Sizing Canada's National Seed Supply Chain:

Preliminary Assessment focused on Trees and Shrubs

INTERIM REPORT
February 2023

Canada

Natural Resources Canada | Ressources naturelles Canada

Sizing Canada's National Seed Supply Chain:

Preliminary Assessment focused on Trees and Shrubs

INTERIM REPORT
February 2023

Canada

Cat. no: Fo4-210/2023E-PDF
ISBN: 978-0-660-47678-0

Natural Resources Canada
Canadian Forest Service
580 Booth Street
Ottawa, ON K1A 0E4

A pdf version of this publication is available through the Canadian Forest Service Publications database: http://cfs.nrcan.gc.ca/publications.

Cet ouvrage est publié en français sous le titre : *Dimensionnement de la chaîne nationale d'approvisionnement en semences du Canada : Évaluation préliminaire sur les arbres et arbustes*

TTY: 613-996-4397 (Teletype for the deaf)

Preface

We acknowledge that we conduct our work activities on the treaty lands and territory of numerous and diverse Indigenous Nations and pay tribute to their heritage and legacy.

We aim to walk lightly, harvest with respect and learn from local knowledge-keepers of every Nation.

NTSC Staff with Earth Keepers from the Confederacy of Mainland Mi'kmaq and Unama'ki Institute of Natural Resources, Cape Breton during a two-way knowledge exchange session, October 2021.

Acknowledgements

This report was prepared by:

Melissa Spearing
Biologist, National Tree Seed Centre
Natural Resources Canada, Canadian Forest Service – Atlantic Region
Hugh John Flemming Forestry Centre, 1350 Regent St. S. PO 4000,
Fredericton, New Brunswick, E3C 5P7
Email: melissa.spearing@nrcan-rncan.gc.ca

Donnie McPhee
Forestry Officer, Coordinator of the National Tree Seed Centre
Natural Resources Canada, Canadian Forest Service – Atlantic Region
Hugh John Flemming Forestry Centre, 1350 Regent St. S. PO 4000,
Fredericton, New Brunswick, E3C 5P7
Email: donnie.mcphee@nrcan-rncan.gc.ca

Judy Loo
Tree Genetic Resources Consultant
22748 Rte 2, Springfield
Prince Edward Island, C0B 1M0
E-mail: loo.judy@gmail.com

Contributions by the following are gratefully acknowledged:

Scoping and initial outreach for this research project was funded by the Canadian Forest Service's Cumulative Effects Program (CE-13, 2019-2021). Support to continue the work was provided by the Atlantic Forestry Centre's management team and a collaborative research agreement with Wilder Climate Solutions and Accenture. We appreciate their and Natural Resources Canada's social media teams' commitment and creativity in helping to communicate this information to a wider audience.

We would like to acknowledge the following subject matter experts and organizations who inspired, contributed to, supported, and participated in the research:

- Nicolas Mansuy and Dani Degenhardt (Northern Forestry Centre)
- Solange Nadeau and Nathalie Isabel (Laurentian Forestry Centre)
- Dan McKenney, Heather MacDonald, John Pedlar and Glenn Lawrence (Great Lakes Forestry Centre)
- Gwilym Blackburn (Pacific Forestry Centre)
- Tannis Beardmore, Kathleen Forbes, Katie Burgess, Peter Moreland, Bruce Pike, Lucie Lavoie, Martin Williams, Nairn Hay and Mary Knockwood (Atlantic Forestry Centre)
- Jean-Marie Sobze and Ryan O'Neill (Boreal Forest Plant and Seed Technology Access Centre, Northern Alberta Institute of Technology)
- Dave Kolotelo (BC Tree Seed Centre, Ministry of Forests, British Columbia)

- Fabienne Colas and Sylvie Carles (Ministère des Forêts, de la Faune et des Parcs, Québec)
- Donna Palamarek and Lindsay Robb (Alberta Tree Improvement and Seed Centre, Alberta)
- Michele Fullarton and Shona Millican (Tree Improvement Unit, New Brunswick Department of Natural Resources and Energy Development)
- Bruce Stewart, Kevin Keys and Claire Wilson O'Driscoll (Nova Scotia Department of Natural Resources and Renewables)
- Peter Yates and Barry Linehan (Newfoundland Department of Industry, Energy and Technology)
- Dave Flight and Newton Philis (Manitoba Department of Natural Resources and Northern Development)
- Michelle Kanter and Sarah Winterton (Carolinian Canada)
- Mike Rosen (Tree Canada)
- Rob Keen, Elizabeth Celanowicz, Mark McDermid and staff (Forests Ontario)
- Kerry McLaven, Kristen Sandvall and staff (Forest Gene Conservation Association)
- Laura Coristine (University of British Columbia, Department of Biology)
- Sandy Smith and Eric Davies (University of Toronto, Daniels Faculty Forestry)
- Holly Abbandonato (Mount Allison University)
- The Society of Ecological Restoration: Mae Whyte (Western Chapter) Nigel Finney (Ontario Chapter) and Line Rochefort (Eastern Chapter); Nancy Shaw, Peggy Olwell and Simone Pedrini (specialists within the International Seed-Based Restoration working group).
- Brittany Rantala-Sykes (independent ecological restoration consultant, Ontario)
- Daniel Campbell (Birchbark Environmental Research)
- Steve Hill, Heather Schibili, Summer Graham and Cole White (Dougan & Associates, Can-Plant.ca, now Network of Nature Native Plant Database)
- Holly Bickerton, Darroch Whittaker, Nathalie Stafl, Emily Gonzales, and Robert Sissons (Parks Canada)
- Dan Kraus and Val Deziel (Nature Conservancy of Canada)
- The Canadian Forest Genetics Association and Tree Seed Working Group
- Kat Spencer, Brian Barber and the Forest Genetics Council of British Columbia
- Jamie Aalbers, Jeff Olsen and Fanny St. Hilaire (Canadian Nursery Landscape Association's Growers Group and Provincial Chapter support staff)
- Paul Smith and Suzanne Sharrock (Botanical Gardens Conservation International)
- David Galbraith (Royal Botanical Gardens) and the Canadian Botanical Gardens consortium for biodiversity
- John Skinner (Skinner Native Seeds)
- Eric Girard and Craig Farnden (Suncor)
- Brent Forbes and Sarah Drabble-Bisgould (Somerville Nurseries)
- Don Pigott (Yellow Point Propagation)
- Dan Gaudet (Vernon Seed Orchard Company)
- Laura Caddy and Ben Stormes (UBC Botanical Garden)
- Ron Nataros (NATS Nursery)
- Dan McCurdy (Boreal Horticultural Ltd)
- Ryan Scott and Jackie MacDonald (Scott and Stewart Nursery)
- Bill Schroeder (Agroforestry Solutions)
- Jenny Millson (Millson Forestry Service)
- Chris McGee (McGee Tree Seed)
- Martin Beaudoin Nadeau, Anne Savary and Béatrice Copalla (Viridis Terra International)

- Greg Adams (GDW Adams Consulting)
- Mary Myers and Hailey Blacquiere (J. Frank Gaudet Provincial Tree Nursery)
- Karen and Jim Verboom (Nova Tree Seed)
- Louise Corriveau (retired, Saskatchewan)
- Bonnie Burns (retired, Yukon)
- Michael Arbuckle (citizen scientist, New Brunswick)
- Emily Grave (Terraformation)
- Doug Folkins (JRP Solutions Ltd.)
- Drew Patterson (Tree Time Services)
- Natasha Kuperman (Seed the North)
- Stefan Weber, Carolyn Callaghan and Tracy Etwell (Canadian Wildlife Federation)
- Sue Meades (retired, Northern Ontario Plant Database)
- Laura Mouck (Canadian Forest Service, Natural Resources Canada)
- Several anonymous interviewees, quantitative workbook and survey reviewers
- Anyone or organization forgotten was not intentional.

Table of Contents

Introduction

Seeds that thrive support healthy ecosystems. A core principle of forest landscape restoration is based on sustaining natural biodiversity at multiple levels. This includes the inherited genetics within individuals, adaptive variation between populations, the diversity of species within an ecosystem, and the co-dependent relationships between species. Sustainable forest management and renewal after harvest is an important component of FLR and an important driver of tree seed supply systems in Canada.

For over 100 years, Canada's forest industry has developed robust tree improvement and genetic conservation programs to support tree seed supply needs (see Figure 1 and read Canada's second report for the State of the World's Forest Genetic Resources [2022]). Foresters know the ideal planting locations and growing conditions for each region. They often prescribe the most suitable species and seed sources to replant after harvest or natural disturbance. Tree breeding, provenance testing and seed orchards are continually improving the volume and value of genetically improved seed for growth. Policymakers at all levels of government are also considering assisted migration to sustain forest growth and resiliency under a changing climate.

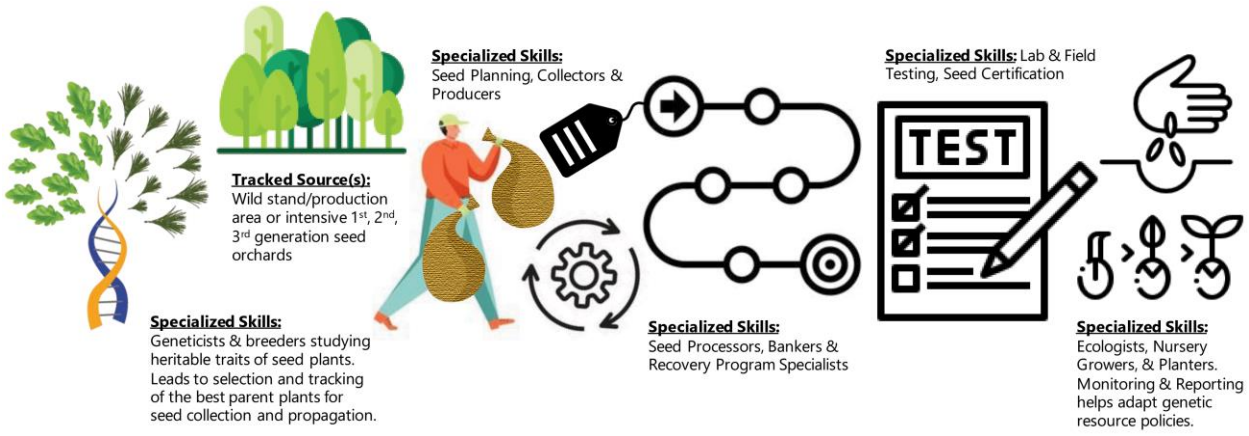

Figure 1. A reliable seed supply chain requires specialized producers and skills at each step.

Reclamation and restoration (R&R) are important emerging FLR sectors capable of reversing damage to fragmented and degraded forested landscapes across Canada. R&R projects often utilize industrial, governmental, or non-profit environmental protection funding to conduct their work rather than timber harvesting revenue. According to Statistics Canada, 87% of Canadian businesses reported $8.9 billion in expenditures on environmental protection, 5.8% of which went to the protection and restoration of biodiversity and habitat. Many local organizations and Canadians benefit or could benefit directly and indirectly from increased R&R spending, including those who plant trees and supply the appropriate plant material. Effective forest landscape restoration also builds on knowledge long held by local Indigenous communities and other professional land managers.

Public seed stewardship on all public lands (including registration, processing, testing and banking at adequately staffed facilities) is an important insurance policy to help public land managers and nurseries plan their long-term activities. In recent decades, private and non-governmental organizations are becoming more involved in seed stewardship and storage in some jurisdictions. Seed banking organizations (including the National Tree Seed Centre) can have single or multiple missions. These can operate on a for-profit or not-for-profit basis. Examples include operational services, long-term conservation, and research and recovery programs.

Since the year 2000, regional surveys have indicated a chronic lack of appropriate seed and nursery stock available to support some reclamation and restoration practitioners in Canada. Many project planners cannot find the diversity, quantity and quality of native stock required. Additional financial pressures, consolidations and a shrinking labour force appear to have led to a reduction in the number of tree seedlings reportedly produced and sold in Canada (since reforestation nurseries were excluded in 2016, Figure 2). However, that survey excludes:

- farms in Canada's three territories
- institutional farms
- community farms
- greenhouses that are marijuana producers
- greenhouses or nurseries that produce tree seedlings for reforestation

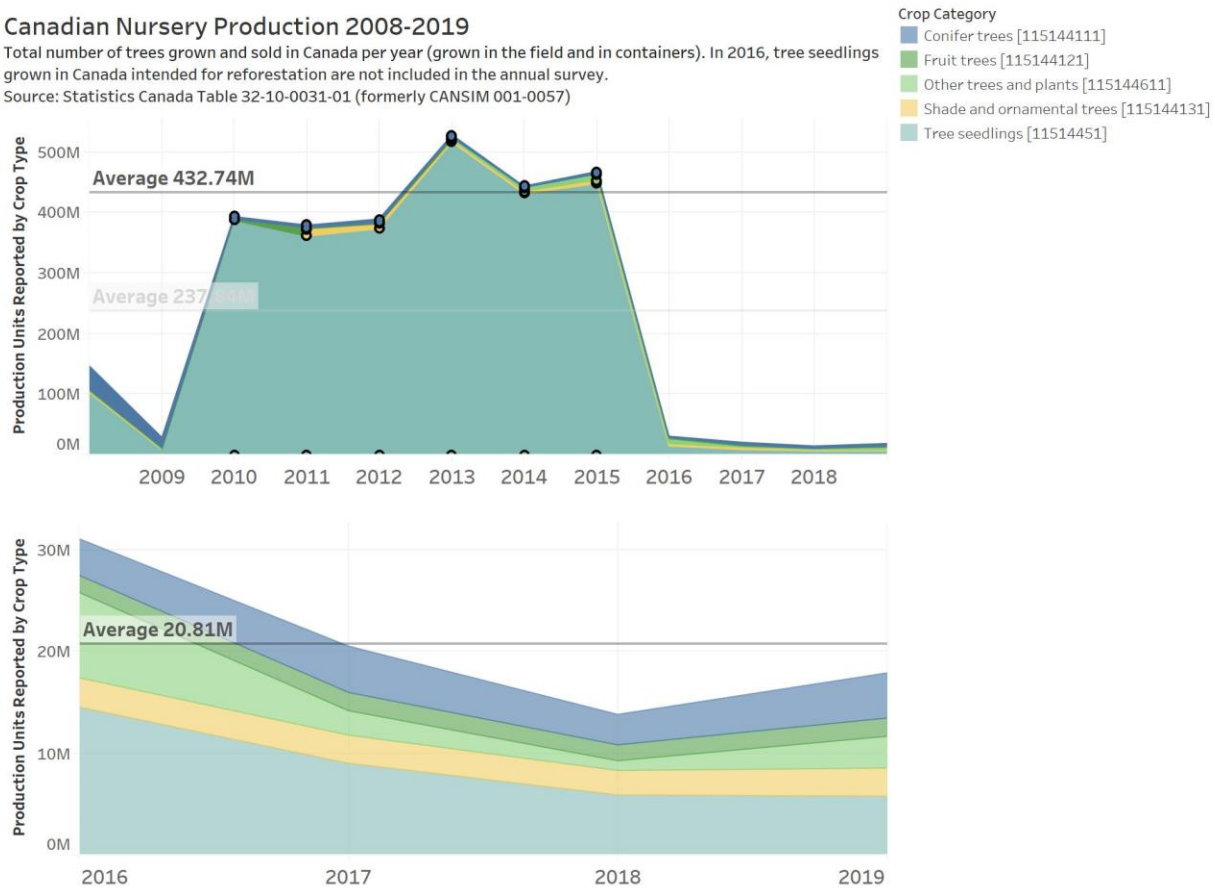

Figure 2. Trends in tree production from Canadian producers from 2008-2019.

This survey aimed to answer the overriding question by 2030 (and beyond): "Where will all the seeds needed for sustainable forestry, restoration and reclamation in Canada come from and who will supply them?" The survey was designed to be as inclusive as possible, as the activities and definitions for what experts and non-experts consider to be effective forest landscape restoration are broad, overlapping and evolving. While Canada's indigenous tree and shrub species were the focus, we allowed and retained any responses indicating the unmet demand for other taxa (non-woody plants and grasses).

Below is a summary of the key findings from each survey. We would like to thank everyone who contributed to this work or participated in our surveys. Please contact us if you have questions or would like to contribute additional feedback.

Survey and Interview Methodology

A Canadian Forest Service (CFS) Cumulative Effects Project (CE-13, fiscal years 2019 to 2021) initiated scoping for this research.

Questions were determined from a 2019-2020 literature review and existing CFS forest genetic resource surveys. A species-specific supply and demand Excel workbook based on Morgenstern and Wang's 1999 national reforestation seed supply data was developed but not deployed during the pandemic.

The first survey was shared with participants at the Society for Ecological Restoration's 9th World Conference (virtual, June 19 to 24, 2021). Surveys and outreach were put on hold during the Fall 2021 federal election. Questions referring to "Growing Canada's Forests" were amended to include or substitute the "2 Billion Trees program." A collaborative research agreement was undertaken with Wilder Climate Solutions and Accenture from February to December 2022. They were also interested in studying the Canadian tree seed supply chain.

From March 4 to May 2, 2022, five survey links were distributed by email to NTSC research collaborators, regional tree improvement programs, publicly listed native seed and seedling producers, nursery and landscape associations, seed collectors and producers, and planting organizations across the country. We thank many NTSC collaborators and supporters who helped raise awareness of the effort and/or provided mailing lists.

Natural Resources Canada promoted each survey through its social media channels (Twitter, LinkedIn and Facebook) and NTSC collaborators shared within their own social media networks. From March 1 to May 31, 2022, the "National Tree and Shrub Seed Supply Assessment" page had 1076 visits and 491 (46%) of visits were a direct result of the campaign. NTSC collaborators had the highest number of visits. Members of the Canadian Forest Genetics Association's Tree Seed Working Group had the highest engagement rate.

The following summarizes the goal of each survey.

1. **Sizing Canada's National Seed Supply (Survey 1, S1 in tables)**
   The primary goal of this survey was to understand current and short-term forecasted activity and players involved in the domestic seed supply chain in Canada before the 2 Billion Tree s program was announced.
2. **Planning, policy, research and education providers (Survey 2, S2 in tables)**
   The primary goal of this survey was to highlight the importance of planners, researchers and education providers in the development of seed-based solutions before the Government of Canada's 2 Billion Trees program was announced.
3. **Seed collectors, orchards and producers (Survey 3, S3 in tables)**
   The primary goal of this survey was to highlight the importance of seed collectors, collection agencies, seed orchards or managed production areas, and current demographic and economic profiles to assess the sustainability of these activities.
4. **Growers (Survey 4, S4 in tables)**
   The primary goal of this survey was to highlight the importance of nursery producers and recent

trends in native plant production before the Government of Canada's 2 Billion Trees program was announced.

5. **Restoration and reclamation planners, practitioners and planters (Survey 5, S5 in tables)**
   The primary goal of this survey was to understand the role and needs within the restoration / reclamation sector before the Government of Canada's 2 Billion Trees program was announced, and anticipated needs for the next decade were outlined.

Each survey was independent and voluntary. The responses were anonymized. Respondents were not required to complete all survey questions. We do not have insight into why respondents may have skipped questions. As a result, there may be selection bias in responses. To accommodate for skips, data presented as percentages (%) has been based on "all answering" per question or choice rather than among all respondents. Once fielding was complete, data was cleaned. Respondents were removed if they:

- did not meet survey qualifications (indication of relevant seed supply chain activity)
- were speeding through the survey and/or leaving a large percentage of questions blank

Given the effects of the COVID-19 pandemic and delays in outreach, insights are likely biased toward those:

- with desire to benefit from the 2 Billion Trees program funding
- with the capacity to grow their operations

Twenty-one qualitative interviews were conducted with voluntary and informed prior consent**.** The NTSC specifically sought active collaborators and recently retired subject matter experts from potentially under-represented geographic areas in the quantitative surveys (i.e., Quebec, the Far North, Prairies, British Columbia, Newfoundland and Labrador, and northern Ontario). Semi-structured interviews were 30 to 60 minutes long and transcripts were coded by Accenture into common themes.

Research Participation

Table 1 summarizes jurisdictional participation by five online surveys and expert interviews. Across the online surveys, greatest participation came from those primarily located in Ontario, Alberta, British Columbia and New Brunswick. A small number of respondents were from Indigenous organizations or communities (4 in the base survey, 2 growers and 1 planting organization). However, independent NTSC inquiries, collaborators and interviews suggested far more communities are or were interested in becoming involved in seed conservation and restoration activities.

Table 1. Summary of study representation as indicated by their primary or head office location in surveys or interviews.

Primary location	S1. Sizing Canada's National Seed Supply Chain	S2. Planning, policy, research and education providers*	S3. Seed collectors, orchards and producers	S4. Growers	S5. Restoration and reclamation planners, practitioners and planters	Interviews
Alberta	12%	4%	10%	21%	13%	14%
British Columbia	17%	28%	20%	25%	16%	29%
Manitoba	7%	4%	3%	2%	8%	5%
New Brunswick	13%	12%	15%	9%	6%	10%
Newfoundland and Labrador	2%	0	0	0	3%	0
Northwest Territories	0	0	0	0	0	0
Nova Scotia	6%	0	0	5%	5%	10%
Nunavut	0	0	0	0	0	0
Ontario	34%	36%	43%	34%	34%	14%
Prince Edward Island	3%	0	0	0	5%	5%
Quebec	6%	8%	5%	2%	3%	5%
Saskatchewan	2%	8%	5%	2%	5%	10%
Yukon	0	0	0	0	0	5%
United States	0	0	0	0	2%	0
Answering (*n*=)	107	25	40	56	62	21
Skipped (*n*=)	4	1	0	0	0	8**
Total respondents (all questions)	**111**	**26**	**40**	**56**	**62**	**21**
Total number of questions	**24**	**28**	**22**	**30**	**35**	**10 (semi-structured)**

Question text in all surveys: Please identify the head office or primary location where you or your organization are based (select one). Notes: totals may not add up to 100% due to rounding, and jurisdictional participation across all surveys should not be summed.

*Due to the small base size we did not analyze the majority of data from the "Planning, policy, research and education providers" survey.

**Eight of the interviewees who were still professionally engaged in seed supply told us they did not take any of the online surveys. Their roles were added to the cumulative supply chain representation in Table 3.

Respondents were also asked to report all jurisdictions where they conduct research, business, and/or purchase/deploy native species of trees and plants. Table 2 summarizes the "Area of Work" and illustrates how seed supply chain expertise and plant material can go far beyond primary centres of production in Canada. This includes activity and trade with the United States.

This was reinforced by some interviews where remote reclamation and restoration projects did not have a local nursery producer or seed source. In one case, seed collection was done and shipped to a nursery for production and return of planting plugs (seed went from Yukon to British Columbia, back to Yukon for planting). In a second case, the planting organization had to source seed from Alberta to plant in Quebec. The second scenario may be riskier for long-term tree survival if the climate of origin is very different from the planting site.

Table 2. Summary of all areas of work involving native species of trees and plants reported by respondents.

Area of Work	S1. Sizing Canada's National Seed Supply Chain	S2. Planning, policy, research and education providers*	S3. Seed collectors, orchards and producers	S4. Growers	S5. Restoration and reclamation planners, practitioners and planters
Alberta	33%	24%	25%	34%	26%
British Columbia	40%	32%	38%	39%	24%
Manitoba	21%	8%	15%	18%	19%
New Brunswick	30%	28%	25%	20%	15%
Newfoundland and Labrador	12%	8%	13%	5%	8%
Northwest Territories	7%	1%	8%	5%	2%
Nova Scotia	21%	12%	18%	20%	11%
Nunavut	3%	0%	5%	0%	0%
Ontario	47%	40%	58%	46%	37%
Prince Edward Island	18%	8%	13%	11%	15%
Quebec	21%	8%	15%	18%	8%
Saskatchewan	18%	16%	23%	18%	16%
Yukon	6%	4%	8%	5%	0%
United States	NA**	1%	18%	18%	3%
Answering (*n*=)	**107**	**25**	**40**	**56**	**62**
Skipped (*n*=)	**4**	**1**	**0**	**0**	**0**

Question text in all surveys following Table 1. Please identify all the jurisdictions in which you conduct research, business, purchase or deploy native species of trees and plants (check all that apply)
*Caution, small base size, see Table 1.

**This choice was missing from the first survey. See Table 5 for supporting data from 86 respondents regarding sourcing seed and/or stock from the United States in the future.

Similar to **Error! Reference source not found.**, respondents were asked what roles they played within the seed supply chain in Canada (Table *3*). After interviews, the NTSC summarized the same roles from those who had not taken any online survey based on transcripts and/or prior knowledge of their professional activities. We consider Table 3 to represent our "core seed supply chain" groups of experts capable of informing the capacity and ways to meet increased FLR demand by 2030. The proportions may reflect the balance of workforce skills required to scale up and sustain long-term production.

Table 3. Summary of key supply chain roles reported by the "Sizing Canada's National Seed Supply Chain" respondents and additional interviewees.

Supply chain roles	Survey Respondents	Additional Interviewees	Total per role (*% of 115*)
Collecting seed from wild, unmanaged populations	61	7	68 (59%)
Planting/restoring sites	59	3	62 (54%)
Distributing seed or seedlings	46	6	52 (45%)
Processing seed	44	6	50 (43%)
Growing seedlings	46	3	49 (43%)
Storing seed	44	4	48 (42%)
Planning and procurement	39	5	44 (38%)
Carrying out seed-based research or education	33	2	35 (30%)
Producing seed from an orchard or managed production area	28	3	31 (27%)
Forest inventory and botanical surveys that identify viable populations	18	4	22 (19%)
Developing seed policies or certifications (voluntary or regulated)	10	0	10 (9%)
Core seed supply chain participants (*n*=)	**107**	**8**	**115**

"Sizing Canada's National Seed Supply Chain" Question text: What role(s) do you fill in the seed supply chain? Please check all that apply. 107 answering. 4 skipped this question.

Just over half of these respondents claim to hold 4 or more roles in the seed supply chain, indicating that a diversity of skills is required to conduct this type of work professionally.

Sizing Canada's National Seed Supply Chain

One hundred eleven respondents were included in the final analysis. Tree planting, restoration and reclamation activities are primarily facilitated by a diversity of small and medium-sized organizations with less than 50 employees. Eleven percent of respondents were from organizations with 250 or more employees. More than one third of activities are driven by private businesses, with non-governmental

organizations, the federal government, research institutions and provincial governments also providing support.

Eighty-five percent of respondents expect to participate in, or benefit from, the 2 Billion Trees program. Respondents indicated for any project, high environmental benefits and tree survival (including reduced costs) are important indicators of success.

Based on their awareness of seed supply outside reforestation planning, we asked respondents to rate the likelihood of future events in their region (Table *4*). The table is sorted according to top 2 "very likely" and "somewhat likely" combined responses.

Table 4. Survey respondents estimated the likelihood of 16 future seed supply chain events based on local awareness in their region in the next 5 years.

Future event or scenario	Top 2 Box (Very likely/ Somewhat likely)	Bottom 2 Box (Not likely/ Not at all likely)	Don't Know
Foresters and restoration practitioners will utilize existing knowledge to encourage and measure additional natural regeneration to reduce costs and count toward the 2 billion tree target. (n=92)	59%	27%	14%
Growers will increase production with contractual assurance seed and afforestation programs will purchase stock. (n=93)	57%	17%	26%
We have or plan to adopt new technology that will increase seed use efficiency or improve seedling establishment on the landscape. (n=93)	55%	26%	19%
We have or plan to adopt new planning tools that will increase seed use efficiency or improve seedling establishment on the landscape. (n=93)	55%	28%	17%
There are underutilized seed orchards and seed production areas that could be accessed to meet additional demand. (n=91)	54%	22%	24%
Certification bodies and provincial governments will ensure and verify that appropriate species and seed sources are utilized to maintain genetic diversity under a changing climate. (n=93)	49%	35%	15%
Community groups and NGOs will increase activity and volunteer hours to help meet increased demand. (n=93)	49%	31%	19%
Municipal planners and policymakers will ensure that genetically-appropriate species and seed sources are utilized in their programs. (n=92)	40%	47%	13%
Growers will increase clonally produced material to compensate for genetically-appropriate seed supply shortages. (n=92)	37%	26%	37%
There are enough general labourers available locally and/or through Temporary Foreign Workers programs to support seed supply, growers and distribution services. (n=93)	37%	41%	23%
There are enough sufficiently trained, capable planters to meet additional demand. (n=93)	35%	46%	18%
There is enough expert seed processing, testing and storage capacity to meet additional demand. (n=93)	27%	57%	16%
There are enough skilled growers and underutilized production capacity to meet additional demand. (n=93)	26%	58%	16%

Reforestation companies will increase the production of appropriate seed and stock beyond reforestation commitments. (n=93)	26%	44%	30%
There are enough sufficiently trained, capable seed collectors in my region to meet additional demand. (n=92)	23%	64%	13%
We have sufficient surplus seed in storage above current reforestation commitments to meet additional demand. (n=92)	18%	62%	20%

Question text: Seed supply chains have been established for commercial timber species beginning with seed collection from managed seed orchards and proven wild stands. These supply chains include the nursery production and 5 to 10 year planting plans to forecast demand. Anticipating seed and seedling needs beyond reforestation plans is not easily accomplished. In addition to acquiring seed, the remainder of the delivery system must be capable of the additional effort and production. Select your responses based on your awareness of the supply chain in your region for the next 5 years. 91-93 answering per choice, 18 skipped this question.

The bottom five least likely scenarios reflect serious practical limitations to immediate increased demands for seed and nursery stock production. Meanwhile, the top 5 most likely scenarios may reflect creative means of achieving reclamation and restoration demand using existing knowledge or supply chain capacity. To meet prospective additional demand for tree and shrub production, respondents were then asked what measures they would take, and when they would take them (Table *5*).

Table 5. Respondents rated 13 future measure(s) and timelines to meet additional demand.

Future anticipated measures and timelines	Total	1 to 2 years	3 to 5 years	6 to 10 years	Yes, but unsure of timeline
Increase, improve or develop training and knowledge exchange opportunities (n=86)	72%	40%	6%	0%	26%
Increase domestic contracts, equipment, capital spending or grant applications (n=86)	64%	44%	7%	0%	13%
Optimize existing capacity and staff to boost productivity and production units (n=85)	63%	45%	5%	2%	11%
Hire additional Canadian summer students (n=86)	58%	36%	2%	0%	20%
Hire additional Canadian part-time workers (n=86)	53%	33%	5%	0%	15%
Plant additional seed production rows, areas or orchards (n=85)	49%	32%	9%	0%	8%
Hire additional Canadian full-time workers (n=86)	49%	26%	6%	2%	15%
Source additional seed and/or stock from other Canadian jurisdictions (n=86)	43%	27%	2%	0%	14%
Add more volunteer hours and outreach to engage new volunteers (n=85)	40%	20%	6%	0%	14%
Source and import additional seed and/or stock from the United States (n=86)	26%	16%	3%	0%	7%
Increase piecework rates for nursery production or tree planters (n=85)	22%	14%	0%	0%	8%
Hire additional Temporary Foreign Workers (n=85)	11%	6%	1%	0%	4%
Source and import additional seed and/or stock from outside North America (n=86)	6%	3%	1%	0%	2%

Question text: Is your organization planning on implementing any of the following measures to meet demand, and if so, when? 85-86 answering per statement. 25 skipped this question.

There were numerous open-end responses throughout this survey regarding the challenge of matching supply and demand, as well as the importance of focusing on native species. Many organizations appear to struggle with forecasting outside of jurisdictions with strong public seed stewardship policies and directives. Without future contractual assurances, it's difficult for the core seed supply chain group to know if they have collected enough seed or to expand their operations confidently.

When asked about major restoration and reclamation planting opportunities in the next 5 years, 105 respondents predicted the top 5 in their jurisdiction would be:

- Specialized habitat enhancement and species recovery programs (40%)
- Naturalizing agricultural fields, windrows, and pollinator strips (36%)
- Carbon offset plantings (25%)
- Urban and community forestry (24%)
- Revegetation of wildfire-damaged sites (19%) and insect and pest-damaged sites (19%)

Question text: What do you foresee being the major restoration and reclamation opportunities in your jurisdiction for the next 5 years? Please select up to 3. 105 answering, 6 skipped this question.

The right seed for restoration and reclamation

Provincial governments are more likely to have excess seed in storage compared to other organizations. Beyond existing reforestation commitments, access to excess tree seed in storage was not common in our survey, and few respondents had more than 1 choice of managed or accessible seed production sources Table *6.* Access to typical managed reforestation seed supply areas and sources.Table *6*).

Table 6. Access to typical managed reforestation seed supply areas and sources.

Choice	%
Manage or have access to mature seed production areas	48%
Excess tree seed in storage	25%
Manage or have access to mature seed orchards	24%
None of the above	39%
Those with 1 or more choices	
1 choice	34%
2 choices	18%
3 choices	9%

Question text: Beyond current or planned reforestation commitments, do you currently have any of the following? Check all that apply. 92 answering. 19 skipped this question.

Approximately half of those who reported collecting from wild stands also have access to mature seed orchards or mature seed production areas. The "None of the above" proportion may have been due to

lack of question applicability combined with those who truly need but do not have access to reforestation seed sources.

In a follow-up question on facilities, more than half of 84 respondents accessed wild and restored natural areas to manage their production. Less than half of those answering have specialized equipment such as seed coolers (46%), seed processing equipment (44%) and seed freezers (36%), which are necessary to improve local seed storage and distribution capacity. Interviewees stated industrial seed extraction equipment is prohibitively expensive for most organizations.

For non-commercial timber species, more than three quarters of organizations are using some type of seed transfer system, best practice, policy, or directive, with 64% referencing ecological land classification units. Just over half of respondents say they are also considering or are already using assisted migration for seed production or R&R planting. In open-end responses, a range of voluntary guidelines and directives are followed, usually specific to specific jurisdictions and land bases (federal, provincial, municipal, private land voluntary certification systems or adaptations from international best practices).

Notable resources for seed planning and verification included, but were not limited to:

- Provincial public land reforestation policies and tools:
  - Alberta Forest Genetics Resource Management and Conservation Standards
  - British Columbia Chief Forester's Standards for Seed Use, Climate-Based Seed Transfer and Seed Planning and Registry Application (SPAR)
  - Ontario Tree Seed Transfer Policy, including seed zones and ecodistricts
- Resources supporting species recovery:
  - British Columbia's best management practices for whitebark pine
  - Parks Canada's directive for mitigation planting for whitebark pine
  - Federal Species at Risk Registry and recovery strategies, including butternut
  - Ontario Endangered Species Act and recovery strategies, including butternut
- Voluntary regional and international standards:
  - Society for Ecological Restoration resources
  - Forest Gene Conservation Association's Certified Seed Collector workshop and manual
  - The US Seeds of Success program, which was originally developed with the Millennium Seed Bank Partnership

Question text: Please refer us to the primary directives, best management practices, recovery plans or open-source spatial files you use for seed source planning, labelling or certification [URLs, separated by commas or semi-colons]. 30 answering, 81 skipped.

As Table *2* indicated, it appears inter-jurisdictional procurement and deployment of native seed and stock is filling gaps to jurisdictions with fewer primary producers. By calculating the difference between primary location and all other areas of work in each survey by jurisdiction, it was clear that as a group, seed collectors and producers, followed by growers, can have a great impact on FLR projects beyond their primary jurisdiction. This may be due to the recent resurgence of online and mail-order shipping. This enables seed and planting stock to be shipped long distances with relative ease. While some retail

transactions may be small in volume, they would have no provincial or federal oversight on seed registration, quality or genetic suitability to the region. These transactions are the end user's responsibility.

Respondents were asked which resources would be helpful to improve their capacity to meet new demand (Table 7). There were additional open-ended responses compiled that indicated there are considerable knowledge gaps within some organizations.

Table 7. Resources that would be helpful to improve capacity and expertise.

Choice	%
Propagation and seed germination protocols	58%
Seed storage guidelines	56%
Seed processing guidelines	52%
Individual species fact sheets	51%
Ecoregional species lists (reference or ecological plant community lists of what is considered naturally occurring)	49%
Seed collection guidelines	49%
Plant establishment protocols, including seed mixes and density guidelines	46%
Seed testing protocols	42%
Seed transfer legislation or guidelines	33%
Seedlot registration standards	28%
Seed priming and pelleting protocols	23%
Other (please specify)	15%

Question text: Which resources would be helpful to improve your capacity and expertise to meet new demand (check all that apply), 79 answering. 32 skipped this question.

After completing the Sizing Canada's National Seed Supply survey, respondents were provided 4 links to additional specialized surveys. Participants could choose any combination or order to take these surveys. Only surveys with more than 30 respondents are reported in detail below (see Table 1 and Table 2 for data for Survey #2: Planning, policy, research and education providers).

Seed Collectors, Orchards and Producers

Forty respondents were included in final analysis with twice the number of respondents from Ontario (43%) as BC (17%). As a lack of skilled seed collectors was already a known concern in many jurisdictions, we attempted to rectify this expected skew with interviews from a wide range of viewpoints and sector(s) serviced.

Within the survey, the 35 to 44 years old and 55 to 64 years old age groups had the greatest number of respondents. Fifty-eight percent were 45 years or older and 76% of respondents collect seed for forest nurseries or nursery producers. The top three reasons for collecting were for their job (56%), their own use (36%), and/or paid contracts with industry (28%). In support of seed traceability throughout the

supply chain, most said their employers or clients were very stringent on documenting seed source and seed registration information.

As far as we know, this survey was unique in being the most current study to try to establish a baseline of job satisfaction, income and expenditures for those involved in the bulk of native seed collection (i.e., values are reported in Canadian dollars [$CAN]).

- 57% of part-time or contract collectors reported making less than $10,000 per year collecting seed, before taxes and expenses, with 21% making over $50,000 annually
- Most collectors spend 30 days or less collecting each year, with a median hourly pay of $27 before taxes and expenses
- 59% do not believe seed collection is a profitable activity. However, there was a significant difference between respondents grouped from Eastern Canada (ON, QC, NB, more likely to report poor compensation) and those grouped from Western Canada (BC, AB, SK, MB, more likely to report better compensation)

Seed collection can be unpredictable, unreliable, and physically challenging work, particularly from tree species that do not set seed in the wild every year. Most collectors travel within a 100 kilometer (km) radius to collect seed, but some travelled upwards of 500 km. Open-ended answers noted challenges with:

- **Health and safety:** ticks, poison ivy, reaching high into the crowns, thorns
- **Environmental conditions and pests:** drought, wildlife, competition from livestock, habitat loss, and timing seed collection with more variable weather patterns
- **Effort required**: travel planning, seasonality, remoteness, labour-intensive collection, tedious seed cleaning, methods to preserve seed quality and difficulty in pricing their work

Despite these challenges, seed collectors and producers generally enjoy being outside in nature, the challenge of learning a diversity of species, and knowing or seeing their efforts multiply into plantings that contribute toward a healthier environment and climate change or conservation targets. These sentiments seem to be important driving factors in engaging new trainees or volunteers as well.

Professional seed collectors learned primarily on the job (74%) or were self-taught through existing resources (50%). Only a few learned from professional or provincial training programs (18%). In a pair of related questions, respondents were asked about typical seed management tasks, related environmental workforce skills, and skills they were interested in learning more about (Table *8*).

Table 8. Expertise and skill development interests of seed collectors, orchardists and producers across Canada.

Choice	Experience with (%)*	Interested in (%)**
Seed orchard maintenance	60%	47%
Wild stand seed forecasting	57%	57%
Grafting	51%	33%
Seed orchard establishment	51%	47%
Controlled pollination	46%	20%
Pollen collection	40%	27%
Progeny measurements or trial evaluation	37%	43%
Wood coring	31%	20%
Plus tree selection	29%	23%
Herbarium specimen collecting	26%	20%
Flower induction (hormone injections)	23%	27%
DNA sampling in the field	20%	43%
Number of respondents	35	30

*Question 6 text: Do you have experience with any of the following? Check all that apply: 35 answering, 5 skipped this question. **Question 7 text: Do you have interest in learning any of the following? Check all that apply: 30 answering, 10 skipped this question.

Seed collectors need dependable tools and technology to conduct their work. The most commonly reported tools were smartphones, a seed cooler or dedicated refrigerator, pole pruners and purpose-built seed racks or cone sheds. The use of cherry-pickers and bucket-truck lifts, as well as tree climbing, watercraft and aerial raking equipment was rare.

Twenty-three collectors suggested many ideas to support the sector including improved communication, education and training, networking, workforce recruitment, support with permits for focal species, and online tools to reduce seed forecasting challenges.

Growers

Fifty-six respondents were included in the final analysis. The majority of respondents work for private businesses or contractors (77%) with 2 to 50 employees (61%). This is a relatively small sample compared to Canadian nursery operators accounted by the North American Industry Classification System (NAICS). In 2021, there were:

- 416 forest nurseries and gatherers of forest products; 120 with employees (Code 1132)
- 4,481 greenhouse, nursery and floriculture operators; 2,350 with employees (Code 1114, includes Christmas trees, short-rotation woody crops grown for pulpwood, food crops and bedding plants grown under cover)

Two national datasets reviewed in 2019 for tree planting and production (National Forestry Database - Regeneration and Statistics Canada Table 32-10-0031-01) indicated a potential domestic production supply chain of 617.4 million trees and related economic activity. Table 9 summarizes the 2019

production units reported in our survey. We allowed input of 0 in either coniferous or deciduous categories. The median value is presented including and excluding 0.

Table 9. 2019 native coniferous and deciduous production and sales in Canada reported by growers.

Choice	Range	Median (including 0)	Median (excluding 0)	Total units
Number of native **coniferous** seedlings or vegetative units grown and sold in Canada in 2019 (n=33)	0 – 220 million	3,000	630,000	370,347,880 (91.9%)
Number of native **deciduous** woody seedlings or vegetative units grown and sold in Canada in 2019 (n=35)	0 – 15 million	5,000	19,000	32,826,800 (8.1%)
			Total	**403,174,680**

Question 7 text: In 2019, can you provide or approximate the number of native coniferous seedlings or vegetative units grown and sold in Canada (whole number)? This can include reforestation, restoration and ornamental production. 33 answering (6 reported 0), 23 skipped this question. Question 8 text. In 2019, can you provide or approximate the number of native deciduous woody seedlings or vegetative units grown and sold in Canada (whole number)? This can include reforestation, restoration and ornamental production. 35 answering (7 reported 0), 21 skipped this question.

As expected, including nurseries serving existing public land reforestation commitments resulted in coniferous native trees dominating domestic production volumes. One respondent reported producing just over half of the 2019 survey total. Some growers specialized only in coniferous species.

The 2019 native deciduous woody production reported in our survey was higher than expected from such a small sample. While there were large growers within the deciduous category, the range of quantities was more normal, with just over a third of growers producing up to 10,000 units each in 2019. Some growers specialized only in deciduous species.

Seventy-eight percent of surveyed growers reported using Canadian seed sources for more than half of their 2019 production (see Table 10 for more detail). Just over half of growers reported that it is not difficult to maintain seed origin or genetic identity through their nursery procurement and production processes. However, 16% reportedly do not maintain genetic identity. Challenges included client education and user-friendly technology such as tracking systems for nursery staff and clients to streamline the process.

The majority of growers reported that client understanding and awareness of local genotypes and seed source origin has changed in the last 5 years. Nearly half of growers (46%) claimed seed source requirements have increased, with 45% describing their clients as stringent (very or somewhat) in verifying seed sourcing and registration. Twenty-six percent said it varied by client, indicating some

growers were likely servicing multiple markets. One respondent emphasized that First Nations and environmental companies want to ensure the "right plant is in the right place" in Western Canada.

Eighty-eight percent of growers think Statistics Canada's Annual Greenhouse Nursery and Sod survey could include definitions of native plants and report the share of production units in the standard crop categories. However, a few disliked the additional reporting requirements.

Outside of policy-driven production, distance is often a coarse metric for "local is best" native seed sourcing principles and short production supply chains in other national studies. Growers were asked to report multiple distances and alternative systems for sourcing native seed, liners and stock (Table 10).

Table 10. Distances and production sources for native seed, liners and stock reported by growers.

Choice (grouped by similarity)	Sourcing Seed (%)[1]	Sourcing Liners or Stock (%)[3]
We do not collect or purchase seed (Q11) We do not purchase liners or stock (Q13)	11%	37%
We collect or produce our own seed on site (Q11) We produce our own liners on site (Q13)	66%	48%
We procure from registered seed sources set by jurisdictional policy (Q11) We procure from registered sources set by jurisdictional policy (Q13)	23%	2%
Less than 50 km radius	28%	9%
Less than 100 km radius	26%	11%
100 to 500 km radius	43%	24%
More than 500 km	19%	13%
United States[5]	17%[2]	9%[4]

[1]Question 11 text: How far do you typically source native seed? Within Canada (check all that apply). 47 answering, 9 skipped. [2]Question 12 text: Within the United States (open box answer). 8 answered[5]. 48 skipped. [3]Question 13 text. How far do you typically source liners or stock of native species? Within Canada (check all that apply). 46 answering, 10 skipped. [4]Question 14 text. Within the United States (open box answer). 4 answered[5], 52 skipped. [5]***caution: extremely small base sizes, calculated from preceding question all answering with responses not "no" or "n/a."

When asked what factors growers encounter that limit their capacity to produce more native trees and plants, 48 responded. Note, this question was phrased similarly to a 2021 nursery survey in the United States, which ranked workforce, market, financing and land as the top 4 of 9 factors affecting nursery production expansion.

Table 11. Factors affecting growers' capacity to produce more native trees and plants.

Choice	%
Infrastructure	48%
General labour	48%
Seed availability	40%
Market demand	40%
Financing	33%
Skilled labour	31%
Seed quality	25%
Land	23%
Technology/innovation adoption	19%
Water	17%
Profitability	15%
Seed cost	13%
Lack of desire to expand	13%
Transportation logistics	10%
Seedling/liner availability	8%
Regulations	6%
Other, or please explain above:	13%

Question text: What factors do you encounter that limit your capacity to produce more native trees and plants? Check all that apply.
48 answering, 8 skipped this question.

In general, seed availability and quality were more significant concerns to expansion than seed cost. Since native seed can be collected and stored in advance of production needs, growers were asked how much seed (reported in terms of years of planned production) they had reserved (Table 12).

Table 12. Years of seed storage by species group reported by all growers.

Species Group	Year(s)	%
Conifer	0	59%
	1	3%
	2	3%
	3	14%
	4+	22%
Hardwoods	0	58%
	1	16%
	2	16%
	3	8%
	4+	3%

Shrubs	0	56%
	1	15%
	2	15%
	3	3%
	4+	12%
Native grasses	0	61%
	1	16%
	2	18%
	3	3%
	4+	3%
Herbaceous plants	0	68%
	1	14%
	2	8%
	3	11%
	4+	0%

Question text: How many years of seed do you have in storage to support your current production (i.e., average season's worth of stored seed; if you collect or purchase annually, put 0) By species group: Conifer, 37 answering, 19 skipped. Hardwoods, 38 answering, 18 skipped. Shrubs, 34 answering, 22 skipped. Native grasses, 38 answering, 18 skipped. Herbaceous plants, 37 answering, 19 skipped.

This question was framed to compare to US reforestation supply chain challenges, which reported eastern states had on average 2.5 years of conifer seed, and 0.8 years of hardwood seed stored, whereas the western states had 4.9 and 2.2 years respectively.

In each of these categories, Canadian growers reported:

- An average of 2.5 years of conifer seed in storage (range 0 to 25 years), with more in
  - Nova Scotia: 10 years for 1 respondent
  - Ontario: average 3.7 years for 13 respondents, and up to 25 years for 1 respondent
  - Saskatchewan: 3 years for 1 respondent

- An average of 1 year of hardwood seed in storage (range 0 to 10 years), with more in
  - Saskatchewan: 3 years for 1 respondent
  - Alberta: average 2 years for 11 respondents, up to 10 years for 1 respondent

- An average of 1.4 years of shrub seed in storage (range 0 to 10 years), with more in
  - Alberta: average 2.7 years for 7 respondents, up to 10 years for 1 respondent
  - Saskatchewan: 2 years for 1 respondent
  - Ontario: 1.5 years for 14 respondents, up to 10 years for 1 respondent

- An average of 0.9 years of native grass seed in storage (range 0 to 10 years), with more in
  - Alberta: average 1.9 years for 10 respondents, up to 10 for 1 respondent

- An average of 0.6 years of herbaceous plant seed in storage (range 0 to 3 years), with more in
    - British Columbia: average 0.9 years for 8 respondents, up to 3 years for 2 respondents
    - Ontario: average 0.7 years for 14 respondents, up to 3 years for 1 respondent

It is encouraging to see that despite a small number of responses, those storing seed are on par or averaging better in certain plant groups than expected, notably for hardwoods and shrubs. Twenty-two percent of growers reportedly have 4 or more years of conifer seed on hand to support current production demands. Our survey is the first in Canada to report national shrub, native grasses and herbaceous plant seed storage metrics. This supports recent regional reports asking for broader resource development and native seed banking support for restoration and reclamation objectives. This builds on the success demonstrated by the reforestation industry.

The majority of growers surveyed reported they did not have any seed in storage. It is important to note this data is influenced by jurisdictional policies or understanding of the question; several provinces require tree seed deployed to public lands to be registered and stored at their facility (i.e., British Columbia, Alberta, and Quebec). Seed is owned by the land management agency and provided to growers as needed. Interviewees clarified that only growers serving clients outside these policies or outside their jurisdiction could choose to store their own seed.

Half of the growers reported having difficulty sourcing a variety of species. This data is reported under "Forecasting Demand and Improving Availability" because restoration and reclamation planners were asked the same question.

Thirty-one growers reported a variety of beneficial online directories and nursery association memberships, with RNGR.net and the Canadian Wildlife Federation supplier lists being among the most popular. One third of the growers accessed Canadian Forest Service and Natural Resources Canada resources for production support. Improved support could include more educational awareness, research and extension services, networking opportunities within the sector and technical resources for seed procurement and import.

Restoration and Reclamation Planners, Practitioners, and Planters

Sixty-two respondents were included in the final analysis. While 40% were private businesses or contractors, this survey included slightly larger proportions of federal government departments (24%) and non-governmental organizations (NGO) than other surveys. As a result, a variety of federal and NGO-related funding streams and reporting mechanisms were noted, with Environment and Climate Change Canada, the Nature Conservancy of Canada, and Tree Canada driving more than a quarter of the reported restoration activities.

Most respondents were not aware of, not eligible for, or did not fill out Statistics Canada's Annual Environmental Protection Expenditures Survey (EPES) in 2019, which reported $167 million in expenditures protecting biodiversity and habitat by over 6,000 companies.

In our survey, 31 planting organizations reported a total of $16.2 million as their average annual spend on supply chain services such as site preparation, bulk seed mixes, planting stock, invasive species and herbivore control, as well as seed collection, cleaning and processing services. This included $3.2 million on seed and stock from domestic producers (0.47% of 2019 Canadian nursery sales and resales). Given the small base size and potential lack of reforestation planting agency respondents, the true market value of native seed and planting stock is likely much higher. However, one organization accounted for almost 70% of the total spend, primarily on-site preparation services. The 5 organizations reporting the highest spend accounted for 85% of the total. Across all 31 organizations, the median annual spend was $49,000.

Most claimed to be restoring less than 100 acres at a time, with a median project size of 55 to 60 acres (including or excluding 0, up to 2,000 acres). Respondents reported a high proportion of projects were to support wildlife habitat, ecosystem services, and conservation of native tree species. When selecting planting species, matching the target ecosystem and functional characteristics were the most important factors. Over a third of respondents typically plant 10 or more native trees and shrub species in their work. More than half indicated they do not use non-native species and 5% often do.

In spite of this, respondents reported difficulty in forecasting their planting needs. A third were not able to forecast beyond this year, and only 8% could forecast plant material needs 3 years or longer.

When asked about the limits to the success of these projects, 45 respondents answered (Table 13).

Table 13. Limiting factors to restoration and reclamation projects.

Choice	%
Lack of seed/planting material of desired species and/or seed sources	78%
Cost	53%
Insufficient funding	47%
Lack of knowledge of production/cultivation of desired species	33%
Germination problems	22%
Lack of support from stakeholders (government, local communities)	22%
Labour shortage	20%
Lack of knowledge for matching best species and seed source to restoration/reclamation site	20%
Seed or planting material of desired species/seed sources are poor quality	18%
Policy or regulation	18%
Seed storage problems	16%
Other (please specify)	18%

Question text. What factors do you encounter that limit the success or extent of your restoration/reclamation projects? 45 answering, 17 skipped.

One notable additional comment was from a respondent focused on "the return of life in the soils and create[ing] conditions for other native species to return using their own adaptions." This respondent claimed over 400 species progressively returned after 7 years to their restoration projects. The limiting factor was implied to be a lack of recognition for such results. There was an emphasis on difficult to procure species and planting techniques instead of waiting.

Half of respondents (49%) include a native species definition in their procurement contracts. Most respondents said that definition also makes reference to ecoregion, seed zone, local sourcing by distance (kilometers [km]), or otherwise specified plants with genetic origin parameters. Practices, tools and policies varied significantly, though two thirds (65%) abided by ecodistricts or ecoregions for the majority of their work. Compared to seed collectors and growers, planting organizations had to source from further away; more than half (54%) sought material from 100 to 500 km away. Only 17% produced their own supply on site.

Fifty-six percent say their organization would be willing to pay up to 25% more for genetically appropriate plants and seeds and improved traceability. Forty-eight percent said they have purchased/utilized certified native stock from Canada. However, this was to understand the awareness of trade seed certification systems; there are no current federal interjurisdictional certification regulations, and only 6 native grass species are listed in Canada's federal *Seeds Act*. Two respondents reported purchasing US bulk seed mixes, which may have been certified elsewhere.

Respondents were asked for their opinions about what types of data should be collected to improve restoration outcomes in the future if funding, time, and labour were not constrained.

Table 14. Types of data that could help improve future restoration outcomes.

Choice	%
Survival 2 to 10 years after planting	78%
Seed source and genetic parameters (i.e., number of parent plants, breeding generation, certified sources)	58%
Weather conditions and extreme events on site after establishment	55%
Carbon sequestration rates (growth/biomass accumulation, soil C, etc.) Successional status on the site 5 to 10 years after planting (i.e., volunteer and invasive species encroachment, biodiversity measures)*	55%
Functional traits measured to better select restoration species (i.e., genetic variation, growth rate, palatability, pollinator preferences, pest/disease/salinity/heavy metal/drought tolerance)	53%
Seed testing results (i.e., purity, germination, viability, empty %)	50%
Soil health, microbiota and fertility	50%
Seeding rate/number of seedlings planted	48%
Technique or quality assessment of planting	43%
Area planted	35%
Seed storage conditions (moisture, temperature)	33%
Species specified and received, including substitutions and misidentification	30%
Stock type	28%

Water quality measures	25%
Other important factors	18%

Question text. In your opinion, what data should be collected to improve restoration outcomes in the future (if funding, time, and labour constraints were not a limitation)? Check all that apply. 40 answering, 22 skipped. *"Carbon sequestration rates (growth/biomass accumulation, soil C, etc.) Successional status on the site 5 to -10 years after planting (i.e., volunteer and invasive species encroachment, biodiversity measures)" was intended to be two separate options but reported as is.

Forty-six percent of respondents in this survey claimed to be professionally certified. About half were very or somewhat satisfied with professional conferences and continuing education regarding seed-based restoration. Frequently noted certifications included:

- Forest Gene Conservation Association Certified Seed Collector (CSC)
- Society for Ecological Restoration Certified Ecological Restoration Practitioner (CERP)
- Alberta Society of Professional Biologists (P. Biol)
- BC College of Applied Biology (CAB)
- Canadian Society of Landscape Architects (CSLA)
- International Society of Arboriculture (Certified Arborist)

Some planting organizations were looking for increased Natural Resources Canada support and engagement with the sector, particularly with additional education and training. Funding, seed tracking and distribution, and better connections to the seed supply chain players for enhanced planning would be helpful.

Forecasting Demand and Improving Availability

Matching supply and demand for native species' seed procurement and production was a continual theme throughout recent Canadian reports, surveys and interviews. In the next 5 years, planting organizations told us their top 5 tree and shrub species needed for planting across Canada and within certain regions. Given the timing of our surveys, we assume these responses were based primarily on prior known forest landscape restoration programs and needs within a respondents' region rather than 2 Billion Tree Program planting site prescriptions. We weighted responses by organization size and converted local common names to accepted scientific names using the Database of Vascular Plants of Canada (VasCan 2022).

1. White spruce (*Picea glauca*) – important in Alberta, Ontario, Prince Edward Island, British Columbia and Quebec
2. Eastern white pine (*Pinus strobus*) – important in Ontario, Prince Edward Island, and New Brunswick
3. Black spruce (*Picea mariana*) – important in Newfoundland and Labrador and Nova Scotia
4. Red oak (*Quercus rubra*) – important in Ontario and New Brunswick
5. Paper birch (*Betula papyrifera*) – important in Quebec and New Brunswick
6. Trembling aspen (*Populus tremuloides*) – important in Manitoba and Alberta
7. Bur oak (*Quercus macrocarpa*) – important in New Brunswick
8. Red maple (*Acer rubrum*) – important in Nova Scotia
9. Silver maple (*Acer saccharinum*) – important in New Brunswick
10. Equally ranked were red pine (*Pinus resinosa*), tamarack (*Larix laricina*), green alder (*Alnus alnobetula*), and sugar maple (*Acer saccharum*)

Question text: Which 5 species do you anticipate will be your most planted over the next 10 years? 40 answering, 22 skipped.

Other important and highly ranked species from respondents included whitebark pine (*Pinus albicaulis*) in British Columbia, balsam fir (*Abies balsamea)* in Newfoundland and Labrador and Nova Scotia, and balsam poplar in Manitoba (*Populus balsamifera*). As we allowed input of any species, western wheatgrass (which could be *Pascopyrum smithii* and/or *Elymus trachycaulus*) and blue grama (*Bouteloua gracilis*) also ranked high from Ontario to Western Canada.

In the list above, it may be important for producers outside some of the regions to understand that there are concerns about the genetic composition of certain local populations. In particular:

1. Bur oak is a species of conservation concern in New Brunswick (see CFS Publications)
2. Red and eastern white pine are species of conservation concern on the island of Newfoundland (see CFS Publications)
3. Whitebark pine, black and white spruce are a species of conservation concern in British Columbia (https://climatebc.ca/cataloguing/default)

In terms of improving availability, we also understood that growers and restoration practitioners would likely know what species they have difficulty sourcing to meet recent or short-term FLR clients' needs in their region. This question was asked the same way in both Survey 4 and 5. While there is a chance of duplicate respondents, we felt it was more effective to combine the data, as it reflects needs within two key parts of the supply chain. As some responses were provided at the genera level (i.e., all maples from their region), we opted to group all responses as seed handling and procurement issues are often similar for related species.

The following tree and shrub genera were listed as being "difficult to source" sufficient high-quality and/or genetically-appropriate seed and stock:

1. Maples (*Acer* spp.)
2. Oaks (*Quercus* spp.)
3. Pines (*Pinus* spp.)
4. Larch / Tamarack (*Larix* spp.)
5. Spruces (*Picea* spp.)
6. Hickories (*Carya* spp.)
7. Ash (*Fraxinus* spp.)
8. Willows (*Salix* spp.)
9. Poplars / Aspen (*Populus* spp.)
10. Walnuts (*Juglans* spp.)

Growers Question 26 text. Please list which species you have difficulty with sourcing sufficient, high quality, and/or genetically-appropriate seed or stock. 33 answering, 23 skipped this question. Restoration and reclamation planners, practitioners and planters Question 31 text. Please list which species you have difficulty with sourcing sufficient, high quality, and/or appropriate seed or stock. 37 answering, 25 skipped this question. English and French vernacular names were converted to binomial scientific names in each jurisdiction.

Deciduous trees were twice as difficult to source as coniferous trees, and deciduous shrubs were just as difficult to source as conifers, according to some respondents. Some genera listed above are widespread and commercially important in reforestation (i.e., pines, spruces, larch, and poplar/aspen). Resolving

availability in these species may be permitting or improving access to surplus reforestation seed banks and/or underutilized seed production sources (orchards and managed stands).

Other species do not have robust tree improvement programs across much of their Canadian range at this time, but may in the United States (i.e., oaks, ash, walnuts). The United States is expected to ramp up reforestation and restoration planting (similar commitments to the 2 Billion Tree program). This may limit access to appropriate seed and stock under assisted migration scenarios in the short term.

Recommended Strategies for Sustainable Development of Forest Genetic Resources

Resolving seed supply bottlenecks in the "difficult to source" group of species may require strong reinvestment research and applied breeding programs in each ecologically distinct region. This includes, but is not limited to:

1. **Improving plus tree selection, grafting and pest resistance screening**
   This has proven to be effective in white pine blister rust resistance in whitebark pine, limber pine and eastern white pine (see specific CFS Publications and find out more from Parks Canada's restoration strategies). Ongoing needs in Eastern Canada include screening existing conservation collections and in situ populations of ash species at continued risk of mortality from the alien emerald ash borer, butternut at risk of mortality from butternut canker disease, red oak species at risk of oak wilt disease in Southern Ontario. The National Tree Seed Centre is currently involved in seed banking in advance of pest resistance screening for all 5 ash species, butternut and eastern hemlock.

2. **Understanding population genetic structure and adaptive capacity**
   Using genomic tools to speed up traditional tree breeding cycles is now being applied to some commercially important timber species across Canada (see specific CFS Publications). Although genomic technologies are increasingly affordable, there is still a lack of genetic data available for many ecologically important species in Canada. Increasing species specific knowledge using next-generation sequencing (NGS) technologies will provide enormous levels of data to help make informed decisions about urban forests, climate-based seed zones and transfer mapping. Landscape-level genomics will also improve our international environmental stewardship reputation, as it can support certification standards. A robust NGS genetic library can confirm species identification and the geographic origin of forest exports with international trade partners. Finally, it will allow the means to assess and analyze gaps in long-term seed bank collections aiming to maximize genetic diversity.

3. **Incorporating strategic seed conservation and banking in advance of new threats**
   Many rare tree species were identified as "in demand" through. However, obstacles such as habitat loss and exotic pests and diseases present various challenges. The National Tree Seed Centre is noted as a long-term bank for eastern hemlock (*Tsuga canadensis*) threatened by the invasive pest hemlock woolly adelgid now found in Ontario and Nova Scotia. The NTSC continues to support jurisdictional ex situ programs as a back-up gene conservation strategy for any rare

or declining tree and shrub species. The NTSC is also involved in the research and development of new methods, conventional and cryobiological, to expand the ex situ capabilities to other species at risk or species with recalcitrant seed behavior (e.g., oaks, magnolias, etc.). These proactive efforts will allow methods and procedures to safeguard presently unbanked seed sources and protect against future known and unknown abiotic and biotic threats.

Those seeking a definitive national action plan to help scale emerging forest landscape restoration sectors in their region should consider Chapter 13 of Canada's Second Report for the State of the World's Forest Genetic Resources (2022). This report concludes with 37 key recommendations to address key gaps and short-term needs, particularly as the cumulative impacts of climate change increase on Canada's forest genetic resources:

- 13.1 Availability of information on forest genetic resources – 7 research needs, 2 outreach and information sharing needs
- 13.2 Conservation of forest genetic resources – 8 identified needs
- 13.3 Use, development and management of forest genetic resources – 8 identified needs
- 13.4 Policies, institutions and capacity-building – 8 needs with respect to policies and institutions, and 4 needs with respect to capacity-building

The authors consider this integrated action plan to be "mission critical" to protecting and planting indigenous species and genotypes in the right places now in order to benefit Canadians into the future. Seed saving and production has long provided people and communities with tangible hope and a means of locally-adapted resilience. Fortunately, seeds of native species are accessible to most Canadians to learn about on a personal or professional level, permitted ethical harvesting and local laws are followed. While trees and shrubs can be the most challenging to predict and conserve, growing a collective "future-proof portfolio" for Canada will be a good investment, and always a good news story.

Next Steps for the National Tree Seed Centre (NTSC)

In 2023-2024, the NTSC will be focused on providing training, seed quality control services and low-technology solutions for Indigenous communities and small and medium-sized enterprises to participate in and support the 2 Billion Trees program.

The NTSC will also continue to support our core mandate by storing and providing seed for research and conservation of indigenous tree and shrub species of concern. The NTSC continues to work with federal departments and other national organizations to improve and support biodiversity conservation and recovery targets in national and international reporting.

Contact the NTSC

Visit our website: https://natural-resources.canada.ca/science-and-data/research-centres-and-labs/forestry-research-centres/atlantic-forestry-centre/national-tree-seed-centre/13449

For more information or new support requests, please contact the National Tree Seed Centre's general inbox: ntsc-cnsf@nrcan-rncan.gc.ca

Indigenous communities can direct inquiries to Mary Knockwood, Indigenous Seed Collection Program Coordinator: mary.knockwood@nrcan-rncan.gc.ca
Mobile: 1-506-434-1075

Atlantic Forestry Centre, National Tree Seed Centre
1350 Regent Street
Fredericton, NB E3C 2G6
Tel: 506-452-4162
Fax: 506-452-3525