America are autotetraploids. Potato genome has been sequenced but functions of most of these genes are still elusive. Some of these germplasm sources with high resistance to different pathogens, along with commercial cultivars, can be used to identify new genes and their functions can be proved based on OMICs approach; these if mutated in a cultivar can be repaired based on genome editing (http://dx.doi.org/10.1071/FP16028).

Genetic diversity occurs due to sexual reproduction, mutation and gene transfer by microbes. Currently we grow more than 200 cultivars but after several years of cultivation mutations and gene transfer may render these cultivars less suitable for cultivation (https://doi.org/10.1071/FP19327). Though there is a lot of genetic diversity among cultivars grown, each cultivar does not have sufficient genetic composition to resist a specific or a group of pathogens. So, it is important to enhance the genetic composition of cultivars. Breeding, based on MAS, is good to combine several plant traits into one cultivar, but specific traits such as disease resistance lacking in a cultivar can only be improved based on genome editing.

Genome Editing: Genome editing, a precision breeding tool, can complement MAS in breeding to enhance genetic composition of cultivars to obtain the required level of multiple disease resistance (https://doi.org/10.1007/s00299-020-02629-6). The susceptible commercial cultivars also have most of the resistance genes as in a resistant genotype, but some may be mutated (http://DOI.org/10.1080/07060661.2016.1199597). These mutated gene segments can be either biosynthesized or obtained from a resistant cultivar or germplasm as a donor to replace based on genome editing to increase the genetic composition for disease resistance in a cultivar (https://www.youtube.com/watch?v=g66HAglQEpY).

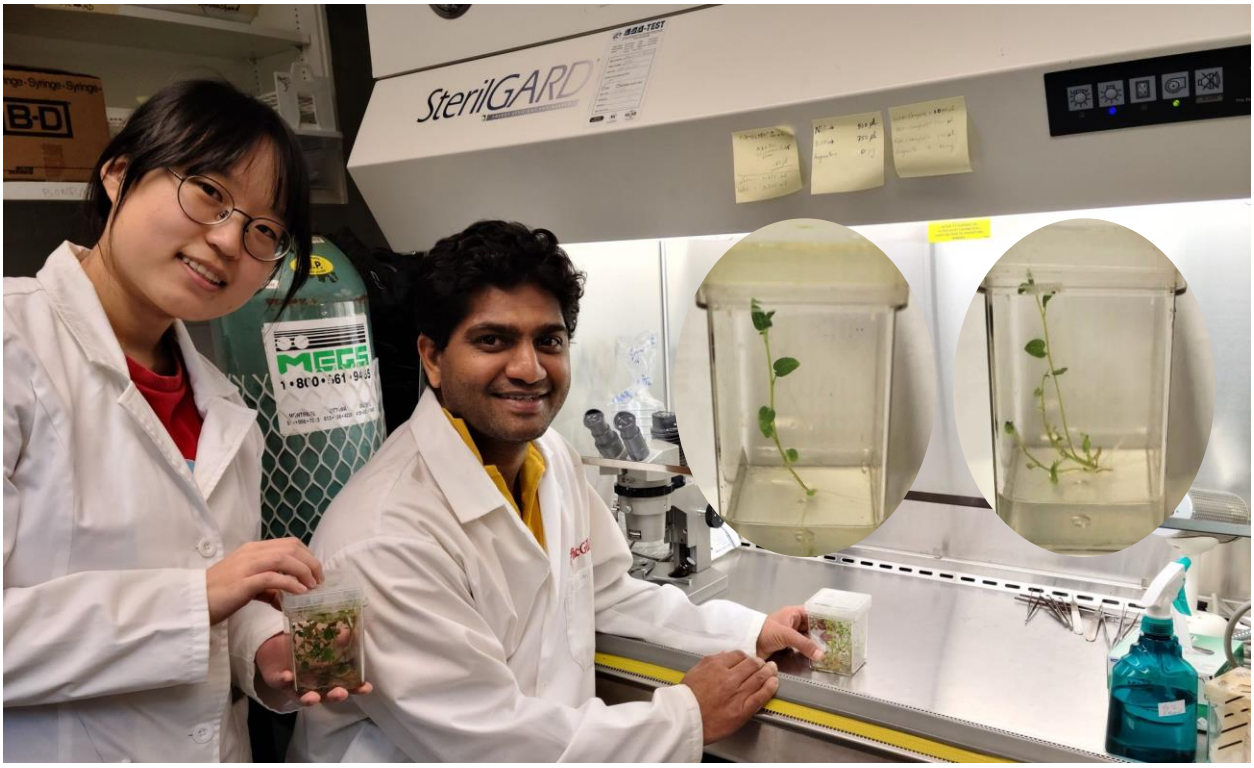


Figure. 1: Post-Doctoral researcher Dr. Niranjan Hegde (L) and BSc honors student Miss Dongeun Go (R) working on potato genome editing, at Dr. Ajjamada Kushalappa's lab, McGill University.

Annual Report 2020

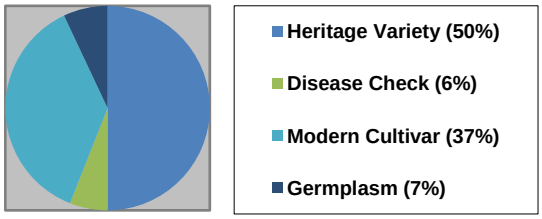
The Canadian Potato Genetic Resources

Sylvia Soucy, Tyler Nugent and Benoit Bizimungu

The Collection

1. Holdings

- The Canadian Potato Genetic Resources is a node of Plant Gene Resources Canada and holds 187 clones within its genebank. Of this total, 187 are maintained *in vitro*, and 31 accessions were grown for tuber production at our Benton Ridge Potato Breeding Substation, Benton, New Brunswick. A full listing of accessions may be found in the request form. The following chart illustrates the types of clones in each category.



2. New Accessions

- There were no new accessions added to the genebank in 2020.

3. Evaluations

- Field trials at the Fredericton Research and Development Centre were deferred to 2021 due to the covid-19 pandemic situation. The evaluation plots are useful for germplasm characterization, identity verification, evaluation of key traits, and photographs documentation.

4. Management

- Passport data for 167 PGR accessions is available online at the Genetic Resources Information Network-Canadian Version (GRIN-CA). GRIN-CA may be accessed through the Plant Gene Resources of Canada website. New information will be posted on the new GRIN- GLOBAL portal.

- Regulatory disease testing was completed by Agricultural Certification Services located in Fredericton, NB in December. All new and existing *in vitro* accessions are tested on a five year rotational cycle. Fifty-two clones were grown from tissue culture in the potato breeding greenhouse and tested for: PVA, PLRV, PotLV, PVS, PVX, PVY, and PSTV. All clones tested negative for associated diseases. In addition, all accessions in the grow out period were tested for tuber borne BRR disease. All samples tested negative for associated diseases. Extra mini-tubers are available for distribution in the spring of 2021.

- All *in vitro* clones were tested in-house once during 2020 for bacterial and fungal contamination using Potato Dextrose Broth and Richardson's Broth. All clones currently in the Genebank are negative for bacterial and fungal contaminants.

- A total of 989 micro-tubers were harvested from 185 of the genebank accessions in 2020. Approximately half of the micro-tubers were sent to AAFC Plant Gene Resources of Canada, located in Saskatoon, SK, in September 2020 as safety duplication back-up. The viability of the collection is protected by this remote storage location arrangement. Dallas Kessler, AAFC Plant Gene Resources of Canada, continues to monitor the micro-tubers in Saskatoon. The remaining micro-tubers are stored at the Fredericton Potato Research and Development Centre.

5. Distribution

- Accessions within Canadian Potato Gene Resources fall under The International Treaty on Plant Genetic Resources for Food and Agriculture, which requires recipients to sign a Standard Material Transfer Agreement (SMTA), before any material is transferred. Any and all material shall only be utilized, or conserved for training/education, research, and breeding purposes for food and agriculture. All request forms include the SMTA. For more information and assistance in determining whether your plans fall into this agreement visit: The International Treaty on Plant Genetic Resources website. By accepting shipment of the requested material, recipients accept all terms and conditions of the SMTA. Recipients names will be submitted to the Governing Body of the Treaty.
- Three requests for 43 clones were received in 2020. Clonal distribution categories are as follows:
- 43 clones of *in vitro* plantlets, zero clones of field grown tubers, and zero clones of greenhouse grown mini-tubers. 'Red Gold' was the most requested accession in 2020.

Distribution of Clones by Purpose – 2020

Purpose of Request	Number of requests	Number of units	Number of Accessions	*In vitro* plantlets	Field tubers	Mini-tubers
Research	3	43	16	43	0	0
Teaching or Demonstration	0	0	0	0	0	0
Conservation	0	0	0	0	0	0
Total	**3**	**43**	**16**	**0**	**0**	**0**

Requests by Destination – 2020

Destination	Number of requests
New Brunswick	1
Quebec	1
Ontario	1
Total	**3**

Five-Year Compilation of Clone Distribution for Potato Gene Resources 2016-2020

Year	Research	Education	Conservation	Total	Field tubers or mini-tubers	*In vitro* plantlets	Total
2016	23	4	5	32	826	195	1021
2017	15	3	0	18	414	98	512
2018	20	3	0	23	335	50	385
2019	19	3	0	22	244	234	478
2020	3	0	0	3	0	43	43
Total	**91**	**14**	**12**	**117**	**2179**	**763**	**2439**

Repository Items of Interest

Communication

- In addition to the requests for clones, many requests for information about the genebank, the availability of clones, clone descriptions and pedigrees, and techniques for handling *in vitro* material were received throughout 2020.
- The annual Potato Gene Resources newsletter has a distribution list of approximately 300 recipients.
- The current newsletter and several back issues may be accessed on the Weekly Checklist of Government of Canada Publications.

Meetings and Miscellaneous Information

- The fifth addition of Agri-Science Days on Biodiversity, Bio-resources and Collections were held on January 20-21, 2021 at the Ottawa Research and Development Centre and was attended via videoconference.

- The 2020 meeting of the NRSP-6 project's Technical Advisory Committee (TAC) was held virtually on August 18, 2020. Dr. Benoit Bizimungu (Curator of the Canadian Potato Genetic Resources) presented a report on the utilization of accessions imported from the US Potato Genebank by Canadian researchers. Information on the genebank and minutes of TAC meetings can be found at the USDA Potato Genebank website.

Donor Agreement

- Donors wishing to provide plant material to Agriculture and Agri-Food Canada (AAFC) for the purpose of research, conservation and distribution by Plant Gene Resources of Canada must now complete a "donor agreement". Decisions on accepting material into the Canadian Potato genebank are up to the discretion of the curator, Dr. Benoit Bizimungu (Benoit.Bizimungu@agr.gc.ca).

Visitors

- There were no visitors at the Potato Genebank at the Fredericton Research and Development Centre in 2020.

Fredericton Research and Development Centre Website

- The Fredericton Research and Development Centre is custodian of the Canadian Potato Genetic Resources. The Fredericton Research and Development Centre website offers an overview of the Centre's mandate, resources and achievements along with research studies being conducted at the Centre and the staff associated with those studies.

Plant Gene Resources of Canada

- Plant Gene Resources of Canada (PGRC), the national Canadian genebank, preserves, characterizes and distributes plant genetic resources for food and agriculture. PGRC is based on collaboration between AAFC Research Centres and people dedicated to preserving the genetic diversity of crop plants and their wild relatives. PGRC plays a significant part of AAFC's commitment to the Canadian Biodiversity Strategy in response to the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources.

- The Plant Gene Resources of Canada (PGRC) website includes information on the PGRC multi-nodal system of germplasm conservation in Canada and allows searching for germplasm information on the Genetic Resources Information Network-Canadian version (GRIN-CA).

The Genebank and the Seed Potato System

- The Canadian Potato Genetic Resources provides *in vitro* plantlets and greenhouse or field tubers for breeding, research and heritage preservation. While extensively tested for freedom from disease, the plantlets and tubers distributed are produced outside the Canadian Seed Certification System and are not eligible for certification.

- The Canadian Seed Potato Certification System operates under the *Seeds Act* and its regulations. Certification begins with tested plantlets established *in vitro* in a facility accredited for this task by the Canadian Food Inspection Agency (CFIA). The plantlets are used to produce greenhouse tubers which then go to the field in a limited generation system, at each step meeting strict standards specified in the regulations. More information on potato seed certification can be found at the CFIA website.

Help us Reduce our Paper Usage

The Potato Gene Resources Newsletter is available as an electronic version. If you are still receiving a paper version and wish to receive future Newsletters by e-mail, in pdf (portable document format), please send your e-mail address to: Sylvia.Soucy@agr.gc.ca. We will continue to send the printed Newsletter to those who do not ask to receive it electronically. Maintaining contact with you is important.

Curator's Note

Due to the Covid-19 pandemic situation, the Canadian Potato Genebank Facility is temporarily closed to all visitors as of March 2020. Genebank laboratory activities related to germplasm preservation continue as usual. Field evaluation trials initially planned for 2020 were deferred to 2021. While germplasm requests, donations and shipments continue to be processed, a delay is expected due to the limited physical presence at the genebank facility and uncertainty about the shipment timelines.

We will continue to monitor the situation carefully and we will be providing updates should there be any further changes to our services.

TO RECEIVE THE NEWSLETTER, PLEASE CONTACT:

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