National Tree Seed Centre

Annual Report

2011

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National Tree Seed Centre
Natural Resources Canada
Canadian Forest Service
Atlantic Forestry Centre
Fredericton, N.B.
June 2012

NATIONAL TREE SEED CENTRE ANNUAL REPORT 2011

EXECUTIVE SUMMARY

The number of seedlots in storage increased to 13 386. Of this number, over 6,650 seedlots are stored under Seed Bank and are available for research, and over 4,600 seedlots are stored for genetic conservation.

Seed production was moderate in the Maritimes in 2011. Ninety collections were made by National Tree Seed Centre staff and 14 *Populus* seedlots from Quebec were processed as part of a genomics project. Fifty-seven seedlots were purchased and nine were donated.

A total of 45 requests for seed resulted in 364 seedlots provided for research. The majority of the requests were from Canada (37 requests; 269 seedlots) but seed was also sent to France (4 requests; 27 seedlots), Spain (2 requests; 29 seedlots), Sweden (1 request; 6 seedlots), and United States (1 request; 33 seedlots).

Seed testing consisted of 1,528 germination tests, 1,297 moisture content tests, and 103 thousand-seed weight tests. A significant proportion of the germination testing was re-testing of seedlots tested 10 years ago which provides an up-to-date assessment of seed quality. The data are also used to evaluate long-term storage potential.

Other activities during the year included:

- Seed storage potential was evaluated for 34 tree species by examining germination data. Seedlots of *Picea mariana* and *Pinus resinosa*, in storage for over 40 years, had the highest germination of 96.5% and 98.0%, respectively. *Betula alleghaniensis* seed stored for almost 40 years germinated at 83%. Overall, the results demonstrate that high quality tree seed stored at a low moisture content and sub-freezing temperature will retain high viability for many decades.

- Results from a *Thuja occidentalis* storage experiment revealed that after four years, seed stored at 4°C exhibited a steady decline in germination and an increasing proportion of low vigor germinants. Seed stored at -20°C had a slight decline in germination.

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INTRODUCTION

In the 1960s, tree genetics and breeding research was expanding across Canada. There was increasing demand for small quantities of seed of known origin and quality for provenance testing. In response to this need, the Canadian Forest Service established the National Tree Seed Centre (NTSC) in 1967 at the Petawawa Research Forest (formerly Petawawa Forest Experiment Station), Chalk River, Ontario. At that time, reforestation programs across Canada were being initiated or were expanding and there was a need for large quantities of seed as well as knowledge on how to collect, process, test, and store tree seed. Germination testing protocols existed for the major conifer reforestation species, but in some cases, fine tuning was required. As well, the Seed Centre played an active role in acquiring and disseminating seed of native and non-native species to researchers to establish provenance trials and other genetic tests. A significant accomplishment of the Seed Centre was the development of the Petawawa Germination Box. This was in response to the need for a container of appropriate size to permit maximum use of germinator space, allow for full development of germinants, and maintain uniform moisture levels in the germination medium.

Following a review of the research program within the Canadian Forest Service the NTSC was transferred to the Atlantic Forestry Centre in Fredericton, N.B. in 1996. The mission of the NTSC is to safeguard Canada's forest genetic resources in the face of climate change and other threats by acquiring, evaluating, preserving, and providing a national collection of forest genetic resources to assist in securing the forest biological diversity that underpins the sustainable development of Canada's forests.

This report covers the activities of the NTSC for 2011. Similar reports were prepared from 1998–2010. The report also captures the results of tests and experiments that were conducted during the year in order to ensure that this information is synthesized and reported.

STATUS OF INVENTORY

Seed is stored in four categories: Seed Bank, Genetic Conservation, Reserved, and Tree Breeding (Table 1). The total number of seedlots increased by 92 to 13 386 in 2011. The numbers in brackets in Table 1 represent the numbers reported in the 2010 Annual Report.

Table 1. Seed stored at the NTSC as of December 31, 2011

Seed Bank		Genetic Conservation		Reserved		Tree Breeding	
No. species	No. seedlots	No. species	No. seedlots	No. species	No. seedlots	No. species	No. seedlots
150 (156)	6,661 (6,623)	49 (48)	4,610 (4,370)	37 (37)	1,725 (1,911)	10 (10)	390 (390)

Seed Bank seedlots are the active collection that are available for distribution for research. Since 1998, the number of seedlots in the Seed Bank collection has increased from 3,079 to 6,661 (Figure 1). This number represents seedlots from native and non-native species. The increase represents the net gain after discarding seedlots due to low germination and the depletion of seedlots as they are provided to clients. In 2011, 24 seedlots were depleted.

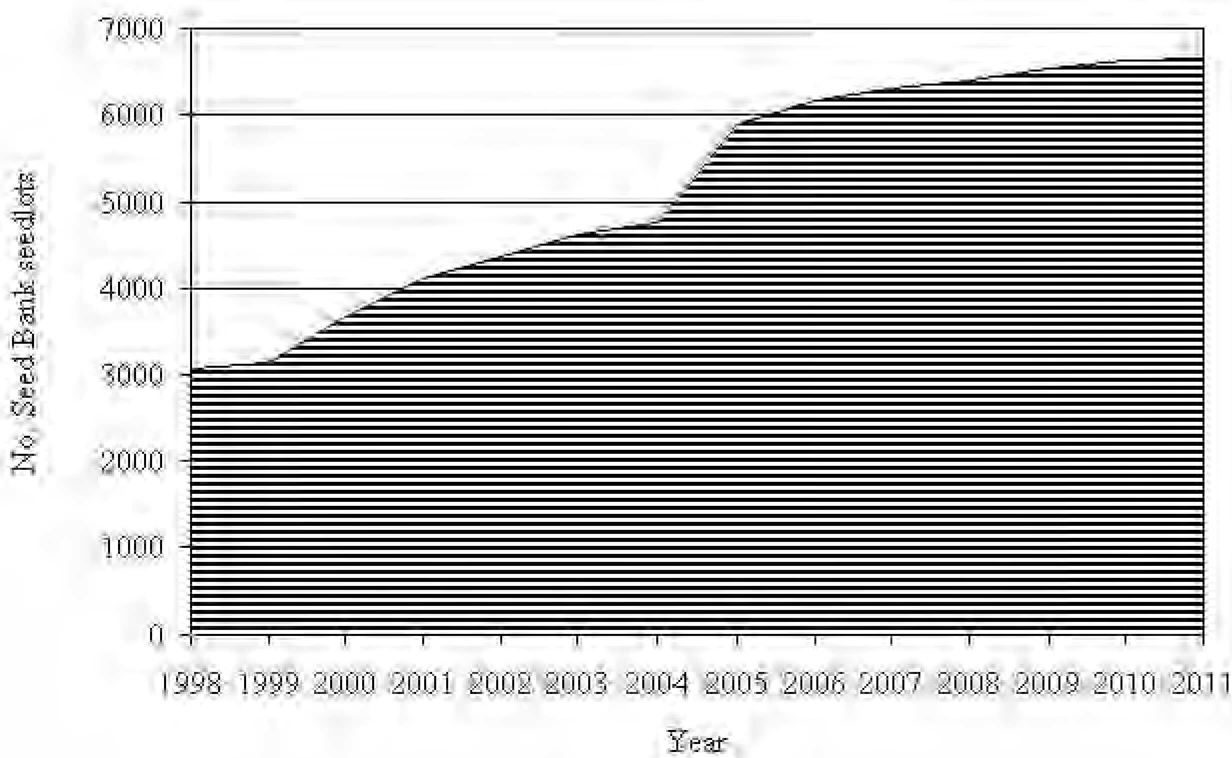

Figure 1. Increase in number of Seed Bank seedlots stored at the NTSC since 1998.

One of the objectives of the NTSC is to obtain seed samples of Canadian tree and shrub species from across their natural ranges. As of December 31, 2011, the NTSC Seed Bank had 6,383 seedlots from 112 Canadian species in storage (Table 2). Seed from 38 non-native species (278 seedlots) are also stored. Seed has been collected from some non-native species growing in Canada but most of the seedlots are from species native to other countries. The proportion of seed from non-native species continues to decrease as seedlots become exhausted due to client requests and no effort is made to replace them. Clients can be directed to seed centres in other countries that have seed from species they need.

Table 2. Number of native species, number of seedlots, and percentages by province of seedlots stored in the Seed Bank category

Province	No. species	No. seedlots	Percent
Alberta	12	45	0.7
British Columbia	32	297	4.7
Manitoba	7	66	1.0
New Brunswick	68	1,471	23.0
Newfoundland and Labrador	17	169	2.6
Nova Scotia	39	555	8.7
Ontario	49	2,354	36.9
Prince Edward Island	32	254	4.0
Quebec	26	1,001	15.7
Saskatchewan	10	125	2.0
Yukon Territory	3	46	0.7
Total	112	6,383	100

Since the Seed Centre moved to Fredericton, staff have concentrated their efforts acquiring collections from New Brunswick, Nova Scotia, and Prince Edward Island. Travel beyond the Maritime provinces is challenging due to limited resources (staff and budget). There is an ongoing effort to acquire seed from other provinces and Seed Centres when opportunities arise. Since collections by NTSC staff are unlikely due to distance and costs, these seedlots are purchased or obtained through donation.

The Genetic Conservation category was initiated in 2000 using seed already in storage. Its purpose is to conserve the genetic variation occurring in natural populations as well as to ensure that genetic material from rare, endangered, and/or unique populations is preserved. Over the past six years, seed collecting has focused on expanding the genetic conservation collection. Any surplus seed from these collections is placed in Seed Bank. The collection increased by 240 to 4,610 seedlots primarily due to the transfer of red spruce (*Picea rubens*) seed from Reserved.

Figure 2 shows the increase in the number of seedlots in this category since 2000. There is seed from 49 species in Genetic Conservation with the number of seedlots ranging from 1 to 1,641 (Table 3).

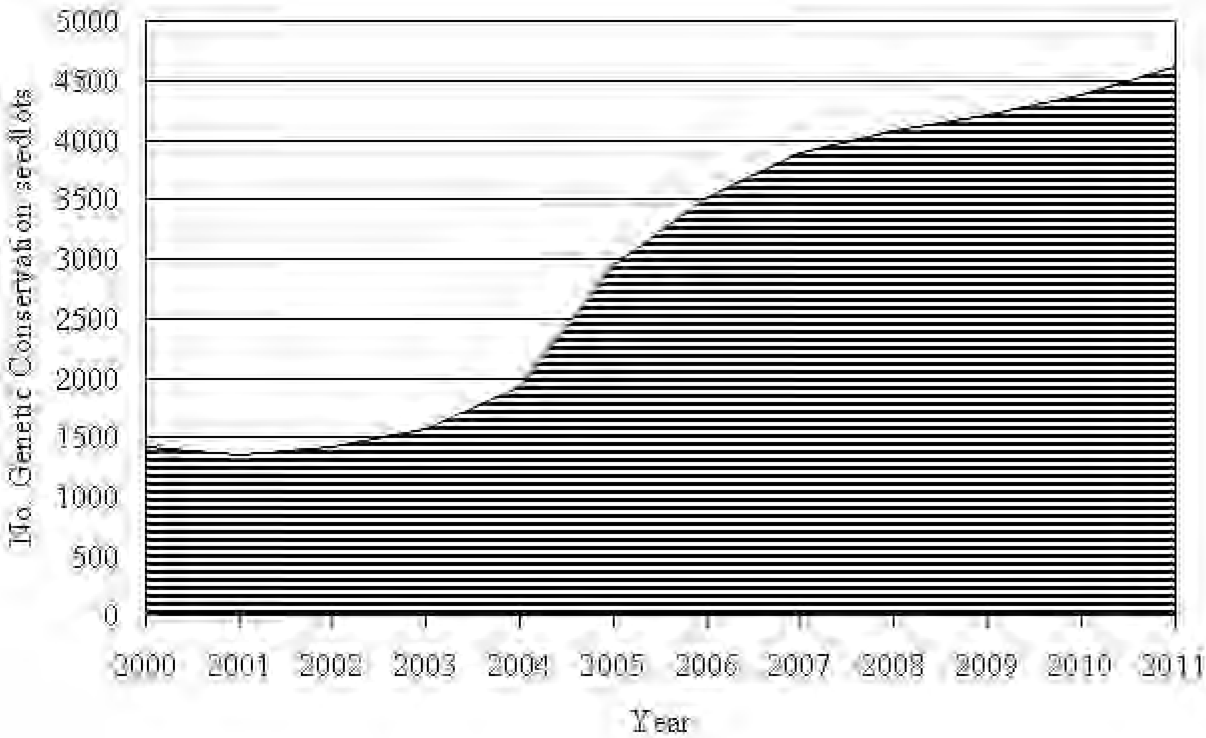

Figure 2. Increase in the number of Genetic Conservation seedlots stored at the NTSC since 2000.

The Reserved category contains seedlots that have been reserved by researchers. Many of these seedlots were collected for special projects. The collection was reduced by 186 red spruce seedlots that were no longer needed by the scientist who had them reserved. The seedlots which were primarily single-tree collections, were tested for moisture content and germination and transferred to the Gene Conservation collection.

The Tree Breeding category is composed of seedlots that originated from the genetics program at the Petawawa Research Forest and were transferred to the Seed Centre for storage. There was no change in this category.

Table 3. Species and number of seedlots stored in Genetic Conservation

Species	No.	Species	No.
Abies balsamea	8	*Picea glauca*	1641
Acer negundo	15	*Picea glauca* var. *albertiana*	9
Acer pensylvanicum	17	*Picea glauca* var. *porsildii*	15
Acer rubrum	109	*Picea mariana*	413
Acer saccharum	23	*Picea rubens*	222
Acer spicatum	50	*Pinus banksiana*	95
Alnus incana spp. *rugosa*	3	*Pinus contorta* var. *latifolia*	2
Alnus incana spp. *tenuifolia*	1	*Pinus flexilis*	101
Alnus serrulata	2	*Pinus pinceana*	181
Alnus viridis spp. *crispa*	9	*Pinus ponderosa*	2
Betula alleghaniensis	57	*Pinus resinosa*	15
Betula cordifolia	5	*Pinus rigida*	4
Betula minor	1	*Pinus strobus*	32
Betula papyrifera	10	*Pinus sylvestris*	12
Betula populifolia	20	*Populus balsamifera*	20
Betula spp.	1	*Populus grandidentata*	13
Cephalanthus occidentalis	1	*Populus tremuloides*	16
Cornus florida	4	*Prunus pensylvanica*	61
Fraxinus americana	223	*Prunus virginiana* var. *virginiana*	337
Fraxinus nigra	159	*Salix lantana* spp. *richardsonii*	1
Fraxinus pennsylvanica	155	*Thuja occidentalis*	89
Fraxinus profunda	1	*Thuja plicata*	2
Fraxinus quadrangulata	1	*Tsuga canadensis*	183
Larix laricina	267	*Tsuga mertensiana*	1
Larix occidentalis	1		

SEED COLLECTIONS

Seed production was moderate for most species in the Maritimes but there were some species that had good seed production, however this varied by location. In order to ensure good quality seed, seed is only collected during good seed years. Seed collected in good seed years is of better genetic quality because of ample pollen production and higher physiological quality due to trees allocating significantly more resources to the developing seed crop. Also, less time is required to collect sufficient seed when there is a good seed crop. A total of 104 seedlots from 13 species was collected or processed by Seed Centre staff (Table 4).

Sixty-six collections were made in New Brunswick, 5 in Nova Scotia, and 33 in Quebec. Seed Centre staff collaborated with personnel from CFS-Laurentian, Quebec by processing and testing seed from several *Populus* species and hybrids. These collections contributed to a multi-agency project titled "Monitoring of novel genome regions during the introgression process in poplars" which is being led by Dr. Nathalie Isabel of CFS-Laurentian.

Table 4. Seed collections made by Seed Centre staff in 2011

Species	NB	NS	QC	Total
Alnus serrulata	2			2
Alnus viridis spp. *crispa*		5		5
Fraxinus pennsylvanica	21			21
Picea abies	1			1
Picea mariana			19	19
Pinus resinosa	1			1
Pinus strobus	20			20
Populus balsamifera			5	5
Populus deltoides ssp. *deltoides*			4	4
Populus x *jackii*			3	3
Populus hybrids			2	2
Thuja occidentalis	20			20
Viburnum alnifolium	1			1
Total	66	5	33	104

The NTSC also acquired seed via donation and purchase. Nine seedlots of *Picea glauca* and four seedlots of *Pinus banksiana* were donated by the Saskatchewan Ministry of Environment. Twenty-five seedlots, purchased from Yellow Point Propagation Ltd., Ladysmith, BC, consisted of: 2 *Abies amabilis*, 1 *A. grandis*, 1 *A. lasiocarpa*, 1 *Alnus rubra*, 1 *Alnus viridis* spp. *sinuata*, 8 *Picea sitchensis*, 4 *Pinus contorta* var. *contorta*, 1 *P. ponderosa*, 4 *Pseudotsuga menziesii* var. *menziesii*, 2 *Thuja plicata*, and 1 *Tsuga heterophylla*. Eleven seedlots were purchased from Silva Enterprises Ltd., Prince George, BC and consisted of 6 *Pinus contorta* var. *latifolia* and 5 *Pseudotsuga menziesii* var. *glauca*. Twenty-one seedlots were collected and purchased from Haveman Brothers Forestry, Kakabeka Falls, ON and consisted of 1 *Picea mariana* and 20

Thuja occidentalis. Table 5 shows the number of seedlots acquired by the NTSC since 1996. About 57% of the seedlots were obtained through collection and a substantial number, 37%, were donated.

Table 5. Number of seedlots acquired by the NTSC through collection, donation, and purchase between 1996 and 2011

Year	Number of Seedlots			
	Collection	Donation	Purchase	Total
1996	239	22	0	261
1997	75	245	0	320
1998	284	47	9	340
1999	139	80	0	219
2000	195	673	0	868
2001	137	122	45	304
2002	367	36	0	403
2003	69	142	0	211
2004	549	381	137	1067
2005	142	29	3	184
2006	329	42	30	401
2007	190	181	0	371
2008	160	3	0	163
2009	137	75	30	242
2010	37	0	2	39
2011	104	9	57	170
Total	3153	2087	313	5553

SEED REQUESTS

The Seed Centre's policy is to provide seed, at no cost, for scientific research. Seed is also provided to universities and other educational institutions for educational purposes and to arboretums. A Seed Request Form must be completed by the client before a seed order is processed. The purpose of this form is to gather information on the type of research being carried out and to serve as a means for screening requests. Seed requests received from international clients are referred to the Canadian Food Inspection Agency to determine if an import permit is required and for the issue of Phytosanitary Certificates.

During 2011, 45 requests representing 364 seedlots were processed. The majority of the requests were from Canada but seed was also sent to France, Spain, Sweden, and United States (Table 6). The number of seedlots provided by the NTSC since 1967 has ranged from a low of 99 in 1996 to a high of 1,603 in 1985 (Figure 3). Canadian researchers have received about 70% of the seed while international clients accounted for the remaining 30%.

Table 6. Number of requests and number of seedlots shipped by country in 2011

Country	No. requests	No. seedlots
Canada	37	269
France	4	27
Spain	2	29
Sweden	1	6
United States	1	33
Total	45	364

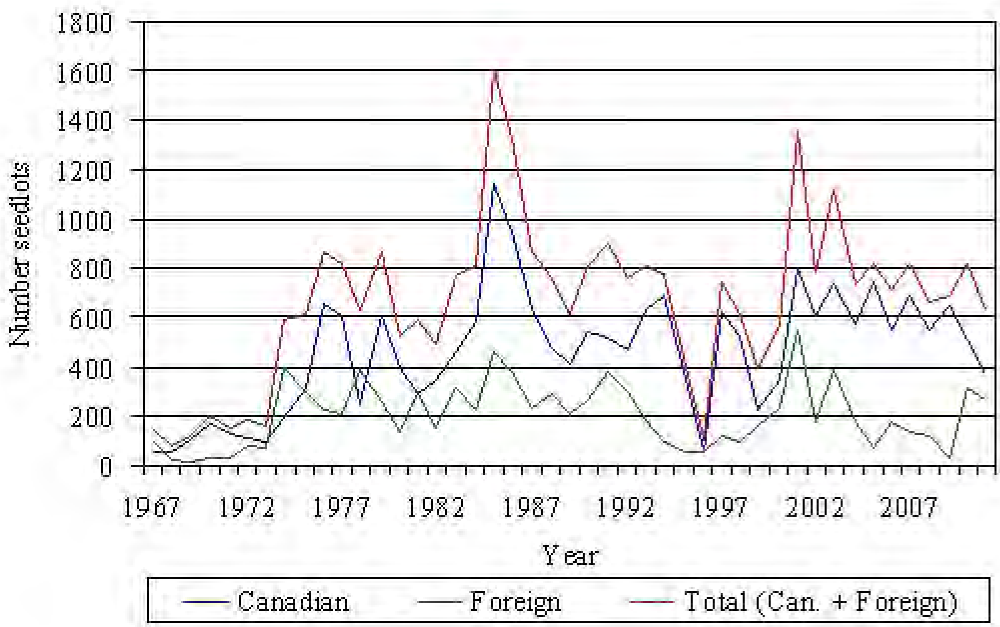

Figure 3. Number of seedlots sent to clients between 1967 and 2011.

SEED TESTING

Germination tests are performed on all seedlots prior to storage as well as seedlots in storage. In most cases, four replicates of 50 seeds each are placed on moistened Versa-Pak in Petawawa Germination Boxes. When larger seed are being tested, the number of seed is usually reduced. **One thousand five hundred and twenty-eight germination tests** were carried out. Seedlots in storage are tested every 10 years. The last cycle of testing was completed in 2001. Now, that these seedlots are 10 years older, the results are particularly useful to evaluate the seed storage potential for many species. See the “Seed Storage Potential” section in Research and Development for further details.

Figure 4 shows the number of tests carried out by the NTSC since 1983. Some testing was carried out prior to 1983 (1970–82), however, the number of tests conducted was low. The reduction in the number of tests between 1994 and 1996 coincided with the transfer of the Seed Centre from Petawawa to Fredericton.

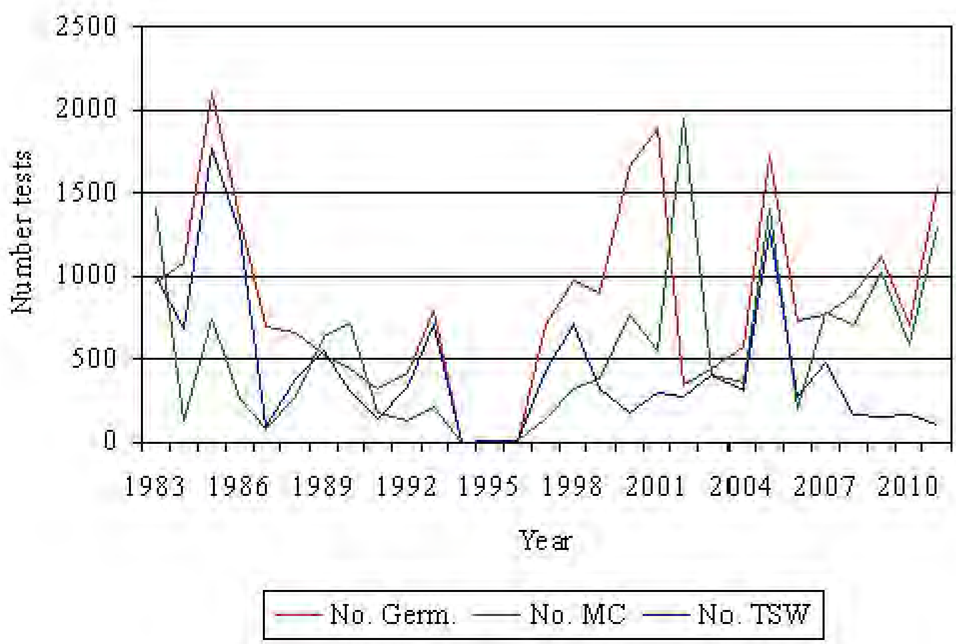

Figure 4. Number of germination tests (No. Germ.), moisture content tests (No. MC), and thousand-seed weight tests (No. TSW) carried out by the NTSC since 1983.

The target moisture content (MC) for orthodox seed is between 5 and 8%. Seed that are above this range are dried before being stored. **One thousand two hundred and ninety-seven moisture content** determinations were carried out. MC is checked when seed are re-tested. If MC exceeds 8% the seed are conditioned to lower their MC. Seventy-nine seedlots were conditioned.

Once MC is within acceptable limits, the 1000-seed weight is determined. This is carried out by counting and weighing eight replicates of 100 seeds. When dealing with small seed (alders, birches, poplars, willows) fewer replicates are performed. When the collected sample is small (less than 800 seeds), the total number of seed is counted, the total weight of the sample is determined, and the 1000-seed weight calculated. A total of **one hundred and three 1000-seed weights** was done.

RESEARCH AND DEVELOPMENT

Seed Storage Potential

Storage of tree seed is important for reforestation programs, research, and conservation. Physiological quality of the seed must be maintained during storage for rapid germination and subsequent development and growth of healthy, normal seedlings. The two principal factors influencing seed storage are seed moisture and storage temperature. Drying seed to an equilibrium of 5–20°C and 15–25% of relative humidity (moisture content of 4–7%, depending on species), and storing seed at -18±3°C are considered to be the minimum storage standards (Anon. 2011).

The National Tree Seed Centre maintains seed moisture less than 8% and stores seed at -20°C. Seed is germination tested to monitor viability. Testing has been conducted for over 30 years using standardized procedures. Some older seedlots have been in storage for over 50 years and many seedots have been tested many times. Hence, a sizeable database has been built up over the years and has been used to demonstrate the long-term storage ability for a number of species (Simpson et al. 2004, 2007).

The frequency at which seed is retested at the Seed Centre is 10 years. Retesting of all previously tested seedlots was completed over a three-year period, 2009–2011. The data provided the opportunity to evaluate the storage potential for a number of species (17 conifers and 17 hardwoods) by identifying individual seedlots that exhibited higher or highest germination following the most recent tests.

Methods

Seed moisture was determined by the oven method whereby seed in aluminum containers was placed in a force draft oven set at 103°C for 17 ± 1 hr. Following drying, containers were weighed and moisture content was calculated on a wet weight basis.

Seed that are dormant were treated to alleviate dormancy before germination testing. The most common treatment is moist chilling for 21 days. *Tsuga canadensis*, *Acer rubrum*, and *A. saccharum* seed require longer durations of moist chilling and seed from *Fraxinus* species require warm and cold treatments. Germination testing was carried out by placing four replicates of up to 50 seed each on moistened Versa-Pak™ in Petawawa Germination Boxes. Seed that required moist chilling were placed in a walk-in cooler at 4°C for the appropriate duration. Seed were germinated in a Conviron G30 germination cabinet set at 20°C for 16 hours with no light and 30°C for 8 hours with light and a constant relative humidity of 85%. *Tsuga canadensis* seed were tested at 15°C with 8 hours light/24 hours.

Germination was assessed regularly and a seed was considered to have successfully germinated when the cotyledons were visible and the radicle and hypocotyl were well developed.

Results and Discussion

The data were evaluated to identify one older seedlot from each species that had the higher or highest, current germination. Once this was done the database was searched to find the first germination test result for each chosen seedlot. As well, the current moisture content for each seedlot was obtained. If no current value was available, then the most recent value was used. Data for 17 conifer and 17 hardwood species are presented in Table 7.

For conifer species, the age of seedlots in storage ranged from 11 to 55 years. The pines and spruces exhibited high germination with *Picea mariana* and *Pinus resinosa* having the highest (96.5% and 98.0%, respectively) for seed in storage for 40 or more years. *Pinus rigida* seed had 100% germination after 25 years. Seed quality declined little for species such as *Abies balsamea*, *Picea mariana*, *Pinus banksiana*, *Pinus contorta* var. *latifolia*, *Pinus resinosa*, and *Pinus rigida* where the test interval was more than 20 years. Seed of the two *Thuja* species showed a marked decline in germination with *Thuja occidentalis* seed deteriorating faster. The rapid decline for these species may be due to aspects of seed morphology such as a thin seed coat, resin vesicles on the surface of the seed coat that can impact viability if they become damaged, and a small amount of megagametophyte which restricts the amount of storage reserves. The two species of *Tsuga* showed differences in seed storability with the *Tsuga canadensis* seedlot having much higher germination than the *Tsuga heterophylla* seedlot after the same storage duration. *Tsuga canadensis* seed are more dormant and this may promote longer storability. Moisture content was below 8% for all species except *Pinus banksiana*. The small quantity of seed remaining precluded updating moisture content for six species.

Hardwood seed also stored quite well. The age of seedlots in storage ranged from 5 to 38 years. No one genus stood out as exhibiting higher germination. The Salicaceae species (*Populus* and *Salix*) exhibited very high germination. However, the three *Salix* species have not been in storage for many years. There was no change in germination of *Betula alleghaniensis* seed over a 23 year period. Seed moisture contents exceeded 8% for *Acer rubrum*, *Alnus rubra*, *A. viridis* spp. *crispa* at the time of germination testing and these seedlots were subsequently conditioned to below 8% but the *Fraxinus nigra*, *Salix bebbiana*, and *S. discolor* seedlots were not conditioned. Seed of *Betula alleghaniensis* and *Ulmus americana* stored well and their moisture contents were 5.37% and 5.55%, respectively.

The results demonstrate the potential for storing seed of these species for many decades. Simpson et al. (2004) suggested that seed of some conifer species can be stored for up to 100 years while maintaining a germination greater than 60%.

Table 7. Impact of storage time on seed germination for 17 conifer and 17 deciduous species. Seed moisture content (MC) is presented for current tests

	Initial testing		Current testing		
Species	Yrs in storage	% Germ.	Yrs in storage	% Germ.	% MC
Abies balsamea	8	81.0	30	81.5	3.87
Larix laricina	14	96.0	27	85.0	4.20[1,2]
Picea glauca	16	96.0	42	81.0	6.212
Picea mariana	24	97.2	40	96.5	6.79
Picea rubens	33	81.2	55	75.5	7.14
Picea sitchensis	29	82.0	39	89.0	7.52
Pinus banksiana	25	95.0	50	92.0	8.88[1,2]
Pinus contorta var. *latifolia*	2	93.5[3]	35	90.0	-[1]
Pinus resinosa	0	97.5	41	98.0	5.60[1,2]
Pinus rigida	0	100.0	25	100.0	4.60[1,2]
Pinus strobus	23	97.0	32	96.5	7.17
Pseudotsuga menziesii var. *glauca*	6	83.0	18	94.0	6.97[2]
Pseudotsuga menziesii var. *menziesii*	5	86.7	17	93.5	7.87
Thuja occidentalis	1	92.8	11	68.5	7.2
Thuja plicata	7	90.0	17	68.5	7.06
Tsuga canadensis	0	63.8[4]	19	96.5	6.17[1,2]
Tsuga heterophylla	3	93.5	19	79.0	6.40[2]
Acer rubrum	5	92.0	15	91.0	9.37
Acer saccharum	12	72.0	22	76.0	7.83
Alnus incana spp. *rugosa*	5	83.2	22	76.0	6.73
Alnus rubra	2	100.0	23	90.0	9.73
Alnus viridis spp. *crispa*	5	83.0	24	78.0	8.99
Betula alleghaniensis	15	83.0	38	83.0	5.27
Betula papyrifera	5	98.0	15	95.0	7.90
Betula populifolia	5	94.0	12	87.5	6.91[2]
Fraxinus americana	23	96.0	28	92.0[5]	6.74
Fraxinus nigra	13	85.0[5]	21	81.0[5]	8.81[2]
Fraxinus pennsylvanica	-	-	14	87.0[5]	7.37
Populus grandidentata	0	99.0	19	93.5	6.27[2]
Populus tremuloides	0	98.0	11	100.0	7.24[2]
Salix bebbiana	0	96.0	6	97.5	9.16[2]
Salix discolor	0	98.0	6	93.0	8.34[2]
Salix nigra	3	97.0	5	94.0	7.67[2]
Ulmus americana	0	96.5	19	96.0	5.55

[1] small quantity of seed
[2] previous MC value
[3] seed not moist chilled
[4] seed moist chilled 8 weeks vs. 20 weeks for current test
[5] excised embryo test

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Eastern White Cedar Seed Storage Experiment

Eastern white cedar (*Thuja occidentalis*) is common in New Brunswick, Québec, and Ontario but can also be found in parts of Nova Scotia and Prince Edward Island. The species is listed as vulnerable in Nova Scotia.

Seed measure 3–5 mm in length and have lateral wings making the seed almost as wide as it is long (Brand and Schopmeyer 2008). Thousand seed weight varies between 0.75 and 1.50 grams. The seed cannot be de-winged and the light seed weight and the attached wing make it difficult to remove empty seed by aspiration. Consequently seed germination is often mediocre unless very good seed set occurs.

Seed do not require moist chilling (ISTA 2012, AOSA 2002) however, there has been some debate in the literature (Brand and Schopmeyer 2008). The seed are considered orthodox and can therefore be dried and stored in sub-zero conditions. There is uncertainty as to how long *Thuja* seed can be stored and retain viability. Seed should retain viability for up to 5 years if stored in sealed containers at 0 to 5°C and at a moisture content of 5 to 10% (Bonner 1991). Seed kept for longer durations should be stored at -18°C (Brand and Schopmeyer 2008). Mean germination of eight eastern white cedar seedlots remained constant at 61% after ten or eleven years of storage at -20°C at the National Tree Seed Centre (NTSC) (Daigle and Simpson 2008).

In 2006, the NTSC received 15 single tree collections of eastern white cedar cones from the Petawawa Research Forest, Ontario. The seed were processed and moisture content and germination were determined. Seed quality was very good and the quantity of seed received provided an opportunity to set up a seed storage experiment. Results after one, two, and four years in storage are reported here from a storage trial established at the NTSC.

Material and Methods

Seed from 12 trees were put in 20 ml screw cap plastic vials. Mason jars (250 ml), containing four vials each, were placed in storage at 4°C and -20°C. Sufficient seed was stored for germination and moisture content assessments at 1, 2, 4, 8, 16, and 32 years.

At the end of each storage duration, jars stored at -20°C were removed and placed at 4°C for 24 hours. These jars and those stored at 4°C were then removed and allowed to warm to room temperature before being opened. Moisture content was determined by the oven method using 0.5 to 1.0 grams of seed per replicate. Germination tests were set up by placing four replicates of 50 seed each on moistened Versa-Pak™ in Petawawa Germination Boxes. The boxes were put into a Conviron G30 germination cabinet for 21 days. Germination conditions consisted of a daily cycle of 8 hours at 30°C with light and 16 hours at 20°C without light with a constant relative humidity of 85%. Seed were assessed every two days starting at day 9. A seed was considered to have successfully germinated when the cotyledons were visible and the hypocotyl and radicle were well developed.

The impact of moist chilling on germination was evaluated using seed that had been stored for four years. Seed were placed in germination boxes as previously described, the boxes put in a walk-in cooler at 4°C for 21 days then placed into a germination cabinet for 21 days following the same germination conditions and evaluation as above.

Results and Discussion

Mean moisture content of the 12 seedlots at the time of storage was 6.47% (Table 8). The moisture content of seed stored at -20°C was less than the initial value following each of the three storage durations but exhibited a steady increase with time. In contrast, seed stored at 4°C had a substantially higher moisture content after one and two years in storage while after storage for four years the value was only slightly higher than before storage. The increase in mean moisture content of seed stored for one and two years was due to an increase for four seedlots and three seedlots, respectively (Fig. 5). These seedlots were stored together in the same Mason jars for each of the storage durations. It is likely that the lids on these Mason jars were not completely tight allowing moisture from the air in the cooler to infiltrate the jar and enter the storage vials. Other than these seven instances, there was little fluctuation in seed moisture content within seedlots among the three storage durations.

Table 8. Mean moisture content (%) of 12 eastern white cedar seedlots before storage and after three periods in storage at 4°C and -20°C

Storage temperature	Time in storage			
	Before storage	1 year	2 years	4 years
4°C	6.47	7.56	7.75	6.66
-20°C	6.47	6.05	6.14	6.28

Seed germination declined with time in storage with the greatest decline occurring for seed stored at 4°C where germination decreased over 60% after four years in storage (Fig. 6). In contrast, germination declined by just over 7% for seed stored at -20°C. The variation among seedlots was higher for seed stored at 4°C. A greater proportion of the seed stored for four years at 4°C developed mold during germination tests than seed stored at -20°C for the same duration.

Mean germination of the four seedlots with high moisture contents after one year in storage was 83.5% compared to the seedlots stored in the other jars which had a mean germination of 67.9%. Mean germination of the three seedlots with high moisture contents after two years in storage was 91.5% compared to the seedlots stored in the other jars which had a mean germination of 46.3%. The low germination of the other seedlots was due to two seedlots that deteriorated faster than the others. Clearly the elevated moisture content of the seed had no or minimal impact on germinaton at those particular time points.

The number of low vigor germinants was recorded. A low vigor germinant is one for which the cotyledons were not visible or the hypocotyl was not well developed or the radicle was poorly developed. Low vigor germination is a good indicator of decline for a seedlot. The proportion of low vigor germinants increased during storage (Table 9). Seed stored at 4°C exhibited an increasing proportion of low vigor germinants with storage time whereas the percentage of low vigor germinants for seed stored at -20°C was substantially less and had reached a plateau after 2 years in storage.

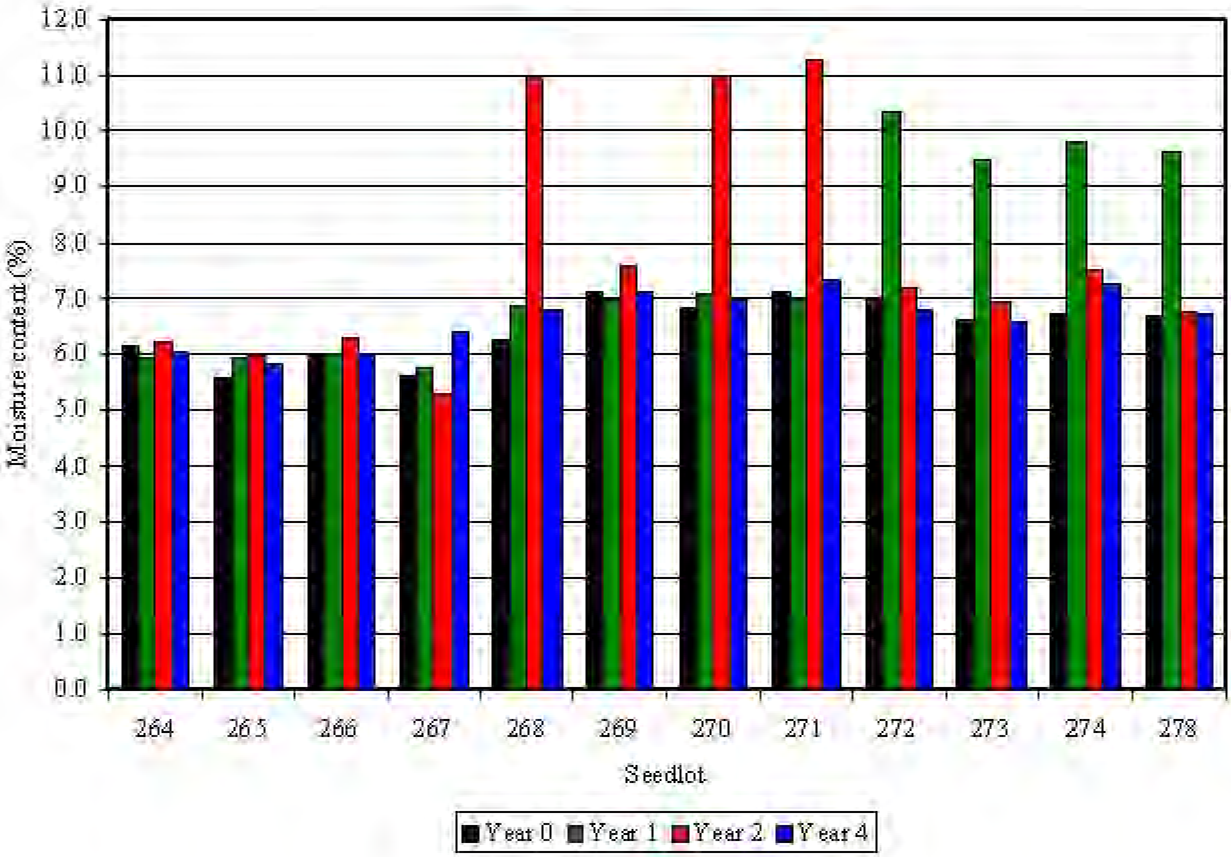

Figure 5. Changes in moisture content of 12 eastern white cedar seedlots before storage and after storage at 4°C for three durations.

Table 9. Mean low vigor germination (%) of 12 eastern white cedar seedlots before storage and after three periods in storage at 4°C and -20°C

Storage temperature	Time in storage			
	Before storage	1 year	2 years	4 years
4°C	1.3	5.9	9.9	13.6
-20°C	1.3	3.6	2.7	2.6

It is generally accepted that eastern white cedar seed are not dormant. However, a supplementary series of germination tests on seed stored for four years was conducted to evaluate the impact that moist chilling would have on germination and germination speed. Total germination of chilled seed was slightly less for seed stored at 4°C compared to unchilled seed but germination of chilled seed stored at -20°C was somewhat higher than that for unchilled seed (Table 10). Essentially there was no difference in germination between chilled and unchilled seed demonstrating that eastern white cedar seed are not dormant. However, there was a difference in mean germination time (MGT) with chilled seed germinating faster. The MGT was least for chilled seed stored at -20°C (12.9 days). Moist chilling seed has two benefits. First, if seed are dormant, moist chilling alleviates dormancy thus promoting more seed to germinate within a prescribed time period. Second, moist chilling increases germination speed which can be advantageous for greenhouse seedling production by decreasing the time period when temperature is elevated to promote germination thus reducing costs.

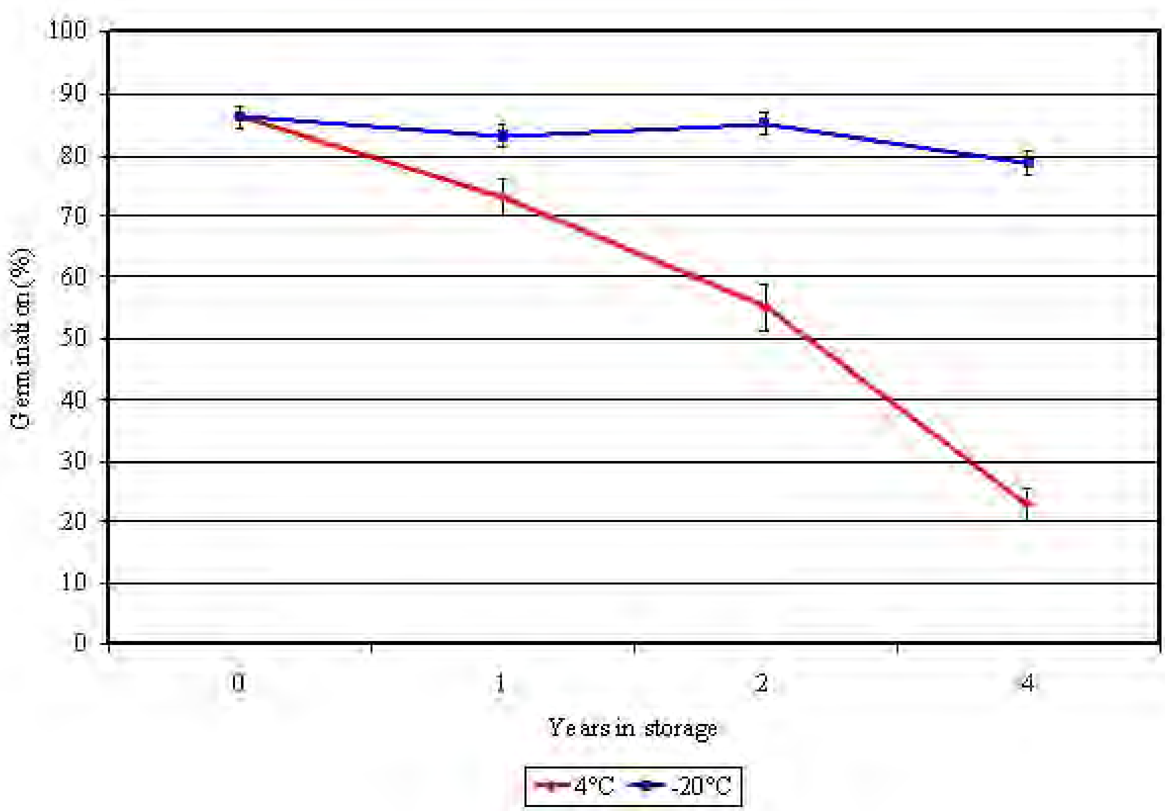

Figure 6. Mean germination over four years of 12 eastern white cedar seedlots stored at 4°C and -20°C.

Table 10. Mean germination (%) and mean germination time (days) of seed from 12 eastern white cedar seedlots stored for four years at 4°C and -20°C and treated by moist chilling or no chilling

	Seed stored at 4°C		Seed stored at -20°C	
	Unchilled	Chilled	Unchilled	Chilled
Germination	23.1	22.5	78.7	81.0
Mean germination time	17.3	14.6	16.3	12.9

Conclusions

Eastern white cedar seed exhibit orthodox storage behaviour demonstrated by their ability to germinate after being dried to less than 7% moisture content and placed in -20°C storage. Seed do not store well at 4°C as was evidenced by a steady decline in germination following one year in storage and a steady increase in the proportion of low vigor germinants. Seed were not dormant as moist chilling did not substantially improve germination. However, moist chilling did increase germination speed most notably for seed stored at -20°C.

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SEED CERTIFICATION

Canada has been applying the OECD (Organization for Economic Cooperation and Development) tree seed certification scheme since 1970 to seed collected for export. The CFS was nominated by the Government of Canada as the Designated Authority to implement the Scheme. All seed certification has been conducted by the Pacific Forestry Centre in response to demand, primarily by European seed dealers, for seed from west coast tree species. Practically all seed has been certified in the Source-identified category.

Demand for certified seed, which was high in the 1970s and 1980s, has declined the past 20 years (Fig. 7) due to less demand from European importers. A total of 77 kg of certified seed was exported in 2011. There was strong demand for grand fir (*Abies grandis)* seed with 64 kg exported and lesser quantities of subalpine fir (*Abies lasiocarpa*), interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and western hemlock (*Tsuga heterophylla*). The European Union (EU) implemented a revised certification Directive on January 1, 2003. There had been concern about equivalence between this directive and the OECD Scheme. Fortunately, the EU has granted equivalence to Canada for *Abies grandis*, *Picea sitchensis*, *Pinus contorta*, and *Pseudotsuga menziesii* seed to be imported as Source-identified.

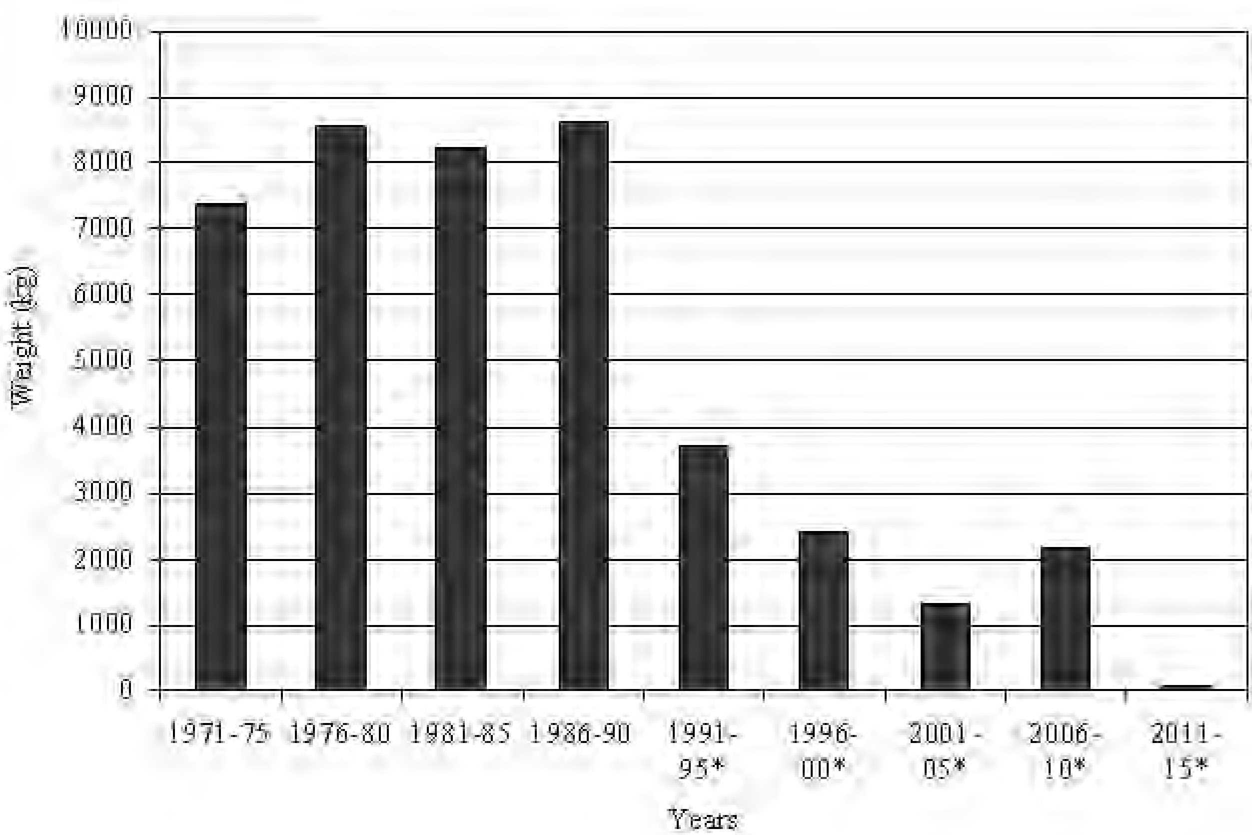

Figure 7. Weight of seed OECD certified or exported* by 5-year periods.

Officially established in 1967, the OECD Scheme for the Control of Forest Reproductive Material Moving in International Trade contained rules and procedures that were adopted in 1974. The Scheme allowed for the certification of seed under four categories: Source-identified (seed collected from a defined geographic area), Selected (seed collected from a stand that was selected for one or more attributes), Untested (seed from untested seed orchards or untested clonal material), and Tested (seed from tested seed orchards or tested clonal material). From its early implementation by a limited number of countries to enable the export of Douglas-fir seed from North America to Europe, the scope of the Scheme was progressively enlarged over time to attract new participants and to deal with many forest tree species. The Scheme's membership is comprised of 25 countries working with more than 250 tree species. Uganda formally applied in 2011 to become a member of the Scheme.

During the late 1980s, it became apparent that the 1974 Scheme required revision because of changes in forest management (environmental and social aspects, biodiversity conservation, etc.) in addition to wood production and the growing importance on the market of new types of reproductive material derived from forest tree breeding programs. A revised Scheme was adopted on 20 June 2007 and is called the OECD Scheme for the Certification of Forest Reproductive Material Moving in International Trade but only included the Source-identified and Selected categories. These categories benefit all stakeholders, including new applicant countries that are strengthening their domestic control systems for forest reproductive material. A proposal was presented at the annual meeting in October 2009 for inclusion of the Qualified category which includes seed collected from seed orchards. The text underwent further modifications in 2010 and was approved at the annual meeting in September. Having the Qualified category will once again provide an opportunity for the marketing of seed orchard seed, the quantity of which is increasing annually. This will afford producers the ability to obtain appropriate monetary value for seed orchard seed.

The Tested category will complete the Scheme. This includes reproductive material from seed orchards as well as parents of families, clones, and clonal mixtures that has been tested thus demonstrating its genetic superiority. A preliminary draft proposal was presented at the annual meeting in October 2011 and will require additional minor amendments. It is anticipated that it will be approved at the annual meeting in 2012.

When the Scheme is once again complete it is hoped that it will be an incentive for more countries to join.

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SEED CENTRE STAFF

Staff at the NTSC consist of one full-time seed technologist (Bernard Daigle) supervised by Dale Simpson. Mr. Daigle returned to the Seed Centre on April 1 from the knowledge exchange position that was shared between the Canadian Wood Fibre Centre and Atlantic Forestry Centre. In mid July he returned to that position. Dale Simpson maintained the essential functions which were filling seed orders and assessing any germination tests that Mr. Daigle had set up.

Chris Allaby who had been hired as a casual in 2010 worked part-time in the Seed Centre until March 31. His time was spent setting up and assessing germination tests that were scheduled for 2011. In mid September Matthew Chase was hired as a casual to assist with seed collection, processing, and setting up germination tests. Mr. Allaby and Mr. Chase worked a total of 23 weeks. Figure 8 summarizes the number of "extra" work weeks provided to the Seed Centre. The chart assumes that there was a full-time seed technologist.

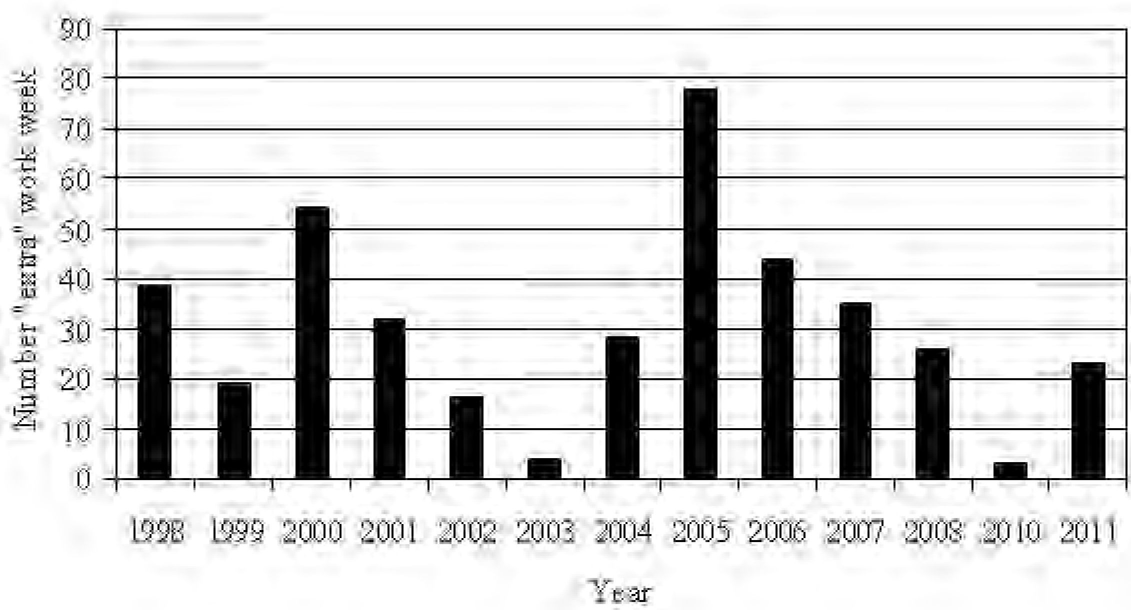

Figure 8. Number of "extra" work weeks provided to the NTSC between 1998 and 2011.