

Trends in forest depletion, seed supply, and reforestation in Canada during the past four decades

E.K. Morgenstern¹ and B.S.P. Wang²

Progress in reforestation is reviewed and the results of a 1999 survey of seed collection and utilization are presented. The review includes forest depletion, regeneration and seed supply for Canada for the 1960–99 period. Depletion of stocked, timber-productive land has increased from less than 2 million ha annually to just under 2.5 million ha, primarily due to an increase in harvesting from about 800 000 ha to slightly over 1 million ha in recent years, and also due to larger fires during the last decade. The depleted area amounts to 1% of the total commercial forest. Natural regeneration consistently covered more than 60% of the depleted area. Artificial regeneration (seeding and planting) has increased dramatically from 86 000 ha per year in 1965 to 513 000 ha in 1990, and has since levelled off at about 460 000 ha. The seed supply situation has also improved greatly, primarily due to tree improvement that resulted in the establishment of seed orchards, which were expanded from 364 ha in 1981 to 3008 ha in 1995. New analytical biochemical methods suggest that in orchard seed, genetic variation and diversity are maintained.

The seed survey, including 36 conifer and 29 broadleaf species, indicated that 2.5 billion seeds were collected in 1999 (which was not a good seed year) and 3.9 billion seeds were sown. These 3.9 billion seeds appear to be sufficient to again restock approximately 460 000 ha per year, i.e., the same area as regenerated annually in the 1995–99 period. Improved seed treatment and sowing methods appear to have made seedling production substantially more efficient during the last 20 years. The major species sown in 1999 were: *Picea mariana* (35%), *Picea glauca* (22%), *Pinus contorta* (13%), and *Pinus banksiana* (12%). For Canada as a whole, 25% of the seed came from seed orchards, but for the Maritime Provinces, Québec, and Manitoba this percentage ranged from 60 to 90%. Orchard production is still growing: British Columbia and Québec will produce 80% of their planting stock from it during the next decade, and New Brunswick and British Columbia are already harvesting seed from second-generation orchards. It is expected that the high quality of seed obtained from seed orchards will contribute significantly to the efficiency of the reforestation program and increase the value of future forests.

Key words: forest depletion, reforestation, seed orchards, seed supply

Cet article fait état du progrès en matière de reboisement et présente les résultats du sondage de 1999 sur la cueillette et l'utilisation des semences. Cette révision comprend la superficie déboisée, la régénération et l'approvisionnement en semences au Canada pour la période allant de 1960 à 1999. Le déboisement effectué sur les terres stockées productives de bois est passé de moins de 2 millions ha annuellement à un peu moins de 2,5 millions ha, principalement par suite d'une augmentation de la récolte de 800 000 ha à un peu plus de 1 million ha au cours des dernières années, et également suite à d'importants feux de forêt au cours de la dernière décennie. La superficie déboisée compte pour 1 % de la superficie totale de la forêt commerciale. La régénération naturelle couvrait plus de 60 % de la superficie déboisée. La régénération artificielle (ensemencement et plantation) a connu une augmentation dramatique passant de 86 000 ha par an en 1965 à 513 000 ha en 1990, et a maintenu un niveau de 460 000 ha depuis cette date. La situation de l'approvisionnement en semences s'est améliorée également de façon importante, principalement grâce à l'amélioration génétique des arbres qui a vu la mise en place de vergers à graines dont la superficie est passée de 364 ha en 1981 à 3008 ha en 1995. De nouvelles méthodes d'analyse biochimique laissent entendre que dans les vergers à graines, la variation génétique et la diversité sont maintenues. Le sondage sur les semences qui comprend 36 conifères et 29 feuillus, a indiqué que 2,5 milliards de semences ont été récoltés en 1999 (qui n'était pas une bonne année semencière) et que 3,9 milliards de semences ont été mis en terre. Ces 3,9 milliards de semences semblent être suffisants pour regarnir près de 460 000 ha par année, c'est-à-dire, la même superficie régénérée annuellement au cours de la période 1995–99. L'amélioration des traitements des semences et des méthodes d'ensemencement semble avoir rendu la production de semis substantiellement plus efficace au cours des derniers 20 ans. Les principales espèces ensemencées en 1999 ont été : *Picea mariana* (35 %), *Picea glauca* (22 %), *Pinus contorta* (13 %) et *Pinus banksiana* (12 %). Pour l'ensemble du Canada, 25 % des semences provenaient de vergers à graines, mais dans le cas des provinces Maritimes, du Québec et du Manitoba ce pourcentage variait entre 60 et 90 %. La production issue de vergers continue de croître. La Colombie-Britannique et le Québec produiront 80 % de leurs semis à partir des vergers au cours de la prochaine décennie, et le Nouveau-Brunswick et la Colombie-Britannique sont déjà en train de récolter des semences issues de vergers de deuxième génération. On s'attend à ce que la grande qualité des semences obtenues des vergers à graines contribuera significativement à l'efficacité des programmes de reboisement et à l'accroissement de la valeur des forêts de l'avenir.

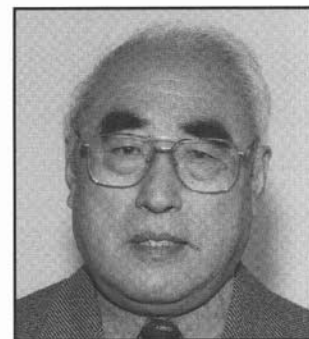
Mots-clés : déboisement des forêts, reboisement, vergers à graines, approvisionnement en semences

Introduction

One of the most significant developments in Canadian forestry during the last decades of the 20th century was the introduction of large-scale reforestation. While natural regeneration still covers more than half of the depleted forest area, artificial regeneration by seeding and planting is now achieved relatively successfully in all regions of the country. This advance is based on a series of new scientific insights and technological



E.K. Morgenstern



B.S.P. Wang

¹Genetic Resource Consultants, R.R. 7, Pembroke, Ontario K8A 6W8.

²Emeritus Scientist, Petawawa Research Forest, Canadian Forest Service, Natural Resources Canada, Chalk River, Ontario K0J 1J0.

Table 1. Annual depletion and regeneration of forests in Canada during the last four decades

Year or period	Loss to fire ha	1. Loss to insects, diseases ^a 2. Insect defoliation ^b ha ⁹	Area harvested ha	Area regenerated	
				naturally ha	seeding and planting ha
1963–72 ^{1,2,3}	834 000	no data	800 000	no data	86 000
1977 ⁴	524 000	data	756 000	324 000 ¹⁰	239 000
1977–81 ⁵	612 000	460 000 ^a	846 000	1 208 000	232 000
1982–86 ⁵	684 000	458 000 ^a	886 000	1 282 000	304 000
1987–91 ⁵	754 000	458 000 ^a	928 000	1 358 000	376 000
1995 ⁶	1 239 000	3 881 000 ^b	1 011 000	no data	462 000
1997 ⁷	879 000	4 000 000 ^b	1 020 000	data	459 000
1999 ⁸	723 000	5 100 000 ^b	1 080 000		458 000

¹Dept. of Fisheries and Environment 1976.²Manning and Grinnell 1971.³Cayford and Bickerstaff 1968.⁴Morgenstern and Carlson 1979.⁵Natural Resources Canada 1994.⁶Natural Resources Canada 1997.⁷Natural Resources Canada 1999.⁸Natural Resources Canada 2000.⁹Note that “insect defoliation” does not imply mortality, and is the total area accumulated from observation on individual insects, so that the same area may be included more than once (Natural Resources Canada 2000, p. 29).¹⁰This figure is much smaller than expected from trends observed in the 1977–91 period, when the most complete data were collected. Assuming similar losses due to insects and diseases (460 000 ha), and 60% natural regeneration on the total depleted area of 1.7 million ha, this figure would amount to 1 million ha.

inventions ranging from better knowledge of seed biology and reproduction, tree physiology and genetics, site classification and seed zoning, nursery and greenhouse technology, to new tools for site preparation and planting (Hallett and Murray 1980, Owens and Blake 1985, Kuhnke 1989, Wang *et al.* 1993, Edwards and El-Kassaby 1996, Downie 1999, Wang and Berjak 2000). Equally important was the generally recognized need for a greatly expanded reforestation program as part of improved forest management with greater investment for the future (Armson 1976, Canadian Forestry Association 1977, Reed 1978, Forestry Canada 1993, Apsey *et al.* 2000).

In the past, the importance of seed has not always been recognized. Because seed is produced so abundantly in our natural forests, it was often taken for granted. But seed is more than just an element of reproduction. Heydecker (1972) recognized its unique role: a “seed is an end and a beginning; it is the bearer of the essentials of inheritance; it symbolizes multiplication and dispersal, continuation and innovation, survival, renewal and birth.” Despite recent advancements in micro-propagation and tissue culture, it is still the primary source of material for reforestation.

There is another aspect of the role of seed in a reforestation program: seed of known quality adds greatly to program efficiency. Greenhouse space is costly and must be used effectively. Sowing too many or too few seeds per cavity may lead to high thinning cost, or may waste expensive greenhouse space. This becomes even more critical when genetically improved seed is used, which in one case in British Columbia was seven times more costly than wild seed (Morton 1999).

In this paper we will briefly review forest depletion, regeneration and seed supply, and then report the results of a national survey of seed collection and utilization for 1999. The paper will show that seed orchard seed generated through tree improvement is now making a significant impact on seed quantity and quality in all provinces.

Review of Forest Depletion, Regeneration and Seed Supply

Depletion

Forest depletion has three sources: natural and man-made fires, destruction by insects, diseases and natural disasters which often precede them (e.g., damage by snow, ice, storms and drought), and harvesting. As will be shown below, the first two sources together have always affected larger areas in Canada than harvesting. It is also important to recognize that fire and cyclical insect epidemics are part of many forest ecosystems and therefore should be considered as natural events initiating sanitation, nutrient recycling, and renewal (Spurr and Barnes 1980).

Table 1 presents summary statistics of depletion and regeneration. Losses to fire given here include only the areas within the accessible and productive forest zone. These losses ranged generally between 500 000 and 800 000 ha per year during the first three decades, 1960–89, but seemed to increase in the last decade. One of the worst fire seasons occurred in 1995, when 6.6 million ha burned in total, but only 1.2 million ha of the area were on stocked, timber-producing forest land (Canadian Council of Forest Ministers 1997, Natural Resources Canada 1997).

The area affected by insects and diseases is listed in the most useful manner only for the 1977–91 period, and this amounted to about 460 000 ha annually (Table 1). Later reports give the total area affected, a cumulative total of all areas damaged through moderate and severe defoliation by individual insects and with beetle-killed trees, which ranged from 3.8 to 5.1 million ha per year (Canadian Council of Forest Ministers 1997, Natural Resources Canada 1997, 1999, 2000). Obviously, this large total area cannot be included in the area of depletion because the same area would be included two or three times if affected by several insects. It seems reasonable to assume that the total area to be included in this category does not exceed 500 000 ha per year.

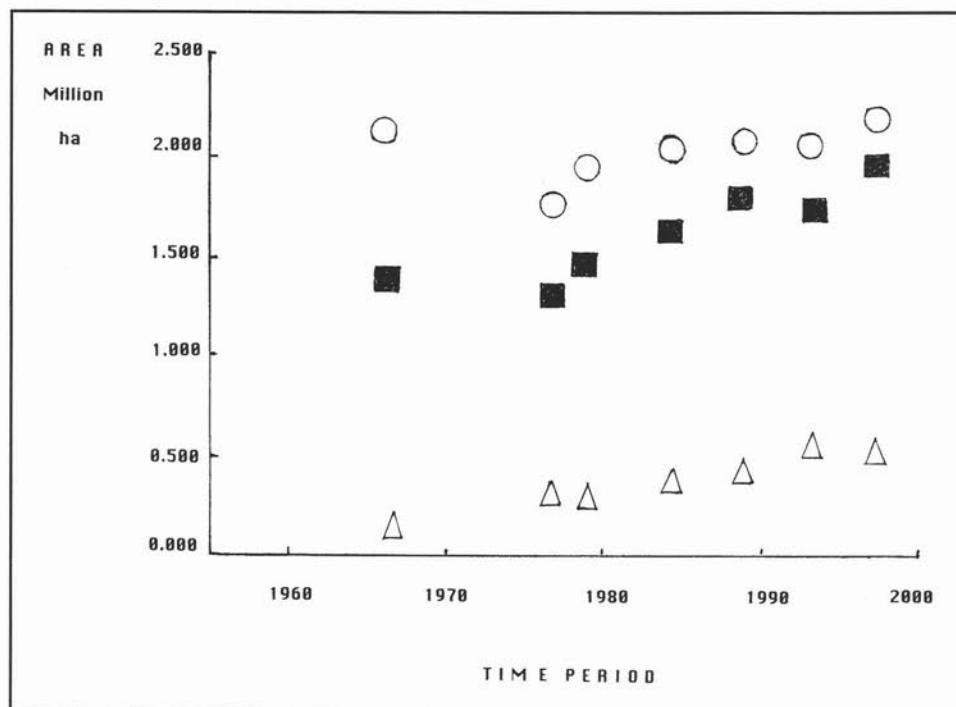


Fig. 1. Forest areas lost by depletion (○), areas of total regeneration including natural and artificial regeneration (■) and areas of artificial regeneration (△). Area losses due to insects and diseases, when not reported in the usual manner, were assumed to be equal to the values given for the 1977–91 period, namely 460 000 ha per year.

The area harvested remained relatively stable at about 800 000 ha during the first two decades, 1960–79, and then rose gradually to reach slightly more than 1 million ha during the last decade.

In summary, the total area depleted by fire, insects and diseases and harvesting currently amounts at most to 2.5 million ha per year, which is 1% of the area of productive, non-reserved forest land (Canada's commercial forest), i.e., of 234.5 million ha (Natural Resources Canada 1997). From the figures in Table 1 it can be shown that the average contribution by fire is 0.36%, by insects and diseases 0.22%, and by harvesting 0.42%.

The depleted area could increase in future years in view of the fact that in 1998 only about 72% of the total allowable cut was harvested (Natural Resources Canada 2000), and also if the percentage of the total area affected by fire increases — but such possibilities will not be investigated here.

Regeneration

Regeneration is the renewal of the forest by natural means, such as by germination from naturally dispersed seed, suckering, layering or sprouting, and artificially by seeding and planting.

Areas of naturally regenerated forest are listed in Table 1. Since regeneration is not an instant process but takes several years, the figures imply that in any given year the areas listed have been recognized as adequately restocked. Because of the regeneration lag, these forest areas may have been harvested or destroyed by fire or insects not in the same or previous year, but 3 to 5 or even 10 years earlier. As a result of this situation, year-to-year comparisons of depletion and regeneration are not as valid as comparisons over a 5- or 10-year period.

For the three 5-year periods between 1977 and 1991 the data are most complete (Table 1). In each of these periods, 1977–81, 1982–86, and 1987–91, 63% of the total depleted area regenerated naturally, and 12, 15, and 18% were seeded or planted.

Adding these percentages for each 5-year period results in 75, 78, and 81% of total regeneration. This suggests that there was still a backlog of insufficiently regenerated areas in the 1977–91 time period.

Some of the backlog was probably restocked by the strong increase in artificial regeneration (Table 1). From an initial 86 000 ha in 1965 (Cayford and Bickerstaff 1968) it grew to more than 300 000 ha 20 years later, i.e., an area 100 000 ha larger than predicted by Cayford and Bickerstaff for that time. A peak of 513 000 ha was reached in 1990, and since then the regenerated area stabilized around 460 000 ha per year, after most of the backlog of treatable understocked areas began diminishing (Natural Resources Canada 1997). Therefore, the area artificially regenerated per annum in Canada between 1965 and 2000 has increased more than five-fold, and this is probably the main reason why between 1979 and 1993 there was a net increase of 4% in the volume of trees growing in Canada's commercial forests (Natural Resources Canada 1996).

The narrowing gap between depletion and regeneration is depicted in Fig. 1. While depletion remained somewhat stable, hovering around 2 million ha per year, except during the last decade when it increased slightly, regeneration showed an upward trend because of the steadily increasing area of seeding and planting.

The contribution of individual provinces to the overall total area regenerated is shown in Table 2. In 1995, 436 307 ha were planted with 665.547 million seedlings, and 25 244 ha were direct seeded. British Columbia, Quebec and Ontario together regenerated 80% of the total area and planted 78% of the seedlings (Canadian Council of Forest Ministers 1997).

Seed supply

Several important ideas have emerged during the last four decades. Clearly, artificial regeneration requires a reliable and sustainable seed supply. Seed collections are preferably made

Table 2. Areas regenerated and numbers of seedlings planted by individual provinces and territories in 1995¹

Province or Territory	Planted	Direct Seeded	Seedlings No. in 000
	Area in ha		
Nfld.	3 453	—	8 632
P.E.I.	837	—	2 383
N.S.	7 186	—	13 477
N.B.	16 162	—	31 124
Que.	75 796	842	154 412
Ont.	64 711	22 890	102 709
Man.	5 697	22	11 003
Sask.	7 547	—	13 850
Alta.	47 745	1 490	65 357
B.C.	206 473	—	261 621
Yukon	619	—	851
N.W.T.	81	—	129
Canada	436 307	25 244	665 547

¹From: Canadian Council of Forest Ministers 1997.

in good crop years and the supply is stored in seed banks for lean years. Experience shows that a 10-year reserve should be kept in storage to meet the requirements of an annual seedling production and direct seeding program. For most common conifers, properly collected and processed seeds can be stored safely in air tight containers at -18°C for 20 to 30 years with moisture content of 5–8% (fresh-weight basis). For other conifers (e.g., the genera *Abies*, *Chamaecyparis*, *Thuja*, and *Tsuga*) as well as broadleaf species, specific individual storage conditions must be observed (Wang 1974). At the same time, constant monitoring of seed viability is needed and an updated inventory must be maintained, so that seedlots with low germinability can be detected (and perhaps be purged) and low quantities of other seedlots identified. With this information it is possible to systematically replenish the resource (Bonner 1990, Hamilton 1993, Wang *et al.* 1993). Under these conditions, the oldest seed is used first and annual sowing depends only on regeneration requirements and is practically independent of the natural cycle of flowering and seed production.

In the past, the availability of seed was a problem when a substantial expansion of the regeneration program was planned, or when seed collections in individual seed zones were inadequate. To deal with all of these questions, the Canadian Forest Service initiated a national review of tree seed production and tree improvement in 1977. All provincial forest services were invited to reveal their plans for program development during the next decade. The research and development needs were discussed at a workshop at the Petawawa Forest Experiment Station and strategies developed. The resulting publication (Morgenstern and Carlson 1979) contained the contribution of all provinces and also summarized the following facts and figures. In 1977, of the 563 000 ha regenerated, 239 000 ha were regenerated artificially by seeding and planting, and 324 000 ha were regenerated naturally (Table 1). At that time, 4.1 billion seeds were used and genetically improved seed made up less than 1%. All provinces planned to restock larger areas, a total of approximately 416 000 ha, and expected to require 7.3 billion seed by 1987. In that year, the share of genetically improved seed was anticipated to be only about 3%, as a result of the long gestation period of selection programs, which take 10–15 years from the time of plus-tree selection to the production of the first seeds in orchards. Consequently, most

provinces planned to meet the rapidly rising demand for seed through general collections in natural stands with some emphasis on seed production areas (Morgenstern and Carlson 1979).

About half-way through the 1977–87 planning period, a seed survey was made (Janas 1985). The results showed that in 1982–83, 14.3 billion viable seeds were collected, 38.3 billion seeds were in storage in 12 seed banks, and 5.2 billion viable seeds were utilized for regeneration. By 1982–83 the contribution of seed orchards had not increased: 87% of the collected seed came from general collections, 12% from seed collection and seed production areas, and less than 1% from seed orchards. Janas (1985) also predicted that the quantity of orchard seed available by 1997 would amount to only 1.6% of the total needed that year — a substantial underestimate as this paper will show.

Since 1977, the number and area of seed orchards have increased greatly. From an area of 364 ha in 1981 (Pollard 1982), the orchard area expanded to 618 ha in 1984, and provincial plans called for a further increase to 2036 ha by 1988 with a total of 18 species (Morgenstern 1986). The latest summary gave the total area as 3008 ha (Natural Resources Canada 1995). In New Brunswick and British Columbia, second-generation orchards are already in production (Tosh 1999, D. Kolotelo, personal communication). It is clear that seed orchards can be expected to make a large contribution to seed supply, with numbers of seeds still increasing from year to year. In British Columbia in 2007, 75% of total provincial sowing will be with orchard produced seed (Reid 1999). In Quebec, 50 million seedlings were produced from genetically improved seed in 1999, 67 million in 2000, and 120 million or 80% of all planting stock are expected to be grown in the year 2005 from such seed (M. Villeneuve, personal communication).

Genetic Diversity and Conservation

In recent years the need for ecosystem management and the maintenance of biodiversity have been widely recognized both by the public and in scientific debate (Kimmins 1992, Friedman and Foster 1997). Reforestation and tree breeding issues related to these concerns are complex and cannot be fully discussed here, but a few key points can be made:

1. Forest trees are wild organisms with much genetic variation and are fundamentally different from most agricultural crop plants, which have been altered by centuries of selection.
2. In contrast to seed production in natural stands where inbreeding is common due to neighbourhoods of genetically related trees, seed orchards are designed so that outcrossing is the rule. In recent years many studies have shown that genetic variation and diversity of seed from seed orchards are very high (see review by Mullin and Bertrand 1999).
3. During the last 30 years, gene conservation has become an important activity (Yeatman 1973, Maini *et al.* 1975, Wang 1975, Wang *et al.* 1993, Morgenstern 1996, Boysen *et al.* 1998). Biochemical methods such as starch gel electrophoresis are now routinely used to check genetic diversity parameters of tree populations with restricted populations sizes or when affected by various harvesting, seed production and regeneration methods. An example is *Picea rubens*, which most likely suffered from past cutting practices in eastern Canada (Mosseler *et al.* 2000, Rajora *et al.* 2000), and now must be managed more carefully. A conference at Toronto in 1993 indicated that all provinces in Canada are now engaged

in gene conservation programs (Nieman *et al.* 1995). We conclude that the need to maintain genetic diversity has been recognized and that appropriate measures to maintain this diversity are considered and implemented, but there is no doubt that gene conservation of late-successional and broadleaf species is still difficult and requires much more attention.

The 1999 Seed Survey

Survey questions

A survey of seed collection and utilization in 1999 was made in 2000 by submitting a questionnaire to all provincial forest services as well as one large private seed bank in Ontario. We asked for the following information:

1. Seed weight (kg) collected of each species in 1999 (or an average of the last three or four years, reflecting typical results), by general collection, in seed production areas, and seed orchards.
2. Seed weight (kg) utilized of each species in 1999 for plant production in nurseries and greenhouses, and by direct seeding in the field.
3. Total areas (ha) of seed production areas and seed orchards of each species.

The quantities collected and utilized were converted to numbers of clean seed based on tables given by the Ontario Department of Lands and Forests (1963), Kolotelo (1997), or values listed for individual broadleaf species by Burns and Honkala (1990). Conversion factors for New Brunswick seed orchard seeds were obtained from Tosh (1999). The results were summarized to show provincial and species contributions. For simplicity, and to help international readers, only the scientific names of species as listed by Farrar (1995) are presented.

Results

We received data from most provincial authorities as expected, but the Ontario component was a source of difficulty. Responsibility for regeneration is now delegated to the sustainable forestry license holders (SFL's), resulting in a decentralization of seed production, collection, and processing. Seed utilization by private and government nurseries meant that a variety of organizations had to be contacted and some did not respond. The actual numbers of seeds handled and utilized in Ontario will therefore be larger than those reported here. Seed exported by British Columbia seed dealers is also not included.

The response with respect to areas of seed production areas and seed orchards was not uniform and also problematic. Because this was not a significant part of the survey, the figures will not be reported.

Numbers of seed collected and sown in nurseries or directly in the field by each of the 10 provinces are given in Table 3. Seed from seed production areas was only listed by Newfoundland and Prince Edward Island, and the numbers were so small that they were included with general collections. Thirty-six conifer and 29 broadleaf species were collected and/or sown. Ontario handled 39 species or hybrids, Quebec 27, Prince Edward Island 19, Nova Scotia 16, British Columbia 15, New Brunswick 13, Alberta 9, Newfoundland 8, Manitoba 5, and Saskatchewan 4.

Table 3 shows that 1.9 billion seeds were obtained by general collection and 633 million seeds from seed orchards. Overall, orchard seed makes up 25% of the seed collected but the provincial percentages vary greatly. In five provinces,

Table 3. Typical annual seed collection and seed use in the 10 provinces of Canada (1999 or average of last four years)

Province	General Collections	Seed Orchards	Sowing in Nurseries	Direct Seeding
Millions of Seeds				
Nfld.	6.613 ¹	0	26.162	0
P.E.I.	14.484 ¹	25.229	10.958	0
N.S.	3.613	54.681	63.174	0
N.B.	18.852	89.877	91.139	0.003
Que.	78.500	128.296	1436.092	411.913
Ont.	659.700	43.900	348.763	206.347
Man.	0.403	3.581	25.023	7.790
Sask.	123.898	25.480	44.229	0
Alta.	657.428	44.901	368.088	229.208
B.C.	325.249	217.424	634.226	0
Total	1888.740	633.369	3047.854	855.261
Overall Total: Collections: 2 522.109 million seeds				
Total sown: 3 903.115 million seeds				

¹Includes minor amounts collected in a seed production area.

namely Prince Edward Island, Nova Scotia, New Brunswick, Quebec and Manitoba, the orchard contribution is larger than that from general collections of unimproved seed.

The number of seed sown amounted to 3.9 billion and was 35% higher than the number collected (Table 3). Apparently 1999 was not a good seed year, an impression confirmed by several of our provincial correspondents. In Ontario, for example, the following year (fiscal year 1999/2000) collections were three times larger (T. McDonough, personal communication).

Seed quantities, by species, collected and sown are given in Table 4. Conifers made up 99% of the seed collected and 99.5% of the seed sown, and broadleaf species the rest. The major contributors with at least 25 million seeds to the conifer collection total were: *Picea glauca*, 27%; *Pinus banksiana*, 22%; *Picea mariana*, 19%; *Pinus contorta*, 11%; *Picea engelmannii* × *glauca* natural hybrids ("interior spruce") 8%; *Thuja plicata*, 2.5%; *Pseudotsuga menziesii*, 1.7%; *Abies lasiocarpa* and *Tsuga heterophylla* each 1.4%, and *Pinus strobus*, 1%. Of the broadleaf tree species, *Betula papyrifera* was the most important with 10 million seeds, making up 40% of the total broadleaf component.

The quantities sown in 1999 show a different picture. *Picea mariana* leads with 35% of the conifer total, followed by *Picea glauca* (22%), *Pinus contorta* (13%), *Pinus banksiana* (12%), *Picea engelmannii* × *glauca* (5%), *Pinus strobus* (3%), *Pseudotsuga menziesii* (1.2%) and *Thuja plicata* (1.1%). Among the broadleaf species, *Betula alleghaniensis* leads with 34%, followed by *Acer saccharum* (20%), *Fraxinus americana* (18%), and *Betula papyrifera* (15%). For this group, the number of seeds collected was larger than the number sown.

Discussion

The organization of an effective reforestation system requires that every component plays its part and functions efficiently. This survey, the first one since 1982 (Janas 1985), clearly suggests that the important role of seed is being recognized and that the quantity of high quality seed (such as from seed orchards) is increasing.

The sixty-five species included in collection and sowing (Table 4) exceed any previous record (Janas and Haddon 1984, Janas 1985) and the large number is a positive sign. Several provinces have decided to grow minor species on a small

Table 4. Collection and Sowing of Seeds by Species in 1999

Species	Collected	Sown ¹	Species	Collected	Sown
Millions of Seeds					
Conifers			Broadleaf Trees		
<i>Abies</i>			<i>Acer rubrum</i>	0.113	0.053
<i>amabilis</i>	21.489	22.04	<i>saccharum</i>	0.895	3.621
<i>balsamea</i>	3.406	10.453	<i>saccharinum</i>	0.326	0
<i>grandis</i>	0.736	1.288	<i>Betula alleghaniensis</i>	2.967	6.240
<i>lasiocarpa</i>	35.69	21.58	<i>papyrifera</i>	10.608	2.733
<i>Chamaecyparis nootkatensis</i>	14.625	4.725	<i>Carya</i>	0.043	0.005
<i>Juniperus virginiana</i>	0	0.007	<i>cordiformis</i>	0	0.005
<i>Larix</i>			<i>ovata</i>	0	0.001
<i>decidua</i>	0	12.45	<i>Castanea dentata</i>	0	0.001
<i>eurolepis</i>	1.459	6.879	<i>Cercis canadensis</i>	0	0.001
<i>kaempferi</i>	0	0.016	<i>Fraxinus americana</i>	6.901	3.403
<i>laricina</i>	17.759	23.177	<i>nigra</i>	0.342	0.169
<i>occidentalis</i>	14.999	17.546	<i>pennsylvanica</i>	0.48	0.206
<i>sibirica</i>	0.17	0	<i>pennsylvanica</i> var.		
<i>Picea</i>			<i>subintegerrima</i>	0.796	0.579
<i>abies</i>	12.630	27.722	<i>Gleditsia triacanthos</i>	0.122	0.012
<i>engelmannii</i> × <i>glauca</i> ²	197.550	203.696	<i>Juglans cinerea</i>	0	0.002
<i>glauca</i> ³	677.138	867.759	<i>nigra</i>	0.153	0.017
<i>mariana</i>	478.560	1368.417	<i>Liriodendron tulipifera</i>	0.047	0.029
<i>pungens</i>	0	1.081	<i>Platanus occidentalis</i>	0	0.237
<i>rubens</i>	5.361	19.641	<i>Populus balsamifera</i>	0.05	0
<i>sitchensis</i>	4.944	4.532	<i>tremuloides</i>	0.9	0.200
<i>sitchensis</i> × <i>glauca</i>	0.458	4.122	<i>Prunus serotina</i>	0.292	0.107
<i>Pinus</i>			<i>Quercus alba</i>	0.039	0.085
<i>banksiana</i>	543.791	473.803	<i>macrocarpa</i>	0.315	0.324
<i>contorta</i>	265.886	505.098	<i>robur</i>	0.017	0.011
<i>monticola</i>	4.576	2.808	<i>rubra</i>	0.694	0.256
<i>mugo</i>	0	0.11	<i>Robinia pseudoacacia</i>	0.221	0.076
<i>nigra</i>	0	0.185	<i>Sorbus americana</i>	0	0.103
<i>ponderosa</i>	5.040	3.26	<i>Tilia americana</i>	0.202	0.039
<i>resinosa</i>	7.355	31.877	<i>Ulmus americana</i>	0	0.003
<i>strobilus</i>	25.334	122.342			
<i>sylvestris</i>	0.801	0.236			
<i>Pseudotsuga menziesii</i>	42.928	47.868			
<i>Thuja</i>					
<i>occidentalis</i>	13.827	10.845			
<i>plicata</i>	62.252	44.916			
<i>Tsuga</i>					
<i>canadensis</i>	1.076	1.46			
<i>heterophylla</i>	34.580	21.736			
<i>mertensiana</i>	0.461	0.922			
<i>Ginkgo biloba</i>	0.001	0.001			
Totals	2 495.586	3 884.598		26.523	18.517

¹Includes sowing in nurseries and direct seeding.²Reported in B.C. as "interior spruce."³In Alberta this includes *P. engelmannii* and *P. engelmannii* × *glauca* natural hybrids.

scale, presumably to maintain biodiversity and support gene conservation. The small populations of rare species, most typically represented by those in southern Ontario, will benefit from this initiative (Boysen *et al.* 1998).

Although the quantities of seed collected and sown are lower than reported in the last previous survey (Janas 1985), these are no cause for concern. Janas (1985) reported the collection of 14.3 billion seeds and sowing of 5.2 billion seeds, as compared to 2.5 billion and 3.9 billion determined here, but the 1999 collections were made in a poor seed year and real numbers may have been slightly larger because of incomplete Ontario records. Furthermore, methods of seed treatment and sowing have been improved or changed. The moist chilling of *Picea mariana* seed (Wang and Berjak 2000) leads to increased germination, and numbers of seed sown in greenhouse container production systems are being reduced to save thinning expenditures, while at the same time maintaining genetic diversity because fewer genotypes are eliminated (El-Kassaby *et al.* 1992). In one case in British Columbia, the number of seeds sown per plant was reduced from 3.7 in 1992 to 2.5 in 1999 (Thorpe 1999). Obviously, more research is warranted to reduce this number even more.

A simple calculation shows that the 3.9 billion seeds sown in 1999 will probably be adequate to artificially regenerate the same area as in the previous five years (1995–99), namely approximately 460 000 ha per year:

1. Direct seeding. The literature suggests that it requires 50 000 seeds per ha as a minimum (Hellum 1974, Groot 1994). At this rate, the 855.261 million seeds allocated to direct seeding (Table 3) will only cover 17 105 ha. Expressed as percentages, 22% of the available 3.9 billion seeds will only restock 3.7% of the 460 000 ha needing regeneration — probably not a good use of valuable genetically improved seed.
2. Seedling production. For the remaining area of 442 895 ha, 3 047.854 million seeds are available (Table 3). From the 1995 planting year (Table 2), we calculate that on average 1525 trees per ha were planted. For the 442 895 ha given above, this requires 675 414 875 trees. Dividing the number of seeds available by the number of trees needed works out to 4.51 seeds available to produce one plantable seedling. According to the British Columbia experience cited above, it should be possible to grow the number of trees needed from the seed available.

If one compares present methods and seed requirements with those used two decades ago (Morgenstern and Carlson 1979), it is clear that substantial changes have occurred and greater efficiency has been achieved. In 1977, the provincial forest services estimated that 7.3 billion seeds would be needed in 1987 to regenerate 416 000 ha in Canada as a whole. Now, approximately only 3.9 billion seeds are sufficient to regenerate a larger area, about 460 000 ha. Although there are many different species and a large number of individual provincial and private organizations, it seems indisputable that methods of seed handling and pretreatment as well as nursery skills have improved. As indicated, however, opportunities exist to further increase seed handling, treatment and utilization efficiency particularly for genetically improved seed, and continuous research and development are needed to achieve this.

The most significant development is the much greater contribution of seed orchards. In British Columbia, orchards contributed 66% to the total collection in 1999 (Table 3) and 36% to the seed used (Reid 1999). In the Maritime Provinces, Quebec and Manitoba the percentages were also very high and ranged from 60 to over 90%. For Canada as a whole, orchards produced 25% of the total seed collected in 1999 (Table 3). This fact, and the greater value of genetically improved seed, which is expressed by heavier seed, higher germination percentages, greater vigour of the seedlings and trees, less susceptibility to disease and better morphological attributes (stem form, smaller branches and less knotty wood), suggest that substantial benefits are now being reaped from genetic improvement. This important role of seed orchards, which is still growing, also means that seed supply is no longer the problem it was several decades earlier. Any sudden increase in sowing requirements due to large fires or other natural disasters can now be met by seed reserves in seed banks, and by collections in seed orchards. Overall, much progress has been made during the last 40 years.

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