Tree improvement and seedling production in Quebec

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Abstract

In Quebec, research and development in genetic tree improvement began in the early 1970's. The establishment of the seed orchard network for eleven species was started in 1980. Forty forest species are now studied in 440 genetic trials. The network will be completed in 1991 with 75 orchards covering 1 024 ha: it will provide all the seed needed to produce the 250 millions seedlings required for Quebec's reforestation programme. Therefore silvicultural practices may have to be modified to guarantee the complete expression of the genotype (growth potential) for ail genetically improved seedlings. Second-generation genetic tree improvement in Quebec combines two new technologies : cutting propagation using the "Bouturatheque" system, and somatic embryogenesis ; both techniques are used to develop multi-familial and multiclonal varieties.

Résumé

Au Quebec, /a *recherche et le developpement en amelioration genetique des arbres datent du debut des annees 1970. L'etablissement d'un reseau de vergers a graines pour 11 especes a commence en 1980. Jusqu'a present, 40 especes ont fait l'objet de 400 essais genetiques. Le reseau sera complete en 1991 pour atteindre un total de 75 vergers repartis sur 1024 hectares; it produira les graines necessaires pour atteindre l'objectif de production de 250 millions de plants fixe par le programme de reboisement du Quebec. Par consequent, les pratiques sylvicoles devront sans doute evoluer pour assurer /'expression complete du genotype (potentiel de croissance) de tous les plants genetiquement ameliores. L'amelioration genetique de seconde generation fait simultanement appel a deux technologies : la propagation par vole vegetative a /'aide du systeme appelle "Bouturatheque" et rembryogenese somatique ; ces deux technologies permettront* de *developper des varietes multi-familiales et multi-clonales.*

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The organizers of this meeting asked me to give a presentation on the following topics :

- Quebec's tree improvement program;
- Quebec's forest protection strategy;
- Needs for improved seedlings and large size seedlings produced in containers or as bare-root stock;
- Experimental results cf plantations established with large size seedlings, and
- Future prospects.

I have decided to group these different topics under three subjects :

1.0 Tree improvement program in Quebec : what has been done to date

2.0 Tree improvement program *versus* reforestation practices in the present conjuncture

3.0 Strategy for a future tree improvement program as a function of new technologies under development

1.0 Tree improvement program in Quebec : what has been done to date

Work in forest tree improvement began in Quebec in the 1950's with seed sources studies and species introduction conducted by the Canadian Forest Service, the Faculty of Forestry and Geodesy of Laval University and the MacDonald Agricultural College of McGill University.

But it is in the beginning of the 1970's that a somewhat well-structured research and development programme was organized with acceptable resources in the provincial and federal government organizations. In 1969, I proposed a tree improvement R-D programme to the Quebec department of lands and forests, which was accepted and supported by a Green Book on forest politics in Quebec published in 1972. This Green Book gave priority to the genetic improvement of fast-growing species like Poplars, Larches and Jack Pine and to the evaluation of exotic species.

Number of genetic trials with the principal tree species studied by research organizations in Quebec

Species	Organizations			Total
	Forestry Canada Québec Region	*Fac.de foresterie Université Laval*	*S. amélioration des arbres M.E.R.*	
Conifers				
Abies balsamea	1		1	2
Larix decidua				
Larix x eurolepis		2	28	30
Larix leptolepis				
Larix laricina			16	16
Picea abies	17	3	30	50
Picea engelmanii			5	5
Picea glauca	23	5	6	34
Picea pungens			3	3
Picea rubens	3			3
Picea mariana	6	1	58	65
Picea sitchensis	3		2	5
Pinus banksiana		2	19	21
Pinus contorta			15	15
Pinus nigra			11	11
Pinus ponderosa			2	2
Pinus resinosa	2	2	2	6
Pinus sylvestris		3	15	18
Pseudostuga menziesii	2		18	20
Pinus strobus	7			7
Hardwoods				
Acer saccharinum			1	1
Alnus glutinosa			13	13
Alnus glutinosa x incana			3	3
Alnus incana			9	9
Alnus rubra			4	4
Alnus rugosa			2	2
Carya cordiformis		1		1
Carya ovata		1		1
Fraxinus americana			2	2
Fraxinus pennsylvanica			4	4
Juglans nigra		1		1
Juglans cinerea		3		3
Populus deltoides			3	3
Populus maximowiczii			3	3
Populus nigra			3	3
Populus trichocarpa			6	6
Populus x sp.			63	63
Prunus serotina		1		1
Quercus robur		2		2
Tilia cordata		2		2
Total : 40 species	64	27	349	440

The first seed orchards were established in 1976 and 1978 with *Larixdecidua* and *Pinus banksiana* progenies. But the most important developments in the Quebec seed orchard network, with the eleven coniferous species used in plantation, began in 1980 following the acceptation of a program prepared by Yves Lamontagne and presented to Quebec's ministry of lands and forests (see Mister Lamontagne's presentation). Up to now a very important quantity of research and development has been realized in Quebec by the forests sector of Quebec's ministry of energy and resources, Forestry Canada's Quebec Region and the Faculty of Forestry and Geomatics of Laval University. Table 1 presents a summary of tree improvement trials carried on by research organizations; you can see that there are 40 forest species studied in 440 genetic trials. Furthermore, some 90 conifer and 60 broadleaf exotic species have been introduced and tested in nursery and in a 20-arboretum network for the species which survive in the nursery. In addition Canadian Pacific Forest Products Ltd. established four seed orchards and two progeny trials for their own reforestation needs on their private lands.

After a real beginning in 1980, the seed orchard network for the eleven coniferous species used in reforestation is nearly complete with 75 orchards covering 1 024 ha. By the year 2000, this network will supply most of the seeds required for Quebec's 250 million-seedling reforestation program, except maybe for a portion of the black spruce seeds. For this species however, the ministry is now going ahead with the second generation of improved stock by producing rooted cuttings harvested on seedlings of the best full-sib progenies selected from controlled crosses between the best trees from the best identified provenances and progenies used in seed orchards.

Results from seed source trials or genecology studies in Quebec now allow identifying the best provenances for reforestation in the different ecological regions of Quebec (C.A.G.A.F.Q., 1987) and delimiting breeding zones for the principal coniferous species used in plantation. This information, combined with progeny trials related to seedling seed orchards, is very useful for second-generation tree improvement. Because of the substantial production gain that can be achieved by using recommended provenances, a special attempt is made by the ministry to use seed from these provenances in the reforestation program.

Many clonal seed orchards also include ramets from trees selected in the best recommended provenances, particularly for species such as white and Norway spruces and European and Japanese larches.

For broadleaf species very little tree improvement has been achieved except for poplar and arborescent alder species (such as *Alnus glutinosa, A. incana,* and *A. rubra)* because of their fast growing characteristics. On the alder species, work has been carried mainly on International Energy Agency provenance-progeny trials, and on progeny trials using full sibs of interspecific hybrids or half sibs harvested on the best trees in our trials (see Table).

For poplar, many clonal trials distributed in different ecological forest regions of Quebec have allowed selecting clones for plantation that are well adapted to the ecological conditions. For the southern Quebec ecological regions, specially the Saint Lawrence River valley, clones have been selected for their growth performance and for their resistance to leaf diseases *(Melampsora Medusae* and *Marsonnina brunnea)* and to *Septoria musiva* canker. To select clones in regard to the latter, the ministry's tree improvement service has developed a large scale artificial inoculation method which allows selecting clones at the nursery level. A relatively large number of interspecific controlled crosses has been made with poplar species during the last 20 years, now making various genotypes available for clonal trials under different ecological conditions.

In 1989 a tree improvement project on hardwood species was initiated in M.E.R.'s tree improvement service. The project gives priority to the improvement of Red oak *(Quercus rubra),* White ash *(Fraxinus americana)* Yellow birch *(Betula alleghaniensis)* and its hybrids. Other hardwood species will also be considered but with less intensive work. The objective of priority species improvement is to select multiclonal varieties adapted to the best hardwood plantation sites of the southern ecological regions of Quebec.

In addition to the tree improvement activities already mentioned, the forest biology research centre of Laval University has conducted research for more than 10 years on the genetic structure and genetic engineering of Betulacea species in Quebec. The genetics group at Forestry Canada, Quebec Region, is also working on transfering the gene of resistance to white pine blister rust from the exotic five-needle pines species to selected white pine clones using genetic engineering techniques.

Introduction of exotic species and provenance trials with those that show promising performance now open opportunities to develop races adapted to the ecological conditions of Quebec and to recommend provenances. This is the case with species such as *Pseudostuga menziesii, Pinus contorta, P. sylvestris, P. nigra, Picea glauca* var. *Albertiana, Alnus glutinosa, A. incana, Juglans nigra, Populus trichocarpa,* etc. We already have seed orchards and selected *Alnus glutinosa* and A. *incana* clones showing good resistance to *Phomopsis sp.* canker.

2.0 Tree improvement program *versus* reforestation practices in the present conjuncture

Investment in genetic tree improvement gives the maximum yield when selected varieties are planted under good site conditions in regards to the species and when the seedling stock used allows full expression of the genotypes. This principle is very important. There is no justification to genetic tree improvement if the wrong type and quality of seedling stocks are planted on sites where there is, or will be limitations to the full expression of the selected genotypes. The promising gains offered by selected varieties can be lost by improper silvicultural practices.

Physiological quality and size of seedling stock must be adapted to the constraints of the plantation site. Reforestation with 15-to 25-cm container seedlings on sites where there will be strong competition from raspberry, other shrubs and herbaceous species and where the seedlings will be suppressed during 3 to 5 years waiting for tending, is a good example where seedling size is not adequate to meet the constraints of the site and of silvicultural practices.

Intensity of soil preparation is also important for genotype expression. If the soil has limiting factors such as fertility, drainage, texture, structure, humus thickness, etc., which favor physiological stress, important losses in growth and, indirectly, in genetic gains will then occur and be amplified by low survival.

Moreover, silvicultural activities are now submitted to public pressure and restrictions. In the actual Quebec conjuncture, it is more and more difficult to use herbicides for the control of competitive vegetation in our plantations. This is very important considering that genetically improved stocks can fully express their growth characteristics when they are planted on the best fertility sites where competition from raspberries, Epilobium, wild cherry, etc., abundant on cutover sites, is very intense. In a forest protection strategy for Quebec forests, presently being written, it is suggested to reduce the use of herbicides to a strict minimum. Considering these constraints, a ministerial comittee on the orientation of seedling stock production has proposed producing larger-size seedlings (> 40 cm) for plantation on sites with intense competition. An inquest made by the committee evaluated the need at 20 million large-size seedlings out of a 250-million reforestation programme.

I have suggested to the ministry some conifer plantation models using 75-cm-tall large-size container seedlings, allowing the use of mechanical tending for competition control. Using 75-cm-tall seedlings gives a gain of at least 5 years on spruce plantation rotation as compared to 20-25-cm-tall containerized seedlings. It is a lot easier to get a 50-cm height increment in the nursery than on the plantation site where competition from raspberry suppresses the young plants as early as in the first or second year after plantation. Many trials comparing large-size bare-root seedlings with conventional-size seedlings used in reforestation in Quebec have confirmed after five years : (a) a reduction of the rotation period; (b) that the initial difference in height still exists or increases after 5 years and; (c) that large-size seedlings need less release from competition or even none (J.-M. Veilleux, personal communication).

Large-size seedlings are somewhat more expensive to produce and to plant but the per-hectare investment can be reduced by planting a lower number of seedlings without seriously influencing the marketable wood production of the plantation. For example, at age 50 there is a difference of 10 cubic metres in marketable wood volume between white spruce plantations having 2 500 and 1 600 seedlings per hectare which have not been thinned (Quebec plantation yield table by Bolghari and Bertrand 1984). These 10 cubic meters do not justify investing 900 additionnal seedlings per hectare.

To conclude on this aspect, apart from silvicultural constraints, public opinion combined with more restrictive laws on the use of pesticides in the environment forces foresters to review their practices in establishment, in species composition and in silvicultural treatments of plantations. This review must be made taking in consideration that genetically improved seedlings need to be planted uder site conditions, and cultivated in a manner that allows maximum expression of the genotype.

3.0 Quebec strategy for a future tree improvement program as a function of new technologies under development

The seed orchard network presently being completed is the first generation of genetic tree improvement in Quebec. The strategy for second-generation tree improvement aims at getting maximum genetic gains for the desired characteristics. To achieve that target, the tree improvement service has suggested to the ministry the development of multi-familial varieties in a first step, and of multiclonal varieties in a second step. Multi-familial varieties will be developed by selecting the best progenies from controlled crossed between trees from the best known provenances, progenies and clones for a given breeding zone. Multiclonal varieties will be developed by selecting clones inside the very best progenies. For certains species, inter-specific crosses will be explored such as the hybrids between the European and Japanese larches.

This strategy, very similar to other strategies followed in different other countries, takes into consideration the potential of technologies already available or nearing the operational level. This is the case for the "Bouturatheque" cutting propagation system, somatic embryogenesis, *in vitro* explant micro-propagation, and seed production under greenhouse conditions using flower induction.

In 1988 the forest sector of Quebec's ministry of energy and resources took the first step towards second-generation tree improvement with the building of a cutting propagation centre based on the "Bouturatheque" system that I had developed for my own projects on poplar and alder genetic improvement. To propagate hybrid aspen and alder clones, I tried different greenhouse procedures to root green cuttings. But most of those were not satisfactory because of variable results depending on seasonal variations and on the requirement for careful tending complicated by large variations in greenhouse conditions, combined with the high cost of greenhouse operation during the Quebec winter. I then decided to apply some techniques from the *in vitro* culture system to root green cuttings in a peat moss-vermiculite substratum as in the greenhouse method. To that end, four-storied shelves were built, each story holding fluorescent tubes 8 cm from the top of a rooting chamber built from transparent acrylic and nearly hermetic to keep relative humidity at 95%. With a collaborator, Richard Noreau, we conducted many trials to find the best type of fluorescent lamps (quality of the light), the best level of light intensity and photoperiod, the best frequency of water and fungicide misting, and the ideal temperature inside the rooting chambers, which is related to room temperature and light intensity. We also tried different rooting chambers and rooting containers (Photos 1 to 4).

We have defined a system where succulent green cuttings are rooted in a 4- to 8-week period for certain hardwood and conifer species under a low light intensity of 2 700 to 3 000 lux at a temperature of 25 to 27°C in the rooting chamber and 23° to 25°C in the substratum. Misting 2 to 3 times a week, once with a fungicide, and using *Daylight* fluorescent tubes gives very good and reliable results.

This cutting propagation system, that I have named "Bouturatheque", is a compact system permitting to root green succulent cuttings under controlled conditions all year long. The system was developed at an operational level by the building in 1988 of the cutting propagation centre at the Saint Modeste provincial nursery, which is described by Michel Campagna in the next conference (Photo 5).

One of the limitations in the cloning of conifer species is clone ageing. Recently the Petawawa National Forest Research Institute has developed for spruce an important aspect of somatic embryogenesis technology as well as embryonic callus cryogeny, opening the possibility for cloning embryos from black and white spruce mature seeds (Tremblay 1990) and of preserving clone juvenility by storing embryo caili at -140°C. This year, the tree improvement service of the ministry of energy and resources has subsidized a Laval University project on improving embryonic cloning and bringing it to the operational level. it is hoped that in the near future, this technology can be used to develop multiclonal conifer species varieties from seed of the best full sibs already selected to compose the multi-familial varieties. As research on somatic embryogenesis progresses rapidly in many countries, part of the known technology can now be used to begin selecting multiclonal varieties of species such as black, white and Norway spruces as well as larch.

For many hardwood species and particulary those to which Quebec gives priority (white ash, red oak and yellow birch) clone ageing can be controlled. Moreover, for many hardwood species, in vitro culture of the apex seems to work relatively well. Thus Quebec's hardwood species improvement strategy aims at selecting multiclonal varieties instead of establishing seed orchards.

References

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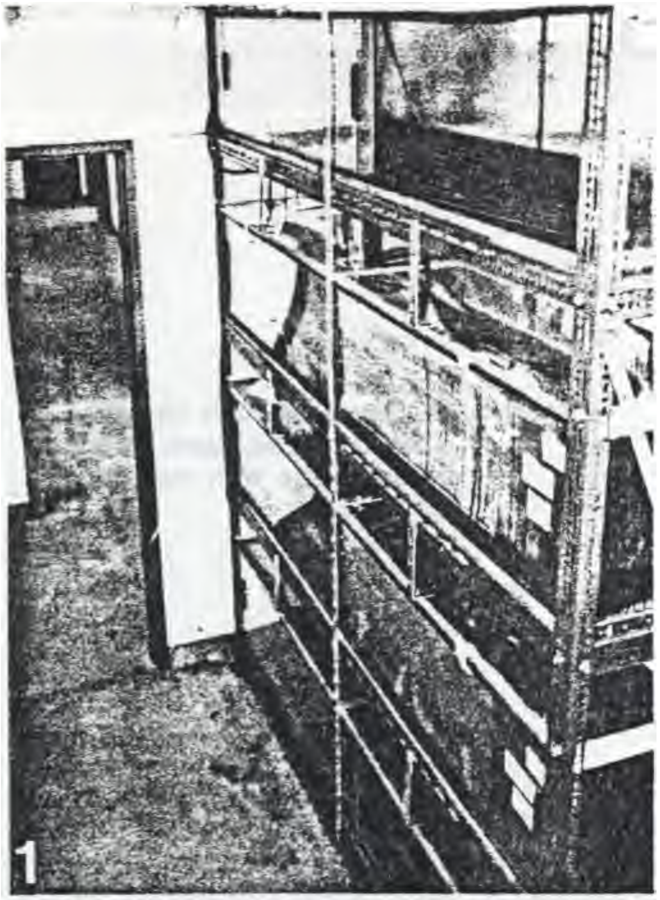

Photo 1. *Bouturatheque* made up of acrylic rooting chambers

Photo 2. *Bouturathêque* made up of rooting containers assembled from plastic fish boxes covered with polyethylene film domes

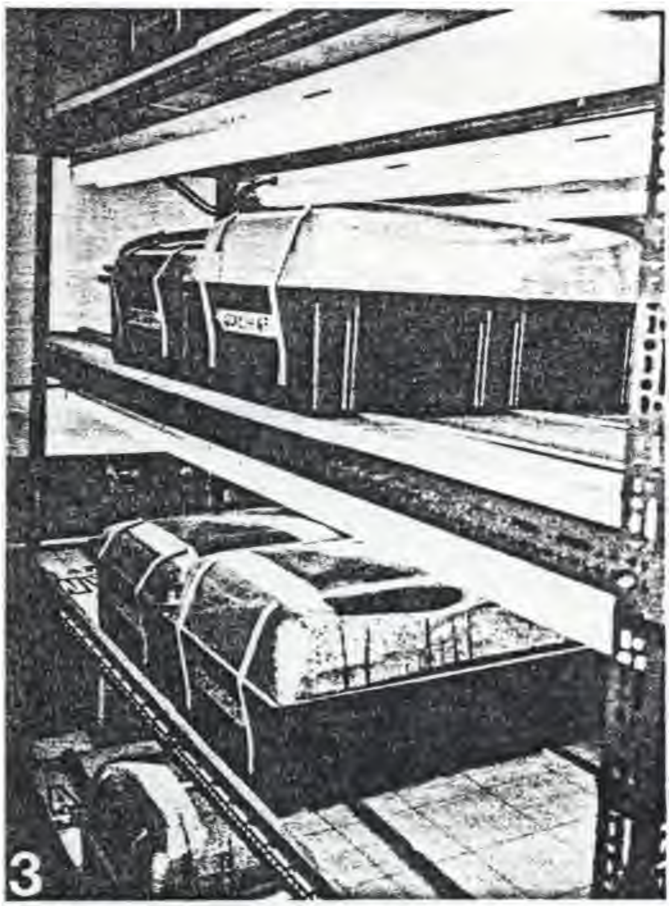

Photo 3. *Bouturatheque* made up from custom molded plastic mini-greenhouses with molded acrylic domes

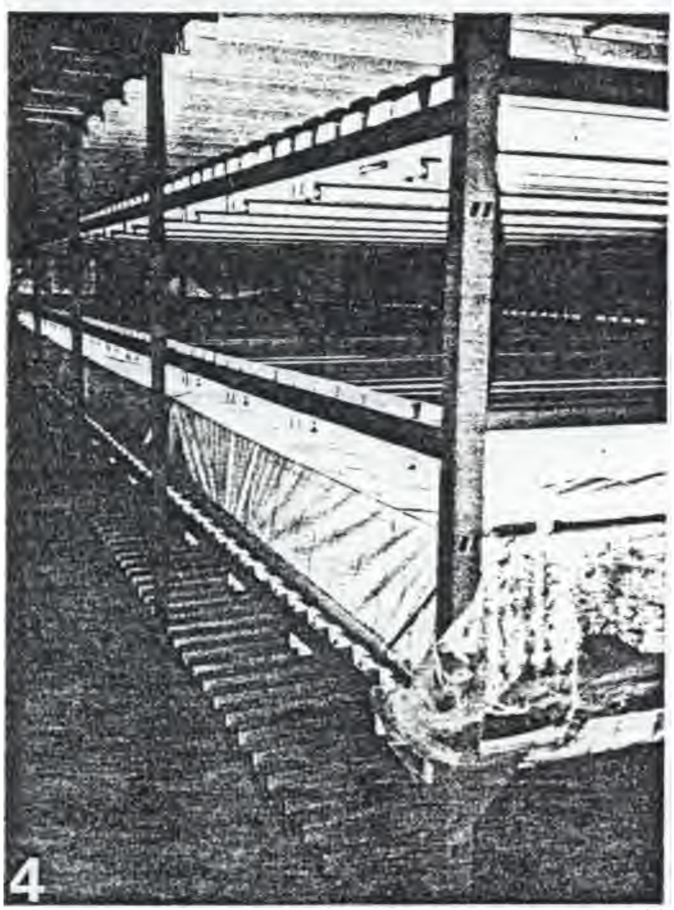

Photo 4. *Bouturathêque* made up of polyethylene film mini-greenhouses. This is the type used in the rooting centre at the St. Modeste nursery.

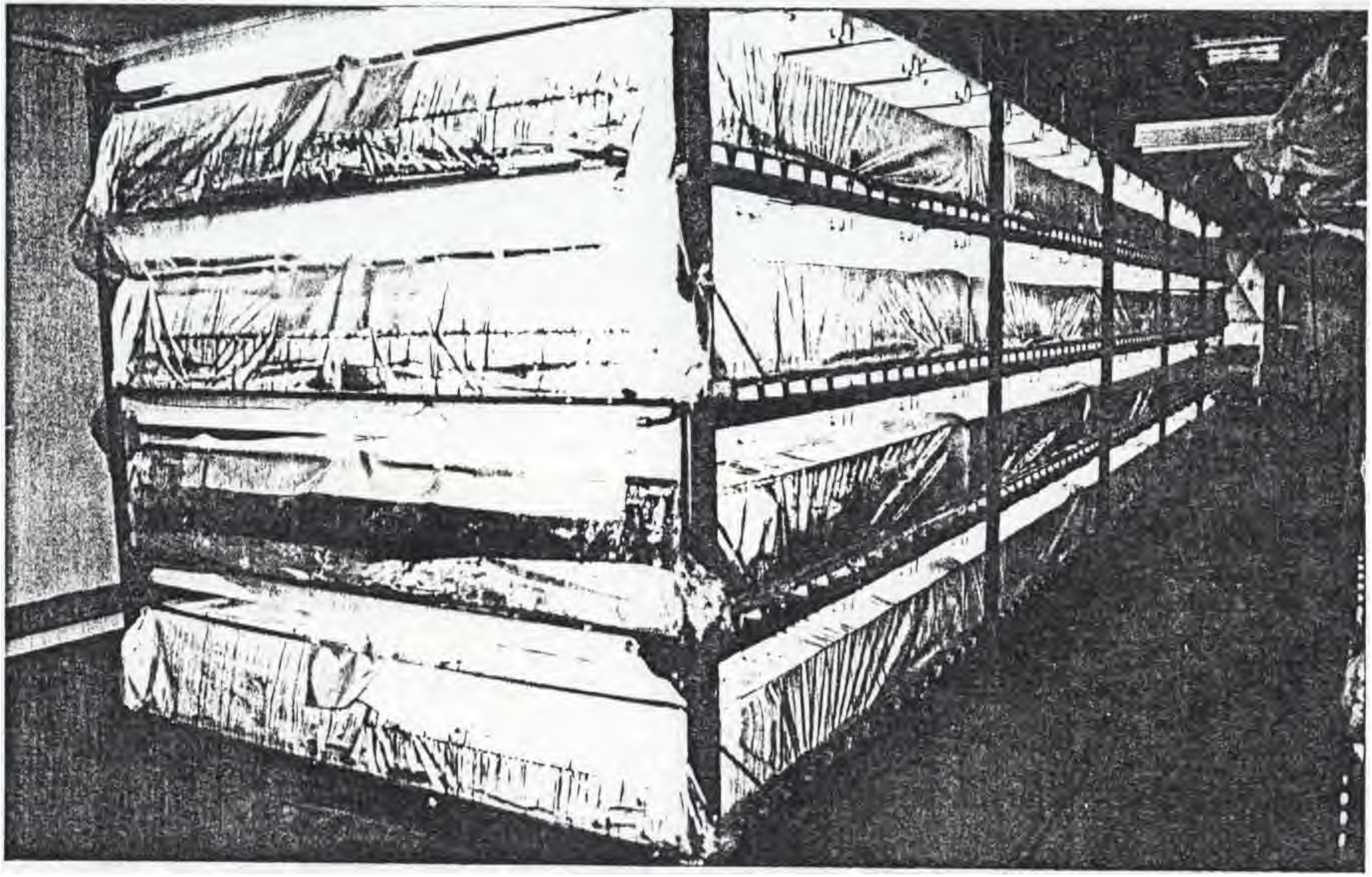

Photo 5. One of the six sets of four-storied shelves with confined polyethylene mini-greenhouses for operational production of I million stecklings *per* year at the cutting propagation centre of the St. Modesto forest nursery