Project title: Evaluation of selection methods and efficacy in on-farm breeding of organic wheat and oat varieties

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A farmer-breeder from the participatory plant breeding program conducting selections on wheat crosses on his organic farm in Manitoba, Canada. (Photo: Helen Jensen)

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1. Project Summary: Provide a brief summary of your project—its purpose, your research questions, and a short description of your main findings.

Participatory plant breeding (PPB), is internationally recognized as a methodology that allows farmers and researchers to work collaboratively to develop crop varieties adapted to local environments and suited to the needs of farmers. Very few PPB programs currently exist in Canada, however. In 2013, in collaboration with the University of Manitoba, our non-profit organization initiated the first ever national PPB program to develop wheat and oat varieties in collaboration with organic farmers. Agronomic data from the program indicates good performance and high yield of the farmer-selected varieties under organic conditions. However, we do not have a strong set of data relating to farmer selection practices and the context within which the PPB work is situated. In this project, we conducted open interviews with 19 participating organic farmers to address the following research questions: (1) What methods do farms deploy to select desired crop traits and why are these methods used? (2) What strengths and limitations do program participants face and how do these relate to either farm-scale systems or industry structure in Canada? (3) How do participating farmers perceive the function of PPB in the broader context of organic agriculture development? Findings include that many farmers practice positive selection at harvest time, with some farmers also conducting a form of "natural selection". Strengths and limitations of PPB were identified at the level of the farm, the program, and the industry. In particular, farmers identified the networks and collaboration derived from the program to be as important as the actual materials developed. They also expressed the need for consistent institutional funding for PPB and organic agronomy. These findings will allow us to improve the structure and methodologies of existing and new PPB programs to the benefit of all stakeholders leading to increased adoption of PPB by a broader range of organic farmers. It also identifies a number of clearly articulated needs identified by organic farmers in Canada that can be advocated for at the policy and funding level.

2. Introduction:

The availability of crop varieties that are well-suited to both organic practices and regional environmental conditions is increasingly recognized as crucial for the continued success of organic agriculture, including the ability of organic farmers to minimize environmental impacts and adapt to environmental change (Lammerts van Bueren et al., 2011, 2018; Entz et al., 2018). Organic crops face challenges from weeds, pests, and diseases in increasingly complex ways, and they must contend with a biologically-mediated nutrient supply system. The adaptations required for varieties to thrive under these conditions lead to a specific organic ideotype which is distinct from conditions in conventional farming that require regular inputs of chemical fertilizers and pesticides (Lammerts van Bueren et al., 2011).

In Canada, few organic farmers have access to varieties developed for regional organic farming practices. Breeding for organic agriculture can reduce farmers' reliance on both conventional and organic inputs by creating varieties that tolerate more stressful conditions (Murphy et al., 2005). These circumstances make early-generation selection under organic management a useful organic crop breeding approach (Kirk et al., 2012; Wiebe et al., 2017). In a country as vast and regionally diverse as Canada, in terms of both growing environments and market access, breeding approaches will require regionally embedded knowledge to address the needs of local organic farmers most effectively.

Participatory plant breeding (PPB) pairs farmers' knowledge with the skills of formal plant breeders to bolster the insights generated by each partner. Increasingly recognized as an effective approach, PPB

develops better varieties for organic farming systems by not only using the environmental conditions of working organic farms as selection environments, but also incorporating farmers' needs and observations into the selection criteria (Adam, 2005; Murphy et al., 2005; Almekinders, Thiele, & Danial, 2006; Dawson et al., 2011; Shelton & Tracy, 2016). A participatory, collaborative breeding model could also prove better suited to sustain locally adapted varieties through *in situ* agricultural biodiversity conservation, which considers the social and cultural dimensions that go into variety development (Graddy, 2013). However, the regulatory context in Canada is not well adapted to facilitate such social and cultural dimensions found in PPB. This presents a challenge to realizing the full potential of the PPB program in Canada.

PPB is already an established methodology in farming contexts outside of Canada. For example, in Nepal, a group of farmers have collaborated with non-profit organizations leading to the development of regionally-adapted strains of 'Pokhareli Jethobodu' rice. In Honduras, local participatory research collectives (FIPAH) supported farmer-led development of 26 different varieties of beans (Halewood et al., 2007). Other examples can be found in countries with regulatory environments and market dynamics similar to Canada. In the Netherlands, farmers successfully engaged in participatory breeding of potato cultivars in collaboration with researchers and industry partners for many years (Almekinders et al., 2014). In the U.S., participatory research projects such as the Northern Organic Vegetable Improvement Collaborative and the Bread Lab at Washington State University developed high-performing varieties of peppers, cucumbers, tomatoes, sweet corn, and wheat (Brzozowksi, Holdsworth & Mazourek, 2016; Myers, McKenzie & Voorrips, 2012; Shelton & Tracy, 2016; Murphy et al., 2005; Healy & Dawson, 2019).

A "common garden" evaluation of wheat varieties from the PPB program at the University of Alberta, 2021. (Photo: @talonstokesphotography)

A participatory model for crop breeding offers an approach for farmers marginalized by conventional production systems to overcome institutional barriers (Rossi et al., 2019). PPB approaches differ from conventional plant breeding methods which rely on centralized research stations to produce varieties that are only tested in limited growing environments (Dawson et al., 2011; Entz et al., 2015; Shelton & Tracy, 2016). This approach reconfigures several unequal power relations that farmers face, providing them with

a more advantageous position in managing their enterprise (Fuchs & Glaab, 2011; Carstensen & Schmidt, 2016). PPB also allows for the local knowledge of farmers to be incorporated in variety development. Local knowledge, and specifically the hands-on knowledge-through-practice developed by these farmers, involves skills "integrating hand, brain, and heart" towards building knowledge (Kloppenburg, 1991). Forms of embodied knowledge, known as 'heuristics', are skills and knowledge adopted more through habitual practice in the workplace than what is made through strictly economic thinking (Findlater et al., 2019). Providing farmers with a strategy to overcome certain challenges of agricultural management and giving voice to their embodied knowledge could allow them to implement more sustainable farming methods and business practices, including low-input systems that lessen environmental impacts.

Beyond strictly monetary benefits, PPB provides additional benefits that contribute to the economic bottom line. Many studies exist describing the benefits of social capital and knowledge sharing associated with PPB and ecological farming (Pretty, 2003; Hellin et al., 2008; Thomas et al., 2020). Working together among farmers and with researchers is assumed to improve the human capital of participating farmers. If work is done in groups or if information sharing is encouraged, then social capital, defined as the ability of farmers to work together and share information, may be increased as well (Johnson et al., 2001). Social capital can contribute to production efficiencies, market access, and sustainable practice; contributing to overall economic benefits overtime.

The literature on PPB as a methodology is diverse, agricultural and technical publications focus on breeding methods, designs, and agronomic results, while social science research and related publications focus on values reflected in methodology and the social implications for farming communities (Ceccarelli & Grando, 2019). However, PPB remains under-researched in Canada from both a physical and social science perspective, as the methodology is only beginning to be formally implemented and adopted by Canadian farmers, and agricultural practitioners.

This document is a summary of the findings from a study evaluating the methodology and perspectives of participants in the PPB program managed at the University of Manitoba and facilitated through The Bauta Family Initiative on Canadian Seed Security (BFICSS). It is intended to provide a focused analysis of participants' selection methods, perspectives of program challenges and opportunities, and motivations for taking part in the program. This will serve to better position and implicate future configurations of participatory breeding and public research programs in the country.

In this study, we will address the following three research questions: (1) What methods do farms deploy to select desired crop traits and why are these methods used? (2) What strengths and limitations do program participants face and how do these relate to either farm-scale systems or industry structure in Canada? (3) How do participating farmers perceive the function of PPB in the broader context of organic agriculture development?

3. Objectives Statement:

There were three objectives outlined in our project proposal. The three research questions framed in the previous section were formulated to structure the research in support these objectives.

<u>Objective 1: To assess the outcomes of selection methods that organic farmers chose to use while they were engaged in the PPB program for wheat and oats.</u>

This objective was framed so that preferences in selection methods could be situated within regional contexts, farming environments, market orientation, scale of the farm, and other influential factors. There were no major changes to this objective but we did note that, a strength of the PPB program is that it allows farmers to define their own selection goals and these differ from farm to farm. It is therefore difficult to define a representative metric of "selection efficacy", that is consistent among growers. In the future we will, cross-reference our work with the results of a separate research project at the University of Manitoba where researchers are evaluating the agronomic performance of the PPB varieties in a number of environments under organic conditions.

Objective 2: To contribute to the knowledge and development of exemplary practices of participatory plant breeding for organic agriculture in Canada.

Meeting this objective involves drawing conclusions about the nature of the PPB program created by farmers, SeedChange, and the University of Manitoba. This established network has also created a "system" within which we can evaluate the methods used and determine how to improve them. This evaluation must consider both strengths and limitations of this PPB project, drawing on interviews with the farmers as well as other key stakeholders such as plant breeders who have contributed to the program, as well as others in the value chain. This objective was maintained with no major changes.

Objective 3: To accelerate the adoption of participatory plant breeding projects among organic farmers in Canada

The rationale of this objective is that if we can clearly demonstrate how the program is adapted to a broad range of organic farming contexts and how it will help organic farmers improve their farming systems and access varieties adapted to their needs, we can attract a much larger number of organic farmers who would potentially have a strong interest in participating in a PPB program. This objective was maintained, and this work will allow us to advise on best practices for PPB program design. Due to the COVID19 pandemic, most field programs were scaled back and it was not possible to recruit many new PPB participants during the time frame of this grant. We anticipate that the results of this work will allow us to recruit new participants in PPB programs post-pandemic.

An additional objective was added to this project in the Fall of 2020, which was to "Map value chains farmers use to sell the products of the varieties they have developed using participatory plant breeding methods". Assessing the value chains that farmers can access or develop to create value from the PPB varieties provided an appropriate follow-up to the initial project work which focused on the earlier stages of the process of conducting participatory plant breeding. We allocated a remaining amount of grant money to cover stipends to support a second series of interviews. These interviews focused specifically on the use farmers are making of the materials on their farm and how they contribute to local value chains. A total of 10 interviews were conducted from May-August of 2021 and the analysis of the results is still underway. As a final output of the work, value chain maps will be produced and shared with producers and other stakeholders. This work was conducted by Murray Jowett (M.Sc. candidate), working under the supervision of Iain Davidson-Hunt at the University of Manitoba.

The COVID19 pandemic made changes to the implementation of the project but not to the overall objectives. Field days were also cancelled in the summer and fall of 2020, and resumed in a very limited capacity in 2021. Communication with farmers was ensured through other means, including the PPB farm club webinars, and the Bauta Family Initiative PPB newsletter.

4. Materials and Methods:

Data for this report were gathered through open interviews with farmers who participated in multiple years of the PPB program, either current participants or in previous years. The BFICSS breeding program works with over 75 farmers across the country to implement a national organic participatory plant breeding program on wheat, oats, and potatoes. From this total, a sample size of 19 program participants were included in the study from all participating regions across Canada (breakdown of study composition by region provided in Table 1). Interviews were conducted by telephone from June - December 2020. Participants were selected through an open invitation (to all participants in the BFICSS program) inviting them to take part in the study. Participants were interviewed in an open interview format, semi-structured, that involved being prompted from a list of predetermined questions to explore their opinions on the function, challenges, and opportunities for PPB in a Canadian context. Questions for the interview process were developed in collaboration with Regional Coordinators of BFICSS. Participants were subject to ethical research guidelines in accordance with Carleton University Research Ethics Board A and provided a copy of their interview transcript after interviewing for reviewing and confirmation of transcription. All participants were given coded aliases to maintain confidentiality.

The occurrence of the COVID-19 pandemic in 2020 interrupted expected research methodologies from going forward as initially planned. Interviews were conducted over the phone with participants rather than in person on the participants respective farm, as was initially intended. This is considered to have not affected study results to a reasonable degree.

Table 1: Participant-Farmer demographic and information profiles.

Farmer ID	Region	Crops (in Study)	Crops (additional)	Acreage
BCFarmer_A	BC	Wheat	various fresh vegetables, potatoes	4
BCFarmer_B	BC	Wheat	cattle, hens, forage/silage, hay, share cropping,	20 grain (94 total)
PRFarmer_A	PR	Wheat, Oat	lentils, flax, cattle	4500
PRFarmer_B	PR	Wheat	flax, hemp, alfalfa seed, peas, mustard	4500
PRFarmer_C	PR	Wheat	cattle, alfalfa, flax, rye	800 grain (2000 total)
PRFarmer_D	PR	Wheat	rye, oats, peas, flax, canola, soybeans, corn, sunflower	2400
PRFarmer_E	PR	Oat	wheat, cattle	130 grain (480 total)
PRFarmer_F	PR	Oat	hay, sunflower	145
PRFarmer_G	PR	Wheat	custom grazing, grain, oilseed, pulses	800
ONFarmer_A	ON	Wheat, Oat	potato, soybean, dry beans, chickens	90
ONFarmer_B	ON	Oats	wheat, barley, buckwheat, triticale, soft wheat, spelt	60
ONFarmer_C	ON	Wheat	NA	
ONFarmer_D	ON	Wheat, Oat	barley, white corn, red corn, dry beans	250
ONFarmer_E	ON	Oat	garlic	34
QCFarmer_A	QC	Wheat	maize, soybean, buckwheat, rye	
QCFarmer_B	QC	Wheat. Oat	NA	na
QCFarmer_C	QC	Wheat	sunflower, soybean	1500
QCFarmer_D	QC	Oat	wheat, maize, soy	240
MTFarmer_A	MT	Wheat, Oat	clover, soybeans, barley, field peas	500

The qualitative data set generated from interviews was imported into Nvivo analytical software and coded for key themes. The major analytical themes found in this study are addressed in greater detail in the following sections. Table 2. provides a basic overview of program participants by region and selection practices. Selection methods are based on either positive selection, negative selection, blended methods, or “natural selections. Positive selection involves targeting the desired individuals within a population for harvest and retaining them for downstream analysis and further stages in the breeding program. Negative selection is when several undesirable individuals within a population are removed, leaving those of interest untouched for cumulative harvest at the end of the season. Blended selection methods involve a combination of both positive and negative selection used during the same

selection season. The use of blended selections would depend on the desired trait(s) of interest in the trial, as well the specific timing that the selections are made. “Natural selections”, though not an official or documented term, is used in this study to describe a type of selection where growers leave their entire trial population in the field until harvest and depend on natural weather and environmental processes to eliminate or cull the weaker plants within the population. The perceived aim of this natural selection method is to select for genetic traits that are most well adapted to the environmental conditions they are grown, with the least human intervention possible.

Table 2: Farmer participation by region. High-level scan of preferred selection methods and selection/assessment timings for each region. Numbers in each column represent the number of farmers in that region that mentioned using that category of methods in their selections. Individual farmer feedback may fit more than one column).

Region	**Total**	Methods of Selection				Timing of Assessment/Selections					
		Positive (+ve)	Negative (-ve)	Blend (+ve/-ve)	"Natural Selection"	Heading	post-Heading	Harvest	Regular visits (1-2 wks)	After Rain Events	Whenever available
BC	**2**	2			1			2			1
Prairies	**7**	3	2	2	1		1	4	2		
Ontario	**5**	3		1	1		1	3		1	1
QC	**4**	1	1	1		1	2	1			
Maritimes	**1**					1	1	1			

Timing of assessment/selection was the time frame or schedule that the farmer followed to make their selections. Timing categories were determined *a posteriori* from interview feedback. The seasonal time frames used for selections were found to be heading, post-heading, at harvest, regular weekly visits, following storm events, or whenever the farmer had time available to visit the plots.

5. Project Results:

Research question 1) What methods do farms deploy to select desired crop traits and why are these methods used?

Selection Methods: PPB in Practice

Study participants were explicitly asked which crop traits they were selecting in their trials, the methods they used to select for desired traits, and how they chose the right time to make selections in the growing season accordingly. Results found are summarized in the following tables, with appendices included.

Results indicate that the majority of farmers in this study use positive selection methods and make these selections at harvest time. The second most popular selection window was at post-heading, which also coincided with those who made negative selections in their trials. Note that interviews from the Maritime farmer and one Quebec farmer did not address the specific question of selection methods used and therefore is expressed as a gap in the data of Table 2. Although only one farmer indicated

selecting timings after rain events, this was worth noting because Regional Coordinators of BFICCS were specifically interested in this relationship of selection practices and weather phenomena. Table 3. provides a more specific breakdown of selection practices by desired traits selected, including methods used, and timing. The most common traits sought after in selection were height (straw length), straw strength, and grain size; followed by yield, disease resistance, and weed competition as traits of secondary importance. Crop height (longer straw length) was selected dominantly through positive selection at harvest time once the crop had fully grown and set its grain. Straw Strength involved a mix of positive and negative selection. This trait was mostly assessed through lodging in the crop, where positive selection was made by assessing lodging at harvest and negative selection being done by removing fallen plants as lodging occurred during the season. Grain size was selected mostly at or close to harvest, though two farmers used negative selection for this trait around heading. Yield was mostly assessed at harvest, though one farmer made visual assessments of potential yield pre-harvest using positive selection. Disease resistance showed the highest prevalence of negative selections, usually coinciding with particular crop development stages such as tillering, heading, or grain filling. These selections involved removing infected individuals from the trial when signs of disease occurred. Other farmers used a positive selection approach by noting signs of disease at harvest. One farmer marked healthy individuals at heading and post-heading stages for positive selection later during harvest. Weed competition was noted by a few farmers as a desired selection trait and was assessed at or close to harvest as it is influenced by straw height and total leaf area. The trait of processing quality (threshing) is noteworthy as it applied specifically to oats where the metric for determining good threshing quality was the absence of hulls on the oats.

Table 3a: Specific breakdown of selection practices and timing by participants by region. pos = positive selection, neg = negative selection, nat = "natural selection", harv = harvest time, pre-harv = pre-harvest, hdg = heading, pre-hdg = pre-heading, pst-hdg = post-heading, stm evt = after storm event, cont. = continuous assessment throughout season

	Height, Vigor			Straw Strength			Grain Size			Yield		
Farmer ID	Selection	Method	Timing	Selection	Method	Timing	Selection	Method	Timing	Selection	Method	Timing
BCFarmer_A	yes	pos	hdg	-	-	-	yes	pos	harv	-	-	-
BCFarmer_B	-	-	-	yes	neg	pre-harv	yes	pos, neg	threshing	-	-	-
PRFarmer_A	yes	pos	harv	yes	pos	harv	yes	pos	harvest	yes	pos	harv
PRFarmer_B	yes	pos	harv	yes	pos	harv	-	-	-	-	-	-
PRFarmer_C	yes	pos	harv	-	-	-	-	-	-	-	-	-
PRFarmer_D	yes	pos	-	-	-	-	-	-	-	-	-	-
PRFarmer_E	yes	pos	pre-harv	-	-	-	yes	pos	pre-harv	yes	pos	harv
PRFarmer_F	yes	pos	harv	-	-	-	yes	pos	harv	-	-	-
PRFarmer_G	-	-	-	-	-	-	yes	-	-	-	-	-
ONFarmer_A	yes	neg, pos	pst-hdg, harv	yes	neg, nat*	cont.	yes	neg, pos	pst-hdg, harv	-	-	-
ONFarmer_B	-	-	-	yes	pos	harv	-	-	-	yes	pos	harv
ONFarmer_C	-	-	-	-	-	-	-	-	-	-	-	-
ONFarmer_D	yes	pos	-	yes	pos	stm evt	-	-	-	-	-	-
ONFarmer_E	yes	pos	-	-	-	-	-	-	-	-	-	-
QCFarmer_A	yes	pos	-	-	-	-	yes	pos	pst-hdg, harv	-	-	-
QCFarmer_B	-	-	-	-	-	-	-	-	-	-	-	-
QCFarmer_C	-	-	-	yes	neg	hdg	yes	neg, pos	hdg, harv	yes	pos	harv
QCFarmer_D	-	-	-	-	-	-	-	-	-	yes	neg	-
MTFarmer_A	yes	pos	pre-harv	yes	pos	pre-harv	-	-	-	yes	pos	pre-harv

Table 3b: Specific breakdown of selection practices and timing by participants by region. pos = positive selection, neg = negative selection, nat = "natural selection", harv = harvest time, pre-harv = pre-harvest, hdg = heading, pre-hdg = pre-heading, pst-hdg = post-heading, stm evt = after storm event, cont. = continuous assessment throughout season

	Disease Resistance			Weed Competition			Early Establishment			Maturity			Processing (threshing)		
Farmer ID	Selection	Method	Timing	Selection	Method	Timing	Selection	Method	Timing	Selection	Method	Timing	Selection	Method	Timing
BCFarmer_A	yes	-	hdg	-	-	-	-	-	-	-	-	-	-	-	-
BCFarmer_B	-	-	-	yes	-	-	-	-	-	yes	-	-	-	-	-
PRFarmer_A	yes	pos	harv	yes	pos	harv	-	-	-	-	-	-	-	-	-
PRFarmer_B	yes	pos	harv	yes	pos	harv	-	-	-	-	-	-	-	-	-
PRFarmer_C	-	-	-	yes	-	-	yes	-	-	-	-	-	-	-	-
PRFarmer_D	yes	neg	hdg	-	-	-	-	-	-	-	-	-	-	-	-
PRFarmer_E	-	-	-	yes	pos	pre-harv	-	-	-	-	-	-	-	-	-
PRFarmer_F	yes	pos	harv	-	-	-	-	-	-	yes*	-	-	-	-	-
PRFarmer_G	yes	neg	-	yes	-	-	-	-	-	-	-	-	-	-	-
ONFarmer_A	-	-	-	-	-	-	-	-	-	yes	nat*	harv	-	-	-
ONFarmer_B	-	-	-	-	-	-	-	-	-	-	-	-	yes	pos	harv
ONFarmer_C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ONFarmer_D	yes	pos	stm evt	-	-	-	-	-	-	yes*	pos	-	-	-	-
ONFarmer_E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QCFarmer_A	yes	pos	pst-hdg	-	-	-	-	-	-	-	-	-	-	-	-
QCFarmer_B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QCFarmer_C	yes	neg	harv	-	-	-	-	-	-	-	-	-	-	-	-
QCFarmer_D	yes	neg	-	yes	neg	-	-	-	-	-	-	-	-	-	-
MTFarmer_A	yes	pos	hdg, pst-hdg	-	-	-	-	-	-	-	-	-	-	-	-

Research Question 2) What strengths and limitations do program participants face and how do these relate to different scales of program integration?

Program Strengths

During the interview process, study participants were asked several questions to address their perceptions of the strengths and benefits that coincide after participating with the PPB program. Strengths here are defined as a situation, occurrence, or state of being that provides benefit or incentive for retention for the farmer. Categories for these perceived benefits were organized into scales of: Farm-level, Program-level, Industry-level. Further detail and insight into each category are provided below with interview quotations as examples:

Table 4: BFICSS PPB program strengths and limitations categorized by which scale they are most relevant. These scales were categorized into on-farm (farm-scale), program structure (program scale), and institutional (governmental and economic system-scale)

Scale of Integration	Strengths	Limitations
Farm-level	● Genetic Innovation and Seed System Resilience ● Stories and Branding for Seeds	● Scheduling Plot Assessments and Time Constraints ● Limited Utility of PPB Varieties Across Regions
Program-level	● Collaboration Among Farmers, Networking and Knowledge Sharing ● Collaboration With Universities, Providing Technical Research Capacities	● Lack of Capacity for Lab-based Assessments ● Multiple, Changing Points of Contact ● Limited Access to Appropriate Machinery
Industry-level	● Public Research for Public Benefit ● Farmer Empowerment to Make Decisions in Research	● Limitations to Growth Without PPB Varieties Registration ● Lack of Proper Governmental Support and Funding

Farm-level Strengths

Genetic Innovation and Seed System Resilience;

> The value of genetic improvement and building resilient seed varieties was a common theme across interviews. Some farmers saw this simply as creating genetically improved varieties for organic systems, while others saw an additional benefit of supporting genetic heritage for varieties that had fallen out of favour in conventional seed systems. The notion of genetic heritage was mentioned most in Ontario, with a few mentions as well coming from the Prairies. Of the 9 farmers that mentioned this theme, the following quotes were the most illustrative.

"one thing that happened is a lot of organic farmers went back and started trying to grow really old varieties, heritage varieties that are no longer registered, and they're successfully marketing those."

“Having varieties that we developed ourselves that work really well on our land, that we can save from year to year, and improve from year to year as well would be a huge part of our resilience in the whole system.”

"Why the hell are we breeding for specialization again when there's so much genetic material in the existing 5,000 named wheat varieties? Maybe we should be reintroducing those, restoring them, and bringing back that broad genetic resilience rather than specializing”

Stories and Branding for Seeds

> Only a few participants mentioned the value of the story created through a PPB developed variety. This relates to increased marketability for the grain in certain contexts, such as CSA baskets. This concept of building a story was applied more broadly to the participants’ farms as a whole than to just the grain variety itself. Of the 2 farmers that mentioned this theme, the following quote was the most illustrative.

"And also at the same time, have that story attached to it, that connection with the land and with the people and with the broader community is really important to all of our customers, bar none...In terms of having this farm be part of that broader community, it's entirely feasible. And in fact, it's now part of what we consider our farm."

Program-level Strengths

Collaboration Among Farmers, Networking and Knowledge Sharing

The most recurring opportunity and benefit from participation mentioned was inclusion in a collaborative network of other farmers alongside researchers. This network of mutual connection and communication facilitates knowledge sharing, as well as access to resources, sharing equipment, and seed stock. Often organic farmers feel isolated in their individual practices and at a lack of information and resources to approach issues found on-farm. This top, and how the PPB program works to overcome this barrier, was discussed across the majority of interviews in the study. Of the 13 farmers that mentioned this theme, the following quotes were the most illustrative.

"And then now, with this club that's been started up and we can all communicate on the webinar, and chat, and learn from each other. So I think that's another positive outcome of the whole program, is the network that's building between us producers."

"it's what happens when you get a group of farmers together, and researchers...It's a great opportunity to share ideas and to share our experiences and, ultimately, we're sharing those selections with each other."

"When you're out in the field by yourself, it's kind of a daunting task just to be there and kind of start to question, if all this work is really worth it? [Farm Clubs and webinars] validated the work that you're putting into it, to see how much it did affect other people."

The program also facilitates a cooperative model for research that helps distribute the costs and lower the risks for the research process. This also adds value to the varieties developed through the program from a marketing perspective (i.e. Developed in direct collaboration with Canadian grain farmers).

"It holds out to me the hope of a greater appreciation for farming done differently, for organic farming, for cooperative farming, for cooperative marketing, for cooperative branding, in a way that that we haven't seen for probably upwards of a generation now."

"Not only are we grateful for the research being done there, but also being able to phone somebody and say, "We have a really bad weed problem," which we do, "what are the various options?" It's been a bit of an extension service"

It's a huge hole. I've been so frustrated about this for years ..That has to be somebody, a person, not a website, that you can phone up and has fingers in all kinds of different pies and knowledge about other people who have knowledge who you can phone up... how do you control [pests] organically, whether it's particular weeds in grain crops, where can I get seed, and all those sorts of things."

<u>Collaboration With Universities, Providing Technical Research Capacities</u>

The access to university facilities, researchers, and technical capabilities allows farmers to try new approaches to farming and scale up the varieties of seed they are interested in growing or have crossed. Of the 11 farmers that mentioned this theme, the following quotes were the most illustrative.

"That's very important, we can't do that on our own. It's very difficult to do, most farmers don't have the ability to do it or the time. And then to actually increase the multiplication of any particular variety that we think is our preferred…That's a really big advantage."

"At no other point where I have had access to plant breeders who were willing to do crosses that we wanted. So, just that potential was amazing"

Related closely to university collaboration is access to leading edge agronomic advice that comes with close contact to university researchers. The advice and support received is not always limited to seeds or breeding alone, but on organic agriculture practices in general. The program in many interviews was compared to an agriculture extension service much needed in Canada.

"...anything, any opportunity to pose a problem to a researcher of any sort who has even half an hour to just scroll through some studies and see if there's something relevant is amazing"

“I think there's a real demand just for extension agronomy on organic farms, period. And then there's the whole demand for better genetics, and genetics that are selected and adapted for organic farms. So I think having agronomist to understand that and are supportive of that is very, very important. And certainly, that's the kind of support that we get from the University of Manitoba and Martin Entz program and his students and researchers who were working with him. So it's the foundation of really improvement of what we do here."

"I felt that they had a wealth of information that we were missing here. Most of our agronomists and our extension workers here, are either employed by chemical companies or fertilizer companies, that are giving advice on a different production model."

Industry-level Strengths

Public Research for Public Benefit

The PPB program is found to compensate, to a certain degree, the gap in public research for Canadian grain. Participants appreciate the transparency of the process and information found from their contribution. Of the 7 farmers that mentioned this theme, the following quotes were the most illustrative.

"what I liked about the public funding for plant breeding was that there wasn't necessarily a plant breeders rate premium that had to get paid, because the collective... All of the society of Canada paid for that whole process. For the betterment of the overall good of Canada."

“this is another reason why I feel honored to be included. Because no information gets out of the Ottawa Experimental Farm. I could go there with a question, and they couldn't care less about my question. It's all for research for a few big companies. It's got nothing to do with helping farmers.”

Participants felt that the research process of PPB addressed many more of their concerns as farmers than what would typically be addressed by research programs facilitated by government or industry. These other research led by government and industry are believed to prioritize seed company profits over the direct agronomic needs of farmers.

"que je souhaite obtenir de ce programme là c’est de prouver à l’industrie et prouver aux gens, aux décideurs, qu’on est capables, en tant que producteurs, de faire de la sélection et de produire nos propres semences sans avoir à être dépendants de l’industrie"

“So much of it has been corporatized and just become more for corporate profit interest rather than the public interest.”

Farmer Empowerment to Make Decisions in Research

The PPB program opens up and democratizes the scientific process in agriculture. Participants believed in the importance of including farmers directly in agricultural research of any kind, and felt empowered to bring forward their opinions and decisions in research. Of the 2 farmers that mentioned this theme, the following quotes were the most illustrative.

"I think it's really important to include farmers in any kind of research, because the work that's done on an experimental farm, or of a university owned little plot, that's all wonderful, but things look different when you're out in a great big field using big machinery."

"maybe the public plant breeders weren't making the same choices that farmers would, so I like this process of getting the farmers involved and we might get different results because of it."

" it wasn't like, "Oh, I'm a plant breeder. And you guys are just farmers." [Martin Entz] really genuinely believes and encourages farmer's participation because he believes that they have the most valuable input."

Program Limitations

Likewise in the interview process, study participants were asked several questions regarding their perspectives on challenges and barriers to growth faced by PPB and how these might hinder growth and adoption of the program. Limitations here are defined as a situation, occurrence, or state of being that limits the potential of participants to fully achieve their program goals. Limitations were again organized into scales of Farm-level, Program-level, Industry-level:

Farm-level Limitations

Scheduling Plot Assessments and Time Constraints

Time constraints and trade-off with other farm duties made it difficult to be able to make assessments at specific critical stages during the season. In particular this was mentioned in regard to assessing disease, maturity, and early emergence. These are typically traits that require negative selection. The additional time commitment on-top of farm duties was also believed to be responsible for lower participation rates among farmers. Of the 5 farmers that mentioned this theme, the following quotes were the most illustrative.

“… our farm was fairly large... We'd find that we kind of neglected paying a whole lot of attention to the plots and focused more of both of our attention to harvesting and the positive selection process rather than the negative selection process”

"And so it didn't necessarily get seeded at the exact right time, it didn't always necessarily get harvested at the exact right time."

Limited Utility of PPB Varieties Across Regions

There is some concern that PPB varieties will be too genetically restricted within particular region(s) of development. This relates to both restricted agronomic performance as well as the marketability of these varieties in the regions they perform best. This limitation was only mentioned as in the Prairies and BC. Of the 3 farmers that mentioned this theme, the following quotes were the most illustrative.

“The notion of trying to insert some of these selections and put a lot of time and effort into making them registered varieties on the prairies might make some sense, but is of no great interest to me on the west coast outside the main grain area.”

"I know there needs to be alternative systems where the control of seed is more democratic, but I still kind of think there needs to be a better way towards an industrial scale approach to cereal seed... I'm just still not sure if that individual farm approach makes sense on the push for cereals."

Additionally, within the region of Quebec, the varieties used in the PPB trail are not found to perform as well when compared to the typical varieties these farmers are using in their production. Of the 2 farmers that mentioned this theme, the following quotes were the most illustrative.

"ça n'a pas sorti côté rendement comme j'espérais...Je ne sais pas ; c'était de la semence qui venait pas mal de l'ouest canadien, je pense. Peut-être que c'est moins bien adapté pour le climat que l'on a ici"

""Le rendement, par contre, est un peu faible par rapport à la variété que j'utilise actuellement sur ma ferme, donc il y a encore des améliorations à faire au niveau du rendement, du yield, qui est inférieur à ce que je peux trouver avec le Walton."

Program-level Limitations

Lack of Capacity for Lab-based Assessments

At this stage in the program, there are limitations to assessing flavour and consumption qualities to help drive demand. This is due to both a lack of resources available to the farmers and to limitations on the amount of grain they can grow of one variety (i.e. not enough seed can be grown out to facilitate a proper tasting trial). Of the 4 farmers that mentioned this theme, the following quotes were the most illustrative.

"The quality aspect of it isn't something that I've looked into at this point. I don't even know exactly what that work would be to do."

"I did three or four years of selections. And during that selection process, we were looking for characteristics that were more agronomic, and now we got to look at the quality characteristics and to see whether it's suitable for the marketplace."

"I had no way of really distinguishing the sweetness, so I didn't bother selecting for that. But that would've been good to know."

Participants are also limited to taking only visual assessments of their plants. Many wish to gain a better understanding of qualities like nutrient uptake and grain protein content in their selections.

"And then towards harvest, you get a better sort of understanding of which ones just look better visually. But that doesn't always tell though, it's really hard to see much differences. You can't really feel real difference very effectively, just looking at it, you have to measure it. So that's a little hard to do without following good science"

Multiple, Changing Points of Contact

Though it was understood that roles often shift in programs such as this, several participants found it difficult from a communications and research continuity perspective that the program has seen many

changing points of contact over the years. Of the 3 farmers that mentioned this theme, the following quote was the most illustrative.

“… but just doing work with farmers, and knowing how important consistent relationships are –, that I could see being a bit of a challenge. I'm thinking back to all of the different main points of contacts that I've had on the PPB over the six or seven years.”

Limited Access to Appropriate Machinery

There is a need for mid-sized, research appropriate seeding and combining equipment to scale up on-farm research capabilities. Farmers are concerned about the size of their regular equipment and the risk of genetic contamination from their regular production. Of the 2 farmers that mentioned this theme, the following quotes were the most illustrative.

"we were fortunate enough to find a small plot combine, and that's one of the reasons our trial work has gone through the roof. We actually grew more wheat last year than they have in the last 10 years put together. Five minutes on the plot combine is almost 14 hours of manual hand harvesting and threshing."

"When you need to multiply there is a problem of scale. Because the farmer usually has large equipment and in research centers, they have small equipment for smaller plants. And when you need to increase your variety...it is very difficult for the farmer to use his own equipment because it is way too big to be able to keep the purity of the variety. With a conventional combine you cannot clean that combine enough to make sure you have the purity for such a small quantity."

Industry-level Limitations

Limitations to Growth Without PPB Varieties Registration

Without any kind of variety registration, the market price of PPB varieties may not justify the additional work needed for their ongoing development. This is related to distances between areas where growing grain is most cost effective and areas with greater local market access. Limitations are created by the current regulatory structure and includes the costs associated with registration, that some farmers believe will fall on them in either real financial costs or opportunity costs through the registration process. Of the 5 farmers that mentioned this theme, the following quotes were the most illustrative.

"I would like to see that Canada recognizes participatory plant breeding as a viable and an important solution to agronomic solutions for environmental change. But it's not even on the radar of most people. ... we need to engage our farmers in participating in this. But we're not going to see that as long as there's so much control on seed stock."

“that doesn't really seem like that benefits the farmer in the end with the hoops to jump through and the cost in the end."

Relatively Smaller Governmental Support Than Other Research

Relevant to previously mentioned strengths in how PPB can facilitate public research is the noticeable lack of funding needed to properly scale up the program. Some participants found that a major limitation to the program meeting its full potential was the relatively small budget, lack of equipment

resources, and staffing limitations. The relatively small support from larger government and institutional structures was pointed out as a barrier to the program achieving greater outcomes for those participating. Of the 2 farmers that mentioned this theme, the following quotes were the most illustrative.

"I'm a bit frustrated that the program has to exist, and that it does exist as a separate entity. Because it's no substitute for an adequate replacement for public research in my view […].I think they do an amazing job given that the funding that they do have that is provided. But it really should be a government-funded program. And that should be a part of the broad public interest research function that is in agriculture research."

"It needs to be valued as a national enterprise, and it needs to feed into that broader public policy research...the same could be said for wheat breeding generally. So much of it has been corporatized and just become more for corporate profit interest rather than the public interest"

Q3) How do participating farmers perceive the function of PPB in the broader context of organic agriculture development?

Perceived Values and Meaning:

Why Do Farmers Choose To Engage in PPB?

Program participants expressed a wide range of initial motivations for taking part in the PPB program. Motivations here are defined as the incentives to participate in this program that were recognized before having taken part in the program but after having initially learned about it and its structure.

Develop tools for organic farmers.

The PPB program offers the chance to develop new tools to improve production capabilities for organic farmers, either at the individual farm scale or across the industry nationally.

"I'd love for the program to progress where we're getting lines available commercially for organic growers."

*"this program was breeding crops in the conditions that they're going to be grown at, so they would have a more representative yield, and disease, and potential all around. So, I felt that it was going to be better for the farmer, rather than for a repo*rt."

Create movement towards greater seed sovereignty

The PPB program is seen as a decided movement away from sole reliance on larger companies to provide seed for grain farmers. This coincides with the inherent control of distribution, use, and pricing of these seeds. This motivating theme often evoked a political tone.

"I think one of the most important things for farmers is genetics. So variety development is very, very important for successful farmers of all types. So being able to be involved in that is significant."

“Les retombées que je souhaite obtenir de ce programme là c’est de prouver à l’industrie et prouver aux gens, aux décideurs, qu’on est capables, en tant que producteurs, de faire de la sélection et de produire nos propres semences sans avoir à être dépendants de l’industrie.”

“There's a philosophical thing too in having control over our own seed, and the drive towards more and more proprietary ... plant breeders rights is not something I've ever felt comfortable with, and continue to have concerns about where the control of seed is going in Canada.”

Empower farmers and creating engagement in the R&D process

Participants felt that respect was given to the farmers’ opinion and agency through contributing to the process of seed variety research and development.

“because I deal with the consumer, something like taste is a factor. Whereas taste isn't even on the radar of a normal crop breeder.”

“part of the rationale behind the program is so that farmers have that economy and freedom and power, like empowered farmers, to take charge of that breeding process a little bit and do some of that work and see some of the benefits”

“I believe that the program is something that's valuable, including farmers in the research portion of breeding and also encouraging farmers and pushing them towards that work”

Support innovation needed in Canada

To many, the very act of contributing to a unique and innovative study like this provided incentive to participate, regardless of individual gain through outcomes. This motivating theme often coincided with a general curiosity for the research process, or interest in scientific innovation in general.

“I found it is quite an absolute honor to be included in the whole information and breeding process. I thought that was quite neat. Way beyond what the direct gain is.”

“I'd say that initially one of our primary interests was to be supportive of the program, not so much what we could get out of it, but rather see if we could be a participant in a scheme that sounded pretty innovative and much needed in Canada. So it really started out trying to be supportive.”

Foster collaboration and cooperation between farmers and researchers

The PPB program offers a collaborative network that spans nationally and regionally. Many participants were inclined to this cooperative approach of operating a farm business and saw this potential initially through taking part in the program.

“The whole cooperative community of like-minded organic farmers across the country helping to build that I think is a real outcome. And it's one that's important to our farm. And just being part of that cooperative venture.”

“the collaborative program came along, and I was kind of just looking for something that would be better suited for our farm.”

Significance of PPB

When asked about their personal values and meaning regarding the process of PPB in general (apart from the BFICSS program specifically), participants provided a wide range of feedback. Responses to the question of meaning were grouped into several categories listed below with examples.

Reinforces a Sense of Empowerment

A political notion of empowerment was noted across responses to the question of meaning regarding PPB. The concept and practice of PPB evoked a sense of resistance to conventional systems, demonstrating to some the power farmers hold to create alternative systems.

*"..**the community aspect of PPB. One of my favorite things that I love about this program is that it's empowering farmers to do things to help themselves**. We're being encouraged to select for lines that work in our region, we're being encouraged to participate in such an important aspect. Seed is so important, and being able to participate in a program that allows us to strengthen the seed supply in organic agriculture is pretty special. That's a big part of what is motivating me to be a part of the program in the first place, is that whole aspect of empowering organic farmers to be able to make their own choices and make their own seed is really important."*

*"Fundamentally to me, **I see it as a resistance. It's giving power back to the seed growers** and the seed users, as opposed predominantly the patent owners."*

"I think one of the things that this program is doing is reminding farmers that we do have a certain amount of power and that this work of saving seed and being aware of just some basics of plant breeding and making selections, that can empower farmers to do more of that and to be more independent"

Allows Greater Autonomy In Farming

The theme of autonomy could also be considered a subcategory to empowerment, though for purposes of analysis and discussion it is given its own section. Autonomy is defined as a sense of independent agency and self-direction and differentiated from empowerment by the practice of maintaining ownership over seed.

*"Pour ce qui **est des pratiques modernes, ça prend de la dimension des développements durables**. Puis pour la développer, ça rejoint l'autonomie de l'agriculteur versus l'industrie des semences. Puis ça aussi, ça conduit à l'autonomie financière de l'exploitation agricole."*

"C'est une très belle évolution, qui j'espère va prendre de l'ampleur, qui va grandir, car c'est une alternative au modèle qui a été développé dans les dernières années, qui a fait que les agriculteurs ont perdu leur autonomie sur les semences."

"it means that the farmers can still have a major role in developing new varieties... companies are leading farmers to believe that it's a really complex thing, breeding seed, and that the farmers shouldn't really be involved, so participatory breeding has flipped that around...it's important [for farmers] to be involved….millions of dollars research budgets aren't necessarily getting any further ahead than what we could do as part of the program as well."

Supports Farmers' Role in Food Sovereignty

Some participants focused on the role of the farmer in the greater society when discussing the meaning of PPB. This went beyond just the process and outcomes of PPB and positioned the process as a tool to help the farmer facilitate greater roles for society. A crucial part of this role was described as the ability of farmers to retain and improve their own seed.

*"The PPB, to me, is literally **empowering the farmer back to the land steward**, to the environmental steward, the biodiversity steward. The old farmer...pre green revolution ... they did all those roles and had a vast amount of knowledge. I think now, there's a real displaced authority,"*

*"PPB to me would be **summed up in food sovereignty and food security**...Food sovereignty and food security mean farmers' rights, which has always been and should always be, and it's part of the reason why I stepped into this, is when we take the right of the farmer to keep back his seed, we have given up the right and we have given up **the ability of the farmer to produce food for their own nation**."*

Offers Democratic Model of Research

The PPB program was described as creating a more democratic and egalitarian process of crop development. This was described by the creation of cooperation in the research process, allowing farmer's input, and overall transparency of the information created by the research. This was linked to respect for farmers' opinions, having those opinions heard, and having access to the information they need to improve their production.

"I think the perception in agriculture often is so that research goals, objectives aren't coming from the ground up, they're coming from other places and other motivations."

*"[on the conventional approaches of government-led research] No information gets out of the Ottawa Experimental Farm. I could go there with a question, and they couldn't care less about my question. **It's all for research for a few big companies. It's got nothing to do with helping farmers."***

*"I think PPB means **respect for the farmer**..the idea of farmers working together with researchers and respecting both the researcher and the farmer. You're coming at it from different angles, as opposed to that conventional thing where you have this big company developing a seed, and then imposing it on the farmer, and it may or may not be appropriate."*

*"To me, PPB means **opening up the breeding and the plant varieties system to a more democratic process**, less controlled by a very small number of companies who own seeds, ... I really do think it's a lot of potential for opening that area of science up to a wider body of people, and then finding the people who have the passion for it...not just something that's locked away to a select few highly trained individuals."*

"It's like citizen science"

Builds Genetic Resources and Offers Agronomic Tools

Participants saw PPB as a practical means to develop better crop genetics with specific adaptations to organic systems. From this perspective, PPB means a more effective method for crop variety development that better answers the needs of organic farmers. The participatory model allows for

farmers to have assistance in the more technical “grunt work” of evaluating and growing larger quantities of experimental seed. There is also potential seen in evaluating PPB varieties across multiple sites, so that these varieties can have a greater utility for farmers across the country.

“the value of genetics on farms and plant breeding, how fundamental it is to its success. To be involved in that, to actually be part of that process and to do selections on our own farm that are going to potentially lead to varieties that are better or more adapted to our organic farm, that's a great opportunity. And to have ***the participatory breeding program means that we don't have to do the grunt work...evaluating them in different sites and collecting data****, and evaluating them for us relative to our weather. That's very important, we can't do that on our own.”*

"We need to be able to produce grain crops with lower inputs, but higher yields. And breeding crops that would respond to those situations, in those climates regionally, I think are paramount to get a diversity of seed, rather than this current system of coming into a handful of less diverse varieties of seed that could be wiped out with one disease… ***Diversity is key, and I felt that that's what this program was allowing people to have their input, and have the diversity of how they wanted*** *the crops to be grown out on their farms****.****"*

6. Conclusions and Discussion:

<u>Research question 1) What methods do farms deploy to select desired crop traits and why are these methods used?</u>

This study aims to understand the selection methods used by PPB farmers and how study participants engaged with selection methods across different regions in Canada (e.g. frequency of selections, selections made, intent).

In the Prairies and BC, grain size was given the most focus, though not much specific focus on yield was mentioned in these regions. Weed competition, height, and disease resistance were also a major focus in the Prairies. Early establishment was a unique trait mentioned in the prairies only. The correlation between the Prairies and BC desired traits could likely be related to the similarities in their supply chain geographies (e.g. Train cars loaded with Prairie grain as “rolling through the Fraser Valley”, was mentioned in both BC interviews).Often in discussion with BC farmers, the comparison was made between their farms’ scale, practices, and markets, with the production in the Prairies. The markets that Prairies farmers supplied to seemed to be held as an aspiration for farmers in BC, as these markets were a very visible and known reality in BC.

Almost all trait selections in the Prairies were made at harvest time or just before harvest time, with two exceptions of farmers who visited plots regularly to assess and make selections. Disease selections were also made as positive selections at harvest time by selecting those plants that had not developed disease and broken down. This was expressed as mostly due to the time constraints on larger farms:

“*we were so busy and our farm was fairly large, we'd find that we kind of neglected, sort of paying a whole lot of attention to the plots and focused more of both of our attention to harvesting and the positive selection process rather than the negative selection process*”

Most Ontario farmers did not select for yield or grain size. Selections made in Ontario were directed more towards agronomic aspects of production such as height and straw strength. Although straw strength can be associated with resistance to lodging and therefore greater yields, some farmers

mentioned directly that if grain size and heads got too large, this would increase lodging and negatively affect overall yields. Maturity was a unique, and somewhat frequent, selection found in Ontario. The unique trait of threshing quality was particular to oats and found in Ontario. The metric for determining this trait was the occurrence of hulls. The farmer who brought forward this desired trait determined the presence of oat hulls through the observation of small, black fungal specks that develop on the hull later in the season. Given the limitations on research appropriate equipment available for measurement, processing quality could only be assessed visually. Using this method of visual assessment might also create trade-offs between threshing quality and disease resistance in oats, given the observation criteria is the physiological presence of disease, if only a benign occurrence.

Farmers in Ontario were the participants that made the most frequently occurring visits to their plots for assessments and selections. Ontario is also where the concept of "Natural Selections" came up in discussions, where plants were left in the fields with minimal management to select themselves against environmental phenomena. This approach can be critiqued because of flaws found in eliminating human agency in selection during a breeding program. Selection practices should involve more observed and understood approaches that relate to understandings of a crop's agronomic trade-offs between defense and growth (Deng et al., 2020). This is important to consider during field trials because phenotype variability of crops will not always indicate genotype variability (McCouch, 2004).

"*So I try and intentionally leave them well past our harvest date so that if there's any of the crosses that want to sprout on head, they're going to weed themselves out because they won't germinate next year.*"

"I kept the big seeds because it may be that some of the heads were well adapted to a wet year, and the small seeds were drought adapted, and they struggled during the wet year, but next year might be a drought."

Yield and grain size as a desired trait was just slightly more of focus in Quebec then in Ontario. In Quebec, farmers seem to have given most focus to traits of disease resistance.

The one farmer from the Maritimes focused selections on height, straw strength, yield, and disease resistance.

Research Question 2) What strengths and limitations do program participants face and how do these relate to different scales of program integration?

- The most frequently mentioned strengths of the PPB program focused on areas of public research, knowledge sharing, collaboration, and agronomic support. These were discussed in greater length and with greater enthusiasm than the other most frequent strength of improved genetic resources for organic farmers. This would suggest there may be potential in focusing attention towards the collaborative and knowledge sharing aspects of participatory breeding networks.

- One way that networks of knowledge sharing might be expanded is through a more regionally-based collaborative system with universities. At present, only two universities are involved in the BFICSS participatory trials in wheat and oats, both located in the Prairies region. Involving more universities and over a wider geography nationally could allow for better distribution of costs associated with program operation, as well as create easier access to needed machinery, equipment, lab analysis, and agronomic support that these universities could offer. Having research centers for PPB outside of the Prairies region would help address the limited utility of some PPB varieties across different

regions and could also better address regionally specific, market-base considerations from the program.

- The questions can be raised as well whether participatory breeding and collaborative research is facilitated adequately by civil society and programs such as BFICSS, or should the government become more involved in public research like this? Limitations such as lack of appropriate equipment, limited resources, and relatively limited funding, the study participants felt the program was relatively quite underfunded relative to the impact of the benefits received, and that benefits could be greatly expanded given adequate program funding and support. Governments can also play a role in supporting programs such as these through modifications to the regulatory environment around seed varieties developed in a participatory system. Farmers who grew grain on larger farms that wished to expand PPB acreages could not justify adopting PPB varieties unless they were properly registered and could enter into the appropriate supply chains.

Research Question 3: How do participating farmers perceive the function of PPB in the broader context of organic agriculture development?

- Farmers perceive the function of PPB in Canada through a wide range of themes, including; genetic innovation, seed sovereignty, farmer empowerment, democracy, and food security.
- One motivation for participating that stands out is how farmers were motivated through seeking a collaboration and cooperative model for research. This supports the discussions in Q2 that PPB programs service a need for organic farmers to access collaboration networks of knowledge sharing and agronomic support.
- The function of PPB that creates a democratic and inclusive research process is linked to addressing gaps in Canadian public research in grains. Farmers feel a sense of empowerment and agency being involved directly in research programs and having free access to the information that is generated from research. Models of research such as PPB support this democratic process and access to necessary agronomic information.
- The motivations for participating and understanding of PPB significance in Canada seem very parallel. This suggests that information of PPB programs globally and understanding of potential outcomes have been communicated well to Canadian organic farmers.

7. Outreach:

1. Podcast: Iain Storosko and Aabir Dey, the director of the Bauta Family Initiative, discussed this research project and the implications of this work for identifying seed policies that can help build a farmer-friendly seed system during an episode of the “Grain on the Brain” podcast, produced by the Manitoba Organic Alliance. The episode is available here: https://manitobaorganicalliance.com/podcasts/season-3-episode-2-plant-breeding/

2. Webinar: A summary of this work will be presented to participating farmers during a “PPB Farm Club” webinar, hosted by the Bauta Family Initiative on Canadian Seed Security. This webinar series brings together past, present and future participants in the PPB program, along with researchers, and Bauta Initiative program staff. We plan to hold this webinar after the harvest season, between November 2021-January 2022, in order to ensure that farmers are available to join. The PPB farm club is held in a French-accessible format, to ensure that francophone farmers from the province of Quebec are able to participate. This means that all presentation slides are bilingual, and that bilingual staff are available to translate and answer questions in

both French and English. Both of the graduate students involved in conducting this work: Iain Storosko at Carleton University and Murray Jowett at the University of Manitoba will participate in the webinar. Previous editions of PPB Farm Club webinars are available for consultation here.

3. Symposium presentation: Iain Storosko presented this work during a roundtable at the "FLEdGE (Food: Locally Embedded, Globally Engaged) Student Symposium, November 2021. Presentation title: Participatory Plant Breeding in Canada: A Critical Discourse Analysis of Organic Grain Farmers.

4. Documents: All final project documents: the research report, research brief, updated PPB manual for wheat, updated PPB manual for oats and value chain maps will be made available in both English and French on the Bauta Family Initiative website (seedsecurity.ca/semencessecures.ca) and will be linked to on the websites of our partner organisations (e.g. Organic Alberta, Ecological Farmers of Ontario, FarmFolk CityFolk, ACORN).

5. Peer-reviewed, scholarly manuscript: This work will be developed as a manuscript discussing the findings of this research using a discourse analysis framework.

8. Financial accounting: Expenditures made to conduct this project included:

Graduate student researcher: $15,592

Farmer participation: $3807,88

Translation services: $38.45

All funds are in Canadian dollars. Please see the budget spreadsheet for further details.

9. Leveraged resources:

We leveraged additional resources from MITACS (a Canadian Network of Centers of Excellence) in the form of an "Accelerate" grant awarded to Iain Storosko at Carleton University. This grant allowed Iain to do two semesters of internship at SeedChange to conduct his research. In the structure of this grant, SeedChange paid two installments of $7,500 to MITACS to support Iain's internship and MITACS contributed an additional $15,000 for a total grant amount of $30,000 CAD that was distributed as follows:

- Mitacs internship stipend paid to Iain Storosko: $27,814
- Translation fees paid to produce French versions of documents: $1186.50
- Communication of Research Results, production fee paid to Manitoba Organic Alliance for the "Grain on the Brain" Podcast Season 3 episode featuring research results from Iain Storosko and a discussion of policy implications: $1000

We received in-kind support from the University of Manitoba to expand the scope of this project: Time contributed by Murray Jowett (M.Sc. candidate) and Iain Davidson-Hunt (Professor, Department of Natural Resources) to develop and conduct a second series of interviews and produce value chain maps for sharing with farmers and stakeholders.

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11. Additional photos:

A farmer-selected variety in a “common garden” evaluation at the University of Alberta, 2021. (Photo: @talonstokesphotography)

A bread-tasting trial from a PPB variety of wheat. (Photo: @talonstokesphotography)