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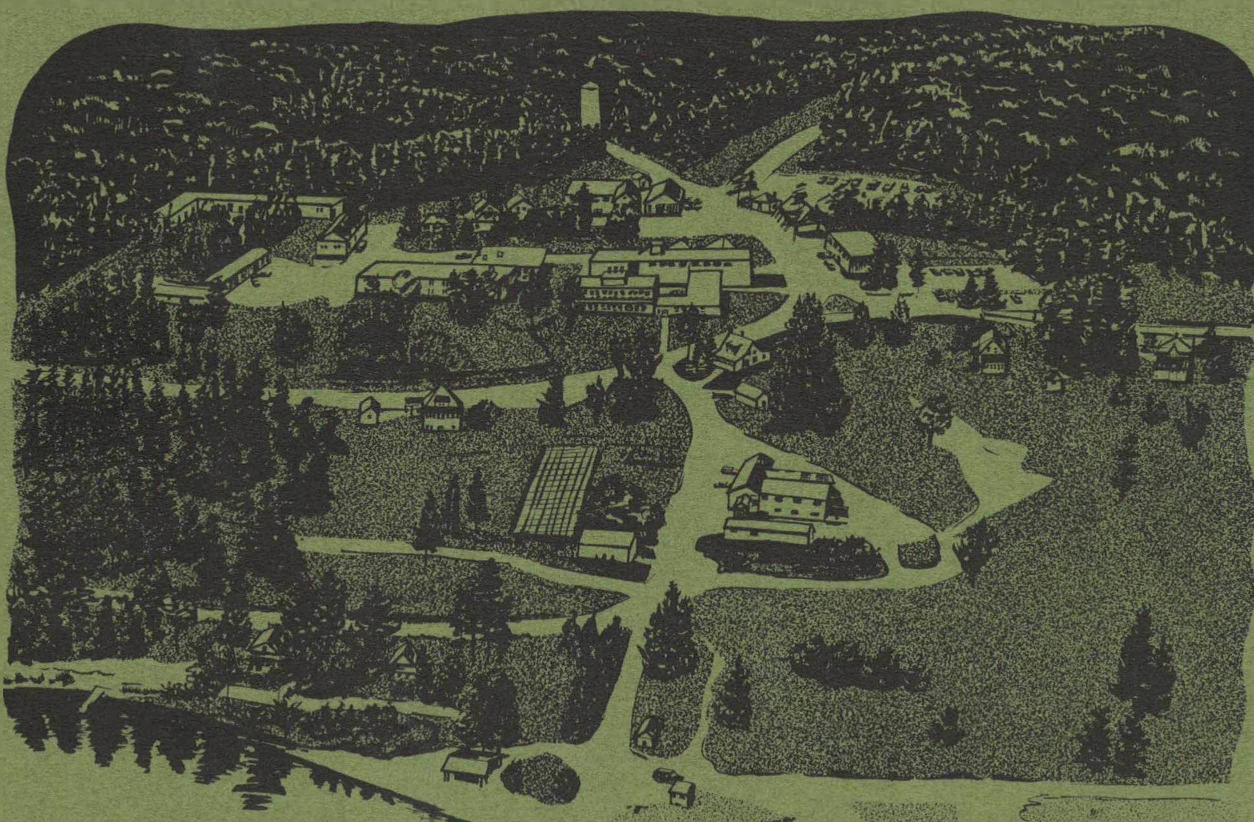
SEED ORIGIN-

FIRST, LAST AND ALWAYS

by C.W. Yeatman



PETAWAWA FOREST EXPERIMENT STATION

CHALK RIVER, ONTARIO

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Note

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ABSTRACT

The proper genetic make-up of seed and plants used in reforestation is a basic requirement to success in plantation management. Natural evolutionary forces of mutation, selection, migration and isolation result in tree populations that differ genetically across and along major environmental gradients. In the rigorous Canadian environment, climatic adaptation is of paramount importance to survival and growth.

Planting and direct seeding provide both the risk of failure due to ignorance or laxity in control of seed origin and the opportunity to ensure that only genetically appropriate material is used. Progressively better choices will be possible as experience and information accumulate and genetically improved seed becomes available. Provenance studies in commercial pine and spruce species have shown that both good and poor sources can be identified in a given climatic region. However, in the absence of strong evidence to the contrary, it remains a safe rule to use seed of local origin. The essential and critical point is to know the true origin of seed and seedlings used in forestation.

Evidence in support of strict control of seed collection and distribution is reviewed for black and white spruce and jack, red and white pine. Each species exhibits its own well defined variation on the general pattern of climatic adaptation.

Delineation of seed zones on ecological criteria is the first approximation to seed control. The boundaries of a zone are useful to practical management by setting outer limits for seed movement. Seed zones are not adequate for identification of seed origin. Systems of seed zones need to be under constant review and subject to modification, species by species. An example is given from data of jack pine provenances growing at two sites in northern Ontario.

Good seed management calls for long-term planning of supply, control of seed collection, and knowledge of seed origin through the nurseries to the forest. Designation and management of natural stands for seed production is particularly urgent in major commercial forest areas. Future supplies of genetically improved seed must be built on this foundation if breeding is to be successful. Responsibility needs to be shared by all levels of management, administration and research.

RESUME

Pour faire un succès de l'aménagement d'une plantation, il est fondamentalement nécessaire de posséder, au point de vue génétique, les semences et les plants appropriés au reboisement. Les forces d'évolution naturelle que sont la mutation, le sélection, la migration et l'isolation produisent des peuplements génétiquement différents à travers et le long des principaux milieux. A cause de climat rigoureux que l'on connaît au Canada, l'adaptation au climat est d'une importance primordiale à la survie et à la croissance.

Le plantage et le semis direct risquent tous deux d'engendrer des faillites à cause de l'ignorance ou du mauvais aménagement de l'origine des semences et aussi parce qu'on ne s'assure pas que l'on emploie seulement du matériel génétiquement approprié. Progressivement, de meilleurs choix seront possibles à mesure que l'expérience et l'information s'accumuleront et que des semences génétiquement améliorées seront disponibles. Des études sur la provenance de Pin et d'Epinette employés dans le commerce ont démontré qu'il est possible d'identifier de bonnes et de pauvres sources dans une région climatique donnée. Cependant, à moins de fortes preuves du contraire, l'utilisation locale de semences récoltées sur place demeurera une règle sûre. Le point essentiel et critique est de connaître la véritable origine des semences et des semis utilisés en restauration forestière.

L'auteur étaye par des preuves le contrôle sévère de la récolte et de la distribution des semences d'Epinettes noire et blanche et de Pins gris, rouge et blanc. Chaque essence affiche ses propres variations bien définies, quant à sa manière générale d'adaptation au climat.

Le tracé des zones de semences selon des critères écologiques constitue le premier pas à considérer dans le contrôle des semences. L'aménagement pratique exige qu'une zone soit délimitée par l'établissement de limites au mouvement des semences. Les zones de semence ne sont pas appropriées pour identifier l'origine des semences. Les systèmes de zones de semences doivent être constamment revisés et pouvoir être modifiés, espèce par espèce. Des données sur des provenances de Pin gris en deux stations du nord de l'Ontario en sont un exemple.

L'aménagement éclairé des semences exige une planification à long terme des approvisionnements, du contrôle de la récolte des semences et une connaissance de leur origine à partir de la pépinière jusqu'à la forêt. La désignation et l'aménagement de peuplements naturels pour la production de semences sont des facteurs particulièrement urgents pour les grands secteurs de forêts commerciales. Si l'on veut faire un succès de nos croisements, les futurs approvisionnements de semences génétiquement améliorées devront reposer sur cette base. Tous les cadres et les chercheurs devront se partager cette responsabilité.

SEED ORIGIN - FIRST, LAST AND ALWAYS

C.W. Yeatman[1/]

INTRODUCTION

Success in planting ultimately depends on the genetic suitability of the planting stock to the climate and site where the trees are to grow. In spite of every care in the nursery and field, genetically ill-adapted planting stock can be expected to have low survival, either short or long-term, to be susceptible to damage by pests, diseases or climatic extremes, and to grow slowly or with unsatisfactory form. Conversely, trees with an inherent rhythm synchronized with the seasons and able to exploit fully the growth potential of the planting site offer long-term security of investment and respond well to good management. Use of local seed sources is a safe and conservative policy but one which, for a variety of reasons, is often difficult to follow closely and may in some cases, and following investigation, not be the best choice. This paper discusses the immediate need for management of seed production and identification of seed origin from collection to return to the forest as plants or seed. The objectives are to upgrade success in planting and seeding now and to help identify and maintain the better natural populations for seed production and breeding.

PLANTING AND SEED ORIGIN

Artificial regeneration is essential if genetic improvement is to be realized (Libby *et al*. 1969) and since planting is the most expensive, and usually the more effective, means of regeneration, cost of seed, even as high as 3% planting costs, is not a major factor in regeneration decision making. Planting on good sites is the best way to capitalize on investment in tree breeding, but in most areas of Ontario even small quantities of seed-orchard seed will not be available for some years and it will be some decades before the bulk of seed required is from orchards of proven breeding value (Rauter 1973). It must be borne in mind that climatic adaptation is paramount in the northern Canadian environment with its steep latitudinal gradient in climate. Breeding programmes must accordingly be organized on a basis of ecological regions and species. Neither the personnel nor the information are presently available to carry out the tasks of selection, testing and seed orchard establishment on the scale required to meet all demands for seed. In the meantime, large quantities of seed of the major coniferous species utilized in Ontario, black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss), red pine (*Pinus resinosa* Ait.), and white pine (*Pinus strobus* L.), must be collected from existing stands to meet present and projected reforestation targets (Lane 1976). Information presently available from research is being used to direct planning and guide seed collection and plant distribution to ensure plants of the most suitable seed origins are available for planting.

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SPECIES AND SEED ORIGIN

Black Spruce

Morgenstern (1975) reported that at two test locations in Ontario, Chalk River (lat. 46°N) and Kirkland Lake (lat. 48°N) trees of local origin had highest survival and best growth among 16 populations (provenances) evaluated at 11 years-of-age. There was also evidence that the northern populations were more susceptible to shoestring root rot (*Armillaria mellea* (Vahl ex Fr.) Kummer) when growing at the southern location. In the absence of contrary evidence, he considered local sources to be the best choice for general collections of seed of black spruce and advocated recording the township of origin of all major collections so that large geographic displacements of seed might be avoided.

Jack Pine

Much the same picture of broad climatic adaptation is emerging for jack pine from seed source tests established at many locations in eastern Canada and the Lake States during the past 30 years (e.g. Rudolf 1958, Holst and Yeatman 1961, Rudolph 1964, King 1966, King and Nienstaedt 1965, Morgenstern and Teich 1969, Yeatman and Teich 1969, Yeatman 1964). At nine of ten range-wide tests planted in Ontario and Quebec, local provenances, or those from equivalent latitudes, rank among the best in comparisons of tree height at 10 years-of-age (Table 1). The exception

Table 1. Mean tree height, percent of maximum, and rank of local or equivalent seed sources, 10 years-of-age, at 10 test sites of range-wide jack pine provenances.

Test Location		Forest[1/]		Mean height		
Place	Lat. N.	Section	Source	cm	%	Rank[2/]
Turkey Point, Ont.	42°45'	D1	Marl Lake, S. Mich.	412	100	1
Petawawa, Ont.	46°00'	L4C	Petawawa	402	99	2
Swastika, Ont.	48°10'	L9/B7	Nellie Lake	344	99	2
Fraserdale, Ont.	49°50'	B4	Smoky Falls	263	100	1
Township 114, Ont.	46°42'	L9	Benny	197	95	5
Caramat, Ont.	49°40'	B8	Caramat	228	85	23
Kakabeka Falls, Ont.	48°20'	L11	Fort Frances	310	100	2
Red Lake, Ont.	51°00'	B22	Red Lake	311	100	2
Baskatong Lake, Que.	46°52'	L4B	Baskatong	229	100	1
Sugarloaf, Que.	47°53'	B7	Downs L., Que.	164	93	6

1 Rowe 1972

2 Total provenances planted range from 64 to 99

Table 2. Mean tree height and mortality due to scleroderris canker at 12 years, and winter injury at 9 years-of-age, recorded for selected jack pine provenances at two all-range provenance test sites in the Boreal Forest Region (Rowe 1972). The results are based on 50 trees per provenance planted at Fraserdale and 45 trees at Sugarloaf.

Seed source			Test Location					
			Fraserdale, Ont.			Sugarloaf, Que.		
Location	Lat. N.	Long. W.	1975 Mean height cm	1975 Scler. mort. %	1972 Winter injury %	1975 Mean height cm	1975 Scler. mort. %	1972 Winter injury %
Manouan L., Que.	47°40'	74°08'	368	3	12	*232	6	8
Downs L., Que.	48°00'	74°15'	337	0	0	*233	5	3
Capitachouan R., Que.	47°45'	76°42'	386	0	7	*236	0	13
L. Villebon, Que.	47°54'	77°21'	363	4	0	*232	0	13
Baskatong L., Que.	46°50'	76°05'	356	0	11	200	15	13
Petawawa, Ont.	46°00'	77°23'	277	17	76	213	52	63
Goulais R., Ont.	46°50'	83°58'	377	3	14	-	-	-
Benny, Ont.	46°50'	81°37'	383	6	15	-	-	-
Gowganda L., Ont.	47°39'	80°43'	369	3	0	-	-	-
Nellie L., Ont.	48°47'	80°48'	375	6	0	-	-	-
Smokey Falls, Ont.	50°05'	82°10'	*381	6	0	-	-	-

* Local and near-local seed sources

is at Caramat, north of Lake Superior, where provenances to the east in Quebec grew up to 18% taller than the local seed source. Jack pine from east of Lake Nipigon and north of Superior are consistently slow growing in the range-wide tests and also in 20-year results of Ontario provenances reported by Skeates (1976).

Relative resistance by some jack pine provenances to scleroderris canker (Gremeniella abietina (Lagerberg) Morelet) was first observed in 1966 in a nursery test near Longlac, Ontario (Teich 1967). The disease is a serious cause of mortality at three boreal provenance test sites, Sugarloaf, Fraserdale and Caramat, where the infection rates of southern sources range as high at 86% with mortality exceeding 50% (Yeatman 1976). Highest resistance and low mortality is found in some of the more vigorous provenances of eastern boreal origin in Ontario and Quebec (Table 2), reflecting a high level of genetic synchronization with, and response to, the demanding seasonal cycles of the environment.

Brown needles and dry buds in spring characterize winter injury typically suffered by non-hardy jack pine provenances planted in a northern continental climate (Table 2). Southern and coastal sources are affected most. Although extreme infection by scleroderris canker is coincident with severe winter injury, winter hardy provenances from the west and north of the species range in the prairie provinces and Northwest Territories are also seriously affected by the disease (data on file). No seed source is immune to infection and susceptibility varies considerably among geographically associated provenances, including those from areas with generally high resistance (Yeatman 1976, Table 1).

Significant differences in growth among geographically associated provenances in Ontario were reported by Yeatman (1974) and Skeates (1976) and are evident in the heights of eastern Ontario and western Quebec seed sources grown at Petawawa (Table 3). All come from Site Region 5E in Ontario

Table 3. Mean tree height at 10 years-of-age, percent of maximum height, and rank of 10 jack pine seed sources from eastern Ontario and western Quebec between latitudes 44°33'N and 47°00'N grown in the range-wide test at Petawawa Forest Experiment Station.

Seed Source			Mean height		
Location	Lat. N.	Long. W.	cm	%	Rank[1/]
Petawawa, Ont.	46°00'	77°23'	402	99	2
York River, Ont.	45°10'	77°44'	397	98	3
Fort Coulonge, Que.	45°51'	76°44'	383	95	12
Douglas, Ont.	45°30'	76°56'	379	94	13
Baskatong L., Que.	46°50'	76°05'	375	93	18
Constance Bay, Que.	45°31'	76°06'	353	87	40
Harry Lake, Que.	46°23'	76°10'	349	86	44
Twin Lakes, Ont.	44°39'	77°53'	343	84	56
Kaladar, Ont.	44°39'	77°08'	342	84	57
Clare R., Ont.	44°36'	77°03'	323	80	66

[1] Total 99 provenances

Table 4. Mean tree height at 10 years-of-age, percent of maximum height, and rank of five central Ontario jack pine seed sources grown in the range-wide provenance tests at Swastika (Site Region 4E) and Petawawa (Site Region 5E[1/]).

Seed Source				Test Location					
				Swastika (84°10'N)			Petawawa (46°00'N)		
				Mean height			Mean height		
Location	Lat. N.	Long. W.	Site region[1/]	cm	%	Rank[2/]	cm	%	Rank[3/]
Goulais R.	46°50'	83°58'	4E	337	97	5	396	98	4
Benny	46°50'	81°37'	4E	328	95	10	361	89	36
Gowganda L.	47°39'	80°43'	4E	332	96	7	388	96	10
Nellie L.	48°47'	80°48'	3E	344	99	2	344	85	52
Smoky Falls	50°05'	82°10'	3E	285	82	50	301	74	76

1/ Site Regions of Ontario, based on Hills (1961)

2/ Total 81 provenances

3/ Total 99 provenances

(Hills 1961) or the equivalent climate in Quebec. The poorest growth is exhibited by trees from three small southern outlier populations growing on shallow soils in association with limestone outcrops (Holst 1967). The poor growth of the Harry Lake and Constance Bay sources appears to be chance variation among the provenances tested.

Differences among associated provenances may be evident in one test plantation but not at another. This is illustrated in Table 4 where five central Ontario provenances are seen to vary widely in height and rank when grown at Petawawa, but at Swastika only the northern most source, Smoky Falls, is clearly inferior. This is a reflection of distance from area of origin to planting site as shown by Morgenstern and Teich (1969) in their analysis of Lake States provenances grown at 12 test sites in the United States and Canada. It is interesting to note that Nellie Lake, in highest rank, and Smoky Falls, in lowest rank, are located in the same Ontario Site Region (seed zone), 3E. The Swastika test is close to the northern limit of Site Region 4E.

White Spruce

Growth responses of white spruce provenances also reflect a broad adaptation to factors of climate [photoperiod (latitude), temperature regime and precipitation] when considered over the entire transcontinental range of the species (Nienstaedt and Teich 1972). Taxonomic and biochemical studies indicate that the species is divided at approximately longitude 95°W into two major populations, eastern and western white spruce (Halliday and Brown 1943, Miksche 1968, Wilkinson et al. 1971). In the east, provenances from the lower Ottawa Valley and vicinity in Ontario and Quebec have grown exceptionally well in tests ranging from the Lake States, through southern Ontario and Quebec to Newfoundland (Nienstaedt 1969, Niensteadt and Teich 1972, Khalil 1974, Teich et al. 1975). In central Ontario tests, provenances from the upper Ottawa Valley and Kirkland Lake areas tend to be superior (Teich et al. 1975). Limestone ecotypes have been identified in a laboratory study (Farrar and Nicholson 1967) and in field tests (Teich and Holst 1974). All the studies to date indicate that above average populations exist within broadly defined eco-regions and that all larger seed collections should be identified by place of origin rather than only by Site Region or seed zone. New cooperative studies are expected to identify superior white spruce seed sources and to clarify the population structure of the species (Morgenstern 1976).

Red and White Pine

Broad regional adaptation is also found in red pine (Holst 1964, Fowler and Lester 1970, Holst 1975, and Fowler 1975) and in white pine (Fowler and Heimburger 1969, Wright 1970, Zsuffa 1975) that must be respected in seed collection and redistribution if losses of growth and productivity in planting these species are to be avoided. Some red pine seed sources show consistently poor growth and their occurrence is apparently random (Holst 1975). Rudolf (1964) advocated "selecting seed origins reasonably close to home until there are demonstrated advantages of certain more distant sources". Gains in early height growth in the range of 10% can be expected by identifying the best red pine sources within large regions (Lester and Barr 1965).

Some advantage may be gained in white pine by moving seed to southern Ontario from Pennsylvania, but generally south to north movement is considered too hazardous because of reduced hardiness and greater susceptibility to white pine weevil (Fowler and Heimburger 1969). Foresters in the Lake States were advised to confine collection of white pine seed to local stands pending the outcome of long-term and more intensive provenance studies (King and Nienstaedt 1968).

SEED ZONES AND SEED ORIGIN

The designation and application of seed zones is the first approximation to control the collection of seed and distribution of seed and seedlings for reforestation. Delineation of seed zones in Canadian provinces is based on ecological criteria, such as Site Regions in Ontario as described by Hills (1961) (Morgenstern 1975). Boundaries are often modified in detail to create seed zones with practical administrative and political boundaries. Such zones prescribe the outer limits for seed movement and ensure that serious reforestation failures due to seed origin are less likely to occur than would be the case with no control. Because seed zones are often large, opportunities for further improvement in genetic quality of general seed collections are greatly reduced if seed is identified only by seed zone. Provenance studies, such as those reviewed above, all point to the need for closer geographic identification of large collections. Identification of seed origin by an area such as a township or by standard map coordinates will permit foresters to plant local seed sources, or, at worst, know the origin of other-than-local plants or seed supplied for reforestation. When this information is included in regeneration reports and maps, better sources can be identified in due course and developed for long-term seed supply. Similarly, poorer populations can be avoided in subsequent seed collection and eventually replaced by superior stock.

In the first instance, seed zones are applied arbitrarily to all species. As evidence accumulates from research and reforestation records, modifications can be made to suit each species, broadening zones for some, narrowing for others (Morgenstern 1975). For example, referring to Tables 3 and 4, the present boundary between Ontario Site Regions (seed zones) 3E and 4E bears little relationship to the responses of the northern jack pine provenances at the two sites, Fraserdale and Swastika. The Nellie Lake source from Region 3E is in top rank at Swastika, Region 4E, where the Smoky Falls provenance, also zone 3E, is significantly poorer by 17% (Table 4). At Fraserdale, zone 3E (Table 2), both provenances are among the best in height, disease resistance and cold hardiness although Smoky Falls ranks slightly higher. Seed zones are not biological realities, for boundaries from one zone to another are necessarily arbitrary breaks in ecological continua. As experience is gained in artificial regeneration, including the use of improved stock, more sophisticated seed transfer rules will emerge for each species and each region. Simplification is a legitimate administrative goal in pursuit of efficiency but may do great harm if insisted upon in spite of contrary evidence or low probability of success.

SEED MANAGEMENT AND SEED ORIGIN

A high priority must be given seed collection and distribution if the genetic quality of planting stock is to be maintained and improved. Natural stands, unimproved in the sense of breeding, will continue to provide the bulk of Canadian tree seed for some time to come. Priority for artificial regeneration is found in the more productive and accessible forest lands within easy reach of large mills and population centres. It is in these areas of high economic value where collection of large volumes of seed representative of original populations is becoming more difficult because of intensive forest utilization, frequently inadequate natural regeneration and large scale planting or seeding with material of only broadly defined origin. Planning and action by management are urgently needed to allocate adequate areas of original tree populations to be managed for seed production and to be retained as genetic reserves of known heritage (Yeatman 1973). It is only necessary to ensure that regeneration is from local seed, either naturally or by planting or seeding. Such forest land is not removed from wood production.

These requirements for seed production and gene pool conservation are being met in Ontario by the creation of seed collection areas in older stands ready for harvest and seed production areas in young stands that will respond to management (Lane 1976). At the same time plus-tree selection and development of seed orchards is proceeding and in time will supply significant quantities of improved seed. Nienstaedt (1976) stressed the need to test material of seed orchard origin for ecological amplitude because the constraints of adaptation to climate and soil apply equally to improved stock. Furthermore, it must be realized that the results of such testing will not be available for a further period of time, perhaps two or three decades, after the orchards themselves become productive.

Managed populations of local origin will be valuable genetic assets for the indefinite future, providing standards against which to measure gain through tree improvement (Hagman 1973), reserves for selection and breeding of genotypes of known genecological heritage, and sources of seed of certified origin and tested performance.

CONCLUSIONS

Responsibility for designation, management, utilization and testing of selected natural populations must be shared by management, administration and research at all levels. The need for good seed management must be as widely understood and practised as is control of wild fires. Close supervision of seed collection is necessary to ensure all cones purchased are of specified origin and are not gathered from unauthorized sources, or from isolated or scattered trees of dubious quality. Tree climbing often becomes mandatory to retain populations of adequate size and to maintain a productive capacity for seed, for example, in white spruce, red pine and white pine. By adopting appropriate procedures for labelling cones at the time of collection, seed source identity can be maintained through seed extraction and nursery to the plantation and subsequently in regeneration records (Dobbs *et al*. 1976).

By insisting on knowing where the seed and trees come from and seeing to it that the required seed is available when needed, foresters will be able to choose provenances with the best potential for survival and growth in relation to species and area to be planted. Planning, execution and labelling are key-words for good seed management and long-term security of planted and direct-seeded forests.

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