FOREST GENETICS PROGRESSES IN QUEBEC

by

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ABSTRACT.--After relating the late interest in forest genetics in Québec to the abundance of the forest resource, serious natural regeneration problems after exploitation are exposed. Mainly initiated at the end of the sixties, forest genetics research and improvement progress are presented on a species basis. Tree improvement is seen not only as a tool to obtain superior returns from artificial regeneration but as a means to secure seed and seedling supplies. Finally important research and development areas where efforts must be emphasized are pointed out.

INTRODUCTION

Constant increasing demand for wood and its derivates result in a growing pressure on the natural forest. It is expected that the world needs will have increased by as much as 30 and 60 percent by 1985 and the turn of the century.

The total harvest possibility has not been reached yet in Quebec. However the southern part of its territory is over exploited. There already is a shortage of fiber in certain administrative regions; the northern boreal forest is more expensive to harvest because of long hauling distances to mills and lower volume per unit area. At the present rythm of cutting, Québec will be facing a fiber shortage by the beginning of the nineties (Hawey

1977). In addition, the diameter limit cutting method as practiced in our hardwood forests has degraded the genetic qualities of our main hardwood species.

The need is there now. Québec must intensify its reforestation programs. The planting and seeding of one hundred thousand acres annually is planned for 1983. The right species in function of the sites and choice of the best genetic stocks are primary to get the maximum return from the future plantations.

Outstanding seed sources have been identified and present information on the nature and importance of the genetic variations of our main coniferous species, permit to expect gains as high as 20 to 30 percent in volume and form, at the beginning of the improvement process.

FOREST GENETICS INTEREST AND THE ABUNDANCE OF THE QUEBEC FOREST RESOURCE

Great interest in forest genetics and tree improvement has taken long to develop in Quebec, as in mcst Canadian provinces, because of the abundance of forest and the omnipresence of trees. Industry and foresters have long taken the forest for granted, as an unlimited goods rather than as a renewable resource. Concern and preservation seemed unnecessary, which is easily understood after a look at the Quebec forest statistics (Le Blanc 1977) (table 1).

The time and the perception of the forest as an unlimited resource have changed. The last few statistics induce to thinking. Today forestry engineers observe that the productive forest area in Quebec is continually shrinking; to the seven million acre total area inadequately regenerated in 1976 after cut and/or fire, some 190,000 acres are adding each year.

Even pulp and paper companies are beginning to look at the forest differently. There would be room to plant 300 million seedlings per year in Quebec if land actually covered by deteriorated forest is included (Vallee 1979). To resolve the regeneration problem, and maintain its forest industry potential and economics, Québec will need 1.2 billion viable seeds annually. For this reason the province has signed a five points agreement with the federal government, among which tree improvement plays an important role:

1 - To produce and harvest forest seeds
2 - To intensify tree improvement programs
3 - To increase the production of hare root and containerized seedlings

4 - To foster plantation establishment and maintenance
5 - To intensify site preparation and direct seeding of clearcut areas.

With the actual reforestation objective every genetic gain obtained from costly tree improvement programs is the promise of an important economic return.

Table 1.--Québec forest resource, harvest and regeneration problem

Québec territory (excluding Labrador)	646,400	square miles
Commercial forest	183.5	million acres
Accessible productive forest	132	million acres
Wood volume	1,430	million cunits
Public forest	1,270	million cunits
softwood	1,000	" "
hardwood	270	" "
Private forest	160	million cunits
Net economic allowable cut	14.6	million cunits
softwood	11.7	" "
hardwood	2.9	" "
Total annual cut on commercial forest	9.2	million cunits
Area clearcut annually (average)	700,000	acres
Area burned annually (1960-1974) (average)	167,000	acres
Annual increase in area inadequately regenerated after clearcut	190,000	acres
Cumulated area inadequately regenerated (1976)	7	million acres

FOREST GENETICS AND IMPROVEMENT PROGRESS

The oldest provenance trial in Quebec was established in 1954. However it is only thirteen years ago that the first forest geneticist was permanently hired by the Canadian Forestry Service to do research on the genetic components of our economically important species and to conduct breeding works. Between 1954 and 1967 most of the effort in forest genetics was limited to provenance trials initiated by Petawawa Forest Experiment Station with the collaboration of the Pulp and Paper industry and with the Québec regional forest research centre of the Canadian Forestry Service. In 1969 two general proposals were suggested to the Ministere de l'Energie et des Ressources of Québec which initiated its own tree improvement programs (Lamontagne 1969, Vallee 1969). In 1970 the Quebec Forest Genetics Research Committee was created and published three reports. Today three public organisms, one pulp and paper company and seven professionals are either part time or fully engaged in forest genetics, tree improvement and seed production activities. Research and breeding responsabilities are divided among these organisms (table 2).

Table 2.--Forest genetics and improvement projects conducted in Québec

Projects	Year of initiation	Organism involved[a]
Provenance research on economic forest tree species	1955	C.R.F.L., S.R., C.I.P., U.L.
Genetics and improvement of high quality hardwoods	1965	U.L., S.R.
Introduction of exotic species	1969	S.R., C.R.F.L., U.L.
Genetics research and improvement of poplars	1968	S.R.
Genetics research and improvement of larchs	1970	S.R.
Genetics research and improvement of jack pine	1974	S.R.
Genetics research and improvement of white spruce	1975	C.R.F.L.
Genetics research and improvement of white pine	1976	C.R.F.L.
Establishment of seed production areas	1968	R.A., S.Res., C.I.P.
Establishment and development of the arboreta network	1969	S.R., R.A.
Selection of plus trees and seed orchards establishment	1975	R.A., S.Res., S.R., C.R.F.L., U.L., C.I.P.

[a] C.R.F.L.: Centre de recherche forestière des Laurentides, Service Canadien des Forêts.
C.I.P. : Canadian International Paper Company.
R.A. : Région administrative du Ministère de l'Energie et des Ressources du Québec.
S.R. : Service de la recherche forestière, Ministère de l'Energie et des Ressources du Québec.
S.Res. : Service de la restauration forestière, Ministère de l'Energie et des Ressources du Québec.
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The realization of a network of twenty-one arboreta for tree improvement in representative edaphoclimatic localities of the main reforestation regions greatly facilitates trials and testings (Chouinard and Vallée 1976). The arboreta system permits a grouping of comparative plantations to save expenses on their establishment, maintenance and measurements, to create a gene pool, to compare performance and phenology between species, populations and individuals growing in the same environment. The arboreta network also assure the protection of the experimental material against changes of politics of the land owner.

Most of the field trials conducted by the tree improvement group are now established in the arboreta. To date some 560 comparative plantations of all kinds representing several species and many hybrids have been established in the arboreta and have started giving valuable information about the genetic structure of the native and exotic species and their value for reforestation. For special purposes field trials may be established in other areas which are then registered at the and protected by the Ministere de 1'Energie et des Ressources.

Introduction and trial of potentially interesting exotic species for reforestation purpose were of much concern at the beginning of the improvement programs. Ninety species were tested for hardiness in the nursery. Species could be classified for resistance to cold climate under favorable conditions of culture. Thirty-three species were found to be hardy enough. Subsequently they were established in some two hundred and eighty introduction and conservatory plantations in the arboreta.

Provenance research on most important economic forest tree species is the oldest tree improvement activity in Québec. Some two hundred trials, some having twenty-five years of age, representing more than a thousand different populations, established in several forest regions, are bringing interesting and reliable results. Accumulated information allowed us to make recommendations on the right species and sources for reforestation in function of the sites.

Experiments have demonstrated that red spruce (Picea rubens Sarg.) should be used as a reforestation species only under shelter because it is highly susceptibile to winter dessication (Roche 1969). On cutover and exposed sites even the best seed source is outclassed by local black spruce (Picea mariana (Mill.) B.S.P.). Performances of geographic races are related to their respective hybrid index (Morgenstern et al. 1980). Few introgressed populations with black spruce genes are hardy and show hybrid vigor. Artificial hybrids are however difficult to obtain and highly variable.

Black spruce is our major tree species. Some knowledge of its genetically-controled geographic variability was obtained from range-wide study. A clinal variation in height growth and in the time of bud onset was identified through its natural range. Growth was negatively related to the increase of latitude of origin while earliness of bud onset was positively related to latitude increase, reflecting the adaptation to local climatic conditions. Five years after field planting in different areas, sources from the south-eastern portion of the natural range turn out to be the best performers.Under all conditions tested, the Great-Lakes - St. Lawrence forest region sources gave the best results. Under the cold and humid climate of Gaspe peninsula and of the North Shore, sources from the colder regions are equivalent to those from milder regions. Grouping of the provenances by Rowe's forest sections and ranking them in function of their height growth confirm preceding observations and reflect the relation between geographic adaptation and performance in different ecological regions. Sources from milder forest sections are predominant in the warmer test areas while sources from colder forest sections are predominant in the colder regions. All improvement programs on black spruce should at the same time consider the type of geographic variations of the species and postulate on the greater growth potential, related to the adaptation to a longer growing season, of the southern sources.

White spruce (Picea glauca (Moench) Voss) occupies a large fraction of Quebec annual planting stock because of its growt h rate, ecological plasticity and wood quality. Fifteen to twenty year-old provenance trials have provided information on the geographic variability of the species. A clinal variation in height growth punctuated with ecotypes has been found within the Great-Lakes - St. Lawrence forest region (Corriveau and Boudoux 1971). Furthermore a particulary good gene pool was identified in the southern tip of Ongario and the southwestern portion of Québec between 73° and 83° of longitude and 44° and 47° of latitude. Few general comments may be drawn from these provenance trials; some sources have a high adaptability and show superior growth in several locations (S.2438 Peterborough Ont., S.2445 Cushing Que., S.2446 Beloeil Que.); particular northern provenances have a better growth than the local source (S.2486 Swastika Ont.); selection for adaptability to a large variety of sites is possible but additional gains may be obtained in selecting for site specificity. On a good site at Drummondville the best seed source (S.1976 Petawawa Ont.) outgrows the local provenance by 25 percent and produce as much as 330 m^3/ha at 1.2 x 1.2 m spacing and 90 percent survival at twenty years.

On the basis of information obtained from the provenance tests one hundred superior trees were selected and vegetatively propagated

to constitute a first genetic base for our white spruce improvement program. Additional genetic samplings are being pursued and genecological tests conducted. A wide range genetic study was initiated with collaborators throughout Canada in containers under plastic greenhouses. More precise early estimates of the genetic make up of the species can be obtained but no measure of the genotype-environment interaction is available. Genetics parameters and heritability estimates were calculated. Juvenile height growth heritabilities on an individual tree basis equal to 0.2 were found. Testing in different ecological conditions is still necessary.

Norway spruce (Picea abies (L.) Karst) is an interesting exotic species for plantation under the climate of southern Québec. More than one hundred provenances have now been or are actually tested. On favorable sites adapted seed sources outgrow the native spruces and leaders near one meter long are obtained. Fifteen hardy and fast growing provenances were identified, plus trees were selected and are being vegetatively propagated in collaboration with Canadian International Paper Company to constitute a first genetic base for improvement of the species in function of the climatic conditions of southern Québec (Corriveau 1976). Adequate Norway spruces for the Great Lakes - St. Lawrence River forest region are generally from eastern regions of the Baltic Sea such as Northern Germany, Eastern Poland, White Russia, Latvia and Lithuania. Even in the balsam fir climax of the Gaspé peninsula, where climate is somewhat maritime, Norway spruce provenances from White Russia and Latvia are suitable and their production may be better than black spruce because of superior diameter growth. However Norway spruce is severely damaged by the white pine weevil and the spruce budworm. Intensive planting of this species should be followed by intensive management and protection to assure a good return.

Red pine (Pinus resinosa Aft.) has not been studied intensively in Québec. However trials underway tend to confirm the relative uniformity of the species in height growth. Provenance to provenance and tree to tree variations are rather small. At nineteen years, the height of 12 provenances from Eastern Canada and U.S.A. varies only by 4 percent. Nevertheless variation in diameter is stronger and the choice of the best source would result in a twenty percent increase in volume production. The best provenance, (S.2212 Sorel, Qua.) produced a total volume mean annual increment of 14 m^3 per ha at fifteen years of age when planted at 1.5 x 1.5 m. Identification and use of the best seed source will be an important step toward optimizing return from red pine plantation.

The large genetic variability, early sexual maturity and the particular characteristic to retain seeds on the tree for years

make Jack pine (Pious banksiana Lamb.) one of the most interesting forest species for genetic improvement. Because of its rusticity and ability to colonize successfully poor sandy sites Jack pine is highly suitable for reforestation in the boreal forest. Our oldest Jack pine provenance trials and geographic hybrid test were initiated in 1966. Among the 64 seed sources tested, representing a large portion of the natural range of the species, the local provenances rank first at one test site and fifth at the second site reflecting the adaptation of the local populations to their particular environment. Furthermore, under northern climatic conditions, northern provenances appear to be more resistant to Scleroderris lagerbergii Gremmen. Some gains in growth may be obtained from inter racial hybridization. Ten year results indicate that the geographic hybrid is superior to both parents in 65 percent of the cases. However the hybrid mean height is only 7.5 percent superior to the parental mean. The best hybrid progeny is 30 percent superior to the parents and indicates interest in setting up two population orchards to postulate on the specific combining ability of particular sources.

In 1974 an intensive Jack pine plus tree selection and progeny testing was initiated in western Quebec with the collaboration of the Canadian International Paper Company. Three hundred selections were made in the superior population of lake Baskatong. Seeds and scions were collected on plus trees to constitute a progeny test, a seedling seed orchard and a clone bank (Beaudoin 1977). At present more than 400 additional selections from 40 Jack pine stands are progeny tested on different edaphic conditions representative of the northern reforestation units. During the same period two seed orchards totalizing 60 ha have been established.

White pine (Pinus strobus L.) did not occupy the position that it should in the plantation programs of Quebec during the past 25 years. Blister rust (Cronartium ribicola, J.C. Fich.) frightened foresters and land owners. A reevaluation of the situation of the disease in Québec demonstrated that the white pine range could be subdivided into four susceptibility zones (Lavallée 1974). Two of these zones have a high potential for white pine production where less than 15 percent of the stems are expected to be affected. Interest in white pine has been revitalized. In 1976 a breeding program taking into account ecological features was proposed (Corriveau and Lamontagne 1977). Species hybridization and testing for resistance will be conducted separately from breeding for growth and form. More resistant genotypes would be necessary for plantation in higher disease incidence zones. The genetic sampling of white pine populations in Quebec is half-completed, seeds were exchanged with collaborators, 250 plus trees were selected and are being propagated. Improved seeds are expected for 1990.

Because of its fast growth the larch group has a particular interest for production of pulpwood and lumber in less than 20 and 30 years respectively. A testing and breeding program was initiated on native tamarack (Larix laricina Du Roi) in 1970 based on a large genetic sample. Genetic improvement was also undertaken on Japanese larch (Larix leptolepis Sieb. and Zucc.) and European larch (Larix decidua Miller) (Stipanicic 1975). More than a thousand seedlots constitute the gene bank. Tamarack is well represented with a collection of 700 seed lots. Some three hundred plus trees were selected and vegetatively propagated to constitute breeding and production orchards. Furthermore sixty comparison plantations, provenance and family trials were established in different forest sections of Québec. These trials are still young but already some information is available. In a provenance trial comparing seventy seed sources of tamarack, large variations in stem straightness, in crown form, branch density and length were observed. Tamarack diameter growth is slower than European and Japanese larches but height growth of certain provenances is comparable. Distribution of this species in small stands suggests a certain degree of inbreeding. Multi-provenance seed orchards combined with seed sources displacement from south to north should result in a volume gain. Two tamarack clonal seed orchards have been established.

In a twenty-one year-old European larch provenance trials located at Petawawa and Harrington (Québec) the best sources are from Poland (Wroctam, Krakow, Scarzysko, Grojec and Blizin). Plus trees have been selected in these superior provenances, as well as in older plantations in Québec, to constitute a clonal seed orchard in collaboration with Canadian International Paper Company and the Petawawa National Forest Institute.

Because of the lack of stability in the Japanese larch provenances tested, this species improvement has been initiated by the realisation of multi-provenance orchards established in three regions of southern Québec. In addition a clonal seed orchard from trees selected in the best plantations was established. Hybrid larch (Larix eurolepis Henry) gives better volume production than the parent species. Controlled crosses between the best European and Japanese larchs are planned to develop a more productive hybrids under local climatic conditions.

Following the first results after the introduction of Douglas fir (Pseudostuga mensiezii (Mirb.) Franco) and lodgepole pine (Pinus contorta Dougl.), provenances trials were realized from a sampling of the International Union of Forest Research Institutes. Results in the nursery (Robert 1975) and after 5 years in arboreta indicate that Douglas fir provenances from Interior British Columbia, especially from Shuswap lake region, and from Northeastern

Washington State are among the best. I.U.F.R.O.'s provenance trials with Lodgepole pine are too young to make any definitive conclusion about the best seed sources. An eight year-old plantation of three interior British Columbia provenances in Gaspe peninsula shows very good growth with shoots often as long as 1 m. Sweet fern blister rust (Cronartium comptoniae Arth.) is no more damaging to lodgepole pine than to jack pine, the cankers remaining on the branchs.

Poplars represent great interest for production of biomass in mini-rotation, pulp wood in short rotation and lumber in 20 years rotation. The program of poplar clonal selection and improvement was initiated in 1968 (Vallee 1971). Its objective is to obtain hardy and disease resistant cultivars that can give interesting returns under the diverse ecological conditions of Quebec.

Since 1968 thirty-two poplar clonal tests including 773 clones were established in 9 localities from which fifteen hybrid poplar clones were selected for three regions of Quebec. Jackii poplar (P. x jackii Sarg.) from northern part of the cottonwood range in Quebec is better adapted to the climatic conditions of the boreal forest than cottonwood (P. deltoides Marsh.) and euramerican poplars (P. x euramericana (bode) Guinier) and most of the exotic balsam hybrids. It also has a better growth than P. balsamifera L. clones included in the trials. Inversely for the St. Lawrence Valley the best clones are from P. x euramericana and the hybrid P. deltoides x P. trichocarpa Torr. and Gray (P. x interamericana). Incidently clones of Dr. Schreiner's selection form the hybrid P. deltoides cv. 'angulata' x P. trichocarpa has good performance in the St. Lawrence Valley. At the Matane populetum a small plantation of a P. x interamericana clone has a total volume mean annual increment of 9.2 m^3 per ha at eleven years of age and at 3 x 3 m spacing. Production of 14 m^3 of wood per year could be obtained with the best clones in that boreal region. In the St. Lawrence Valley, ten to fifteen dry tonnes of biomass per ha per year could be produced on a four year rotation.

During the same period the genetic sampling of Populus deltoides and P. balsamifera was partially completed and provenance trials was established with P. nigra L. and P. trichocarpa. In addition more than a thousand crosses were made between several species and hybrids poplars. The genetic variability of P. deltoides throughout its natural range in Quebec has been studied. Variation in leaf rust resistance and timing of buds formation were found to be negatively correlated with latitude. Also annual growth is negatively related to the severity of leaf rust of the preceding year (Vallee 1979[a]). As in most forest species southern cottonwood provenances grow faster than local provenance when

planted in a northern locality but they are also more resistant to leaf rusts.

Research work is conducted on a few precious hardwood species such as Acer, Fraxinus and Juglans. Important variations in sugar content of sugar maple sap have been demonstrated. After a genecological study superior sources of Juglans cinerea L. were identified in the Eastern Townships region of Quebec. Intraspecific hybrids of hardy Juglans nigra L. introduced in Québec in 1882-85 show better adaptation to local climate than the parental population (Parrot 1971, 1976).

As forest genetics research and improvement works progress, efforts are made to include all possible genetic gains into a portion of the reforestation stock. To date thirty-seven outstanding natural stands of nine different species, covering around one thousand hectares, have been managed into seed production areas. Establishment of seedling and clonal orchards has also been undertaken. First important quantity of forest seeds from the actual 225 ha orchard total area are expected by 1985. We estimate that a thousand hectares of orchard would be necessary to produce half of the required seeds for the present reforestation needs.

It is important at this point to mention the serious implication of the Canadian International Paper Company in tree improvement in Quebec. C.I.P. initiated last year a selection and propagation program of black spruce and jack pine for reforestation on its 333,000 ha freehold in the Upper St. Maurice River. The total area to be regenerated annually is estimated at 600 ha (Paille 1979). By next spring the company will have selected and cloned one hundred plus trees of each species. The global objective is to select one hundred trees per species annually during the next five years. These will be progeny tested in representative planting sites of the freehold and seedling and clonal orchards will be established near La Tuque to produce the 1.5 to 2 million seedlings needed annually. We hope that the welcome initiative of C.I.P. will be followed by a number of other pulp and paper companies operating in Quebec.

MORE RESEARCH AND DEVELOPMENT ARE NEEDED

As we have seen, noticeable efforts are made in Quebec to study the genetics of our important forest tree species and improve their genetic quality (appendix I). However this is still too little when compared to the importance of the forest resource in the provincial economy. Much more of the benefits derived from the forest must be returned to it. Each time its productivity is reduced by lack of proper management a part of our total potential for a high quality of life is threatened. Forest management poli-

cies for better conservation of the genes resources must be implemented. The prime utilizers of the forest must be implicated. The forest must be considered by companies and governments as a part of factories where investment is necessary to improve production and to lower harvesting costs.

A series of research and development areas in which effort must be intensified to accelerate genetic gains and their integration into the planting stock were pointed out to the Committee on Tree Seed Production and Tree Improvement in Canada and at the Tree Improvement Symposium held in Toronto in 1978 (Corriveau 1978, Vallee 1979). More basic research in physiology and biochemistry should be initiated to find the relation between juvenile physiological characteristics and ulterior growth traits which would accelerate the selection process. Biochemical studies such as isoenzymes analyses with electrophoresis techniques should be undertaken to help define population structures, seed movement criteria and detection of different degrees of pathogenic resistance. Research on the induction of flowering and seed production on young plants through the use of phytohormones, environmental stresses, etc. would allow to shorten generations and to accelerate selection, testing and genetic gains. Root promotion on physiologically mature cuttings and tissue cultures would be important fields of research to make the most of findings superior hybrids and lines. Research efforts should equally be increased on the stimulation of seed production in seed orchards, protection against seed and cone insects and on seed treatments.

Already the gene pool of our high quality hardwood species has been seriously depleted. Intensive genetic sampling of these species must be initiated as soon as possible and efforts for improvement must be emphasized on the most economic ones. Combined provenance-progeny trials based on intensive genetic sampling of native and exotic coniferous species on a regional level must be achieved (Vallee 1975). These trials will help make recommandations for seed movement, to refine the delimitation of the seed zones and to identify superior genotypes. Management of our oldest provenance trials into improved seed production areas must be accelerated, especially for exotic species for which seeds are not always available. The best trees in those essays have shown adaptation to local conditions and severe selective thinning followed by interprovenance open pollination can produce valuable progenies.

Supply of improved seed in Quebec is an increasing necessity not only for gain in production per unit area but to secure the availability and to lower cost of seeds and seedlings for reforestation. In the present Quebec situation forest geneticists must

not only consider important genetic gains obtained from long and sophisticated methods but also smaller gains obtainable from sure and quickly applicable techniques.

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APPENDIX I

Main material realisations in tree improvement to date in Québec

- Seed zone map based on ecological and administrative factors
- Network of 21 tree improvement arboreta in different forest sections
- 205 provenances trials on 33 species
- 43 progeny trials on 16 species
- 280 introduction and conservatory plantations of exotic species
- 32 clonal trials comprising 773 poplars clones
- 37 managed seed production areas of 9 species totalizing more than 1000 ha
- 4500 selected plus trees of spruces, pines, larches, and poplars
- 11 clonal seed orchards of larches, Jack pine and Douglas fir
- 20 seedling seed orchards of larches, Douglas fir, jack pine, poplars and walnut
- 15 super seedling seed orchards of spruces, pines and fir
- 8 clone banks of spruces, pines, fir andpoplars