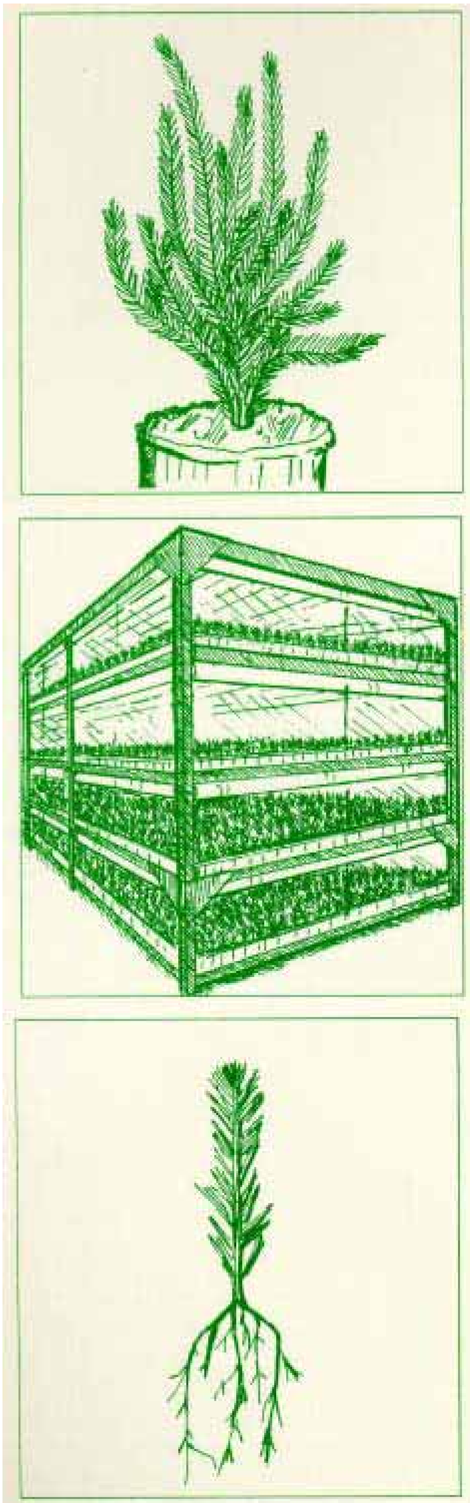
BLACK SPRUCE CUTTING PROPAGATION AT THE PÉPINIÈRE DE SAINT-MODESTE



Denise Tousignant
Pierre Périnet
Michel Rioux

Québec

BLACK SPRUCE
CUTTING PROPAGATION
AT THE PÉPINIÈRE DE SAINT-MODESTE

Denise Tousignant, biologist, M.Sc. [1]
Pierre Périnet, Forest Engineer, M.Sc. [2]
Michel Rioux, Forest Technician [1]

Notes for cover page :

1. Gouvernement du Québec, ministère des Ressources naturelles,
Pépinière de Saint-Modeste,
410, rue Principale, Saint-Modeste (Québec, Canada), G0L 3W0
Telephone : (418) 862-5511 Fax : (418) 862-0564

2. Gouvernement du Québec, ministère des Ressources naturelles,
Service de l'amélioration des arbres,
2700, rue Einstein, Sainte-Foy (Québec, Canada), G1P 3W8
Telephone : (418) 643-7994 Fax : (418) 643-2165

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ABSTRACT

The Pépinière de Saint-Modeste has set up a pilot project to industrialize the *Bouturathèque* system used for the vegetative propagation of genetically improved black spruce. The system is based on the continuous culture of young stock plants in greenhouses and on the rooting of the cuttings under artificial conditions. The center produces two million black spruce stecklings annually, which are delivered as large-sized plants for reforestation.

In this document, we explain the various steps of steckling production, from stock plant sowing to cutting transplantation and bareroot or container cultivation. One chapter describes the organization of the propagation work. The key factors in the success of each step are also discussed and possible ways to improve production techniques are explored.

RÉSUMÉ

Le Centre de bouturage de Saint-Modeste réalise un projet pilote en vue d'industrialiser le système Bouturathèque utilisé pour la multiplication végétative de l'épinette noire. Ce système est basé sur la culture continue de jeunes pieds-mères en serre et sur l'enracinement des boutures dans des conditions artificielles. Le bouturage permet de multiplier les plants cultivés dans le cadre des programmes d'amélioration génétique. On produit chaque année deux millions de boutures d'épinette noire à partir desquelles on cultive des plants de fortes dimensions destinés au reboisement.

Dans ce document, on explique toutes les étapes de production, depuis l'ensemencement des pieds-mères jusqu'au repiquage des boutures et à leur culture, à racines nues ou dans des récipients. De plus, un chapitre est consacré à l'organisation du travail de bouturage. On traite aussi des facteurs qui déterminent le succès de chaque étape de culture et l'on identifie les avenues à explorer pour améliorer les performances.

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INTRODUCTION

In 1989, the ministère de l'Énergie et des Ressources (MER), now known as the ministère des Ressources naturelles (MRN), inaugurated the cutting propagation centre of the Pépinière de Saint-Modeste, where conifer plants obtained through genetic tree improvement programs are propagated. At the time, nearly 48 % of the plants used in Québec's reforestation program were black spruce. Every year, the centre had to produce one million genetically-improved **stecklings**[1]. Since then, annual production has increased to 2.25 million stecklings.

The MRN now encourages more and more the use of **large-sized plants** (**LSP**) and genetically improved material. In the case of black spruce, the breeding strategy is based on **controlled crosses** followed by **progeny tests** to evaluate the **families**. Controlled crosses are expensive and do not produce enough seeds to satisfy current requirements. **Cutting propagation** is therefore used for **vegetative propagation** of elite families.

During the 1980s, a new experimental propagation system was developed by the Service de l'amélioration des arbres at the MRN's Direction de la recherche forestière (Vallée and Noreau, 1990). The system, known as the ***Bouturathèque***, is based on an original propagation method that differs from traditional techniques in terms of the **cutting** supply and the rooting conditions used. The system can be automated and operated throughout the year, which means that the infrastructures quickly become profitable. In 1989, a pilot project was launched to industrialize the *Bouturathèque* system at the Pépinière de Saint-Modeste.

The centre's current production objectives are two million black spruce (*Picea mariana*) stecklings, 200,000 white spruce (*Picea glauca*) and 50,000 Norway spruce (*Picea abies*). The centre also produces the cuttings used for progeny testing as part of spruce and hybrid larch (*Larix* × *eurolepis*) genetic improvement programs.

This document describes the cutting propagation technique as applied to black spruce. It contains a summary of the experimental and operational results obtained.

1 The words in bold type are defined in the glossary at the end of the document.

1 THE ORIGIN OF VARIETIES

In most tree improvement programs of the 1950s, the main purpose of vegetative propagation was the **cloning** of outstanding individuals. However, the difficulties inherent in cloning made it less popular, and today **bulk propagation** is generally preferred. This latter technique does not provide the same **genetic gains**, because it does not capitalize on intra-family genetic variations, but it does allow easy reproduction of superior families (Bentzer, 1993). It was therefore selected for use in Québec's black spruce genetic improvement program, undertaken in the early 1970s. In the 1980s, a number of cutting propagation programs were launched throughout the world for mass propagation of conifers (Ritchie, 1991, 1994).

Around this time, Québec breeders began to select the best black spruce specimens in **provenance tests**, set up in 1974-1975 as part of a pan-Canadian program, for controlled pollinations (Gagnon *et al*., 1993; Gagnon and Villeneuve, 1994). The full-sib families obtained are grouped together to form varieties, and then evaluated in progeny tests set up simultaneously in nurseries and forest sites. On the basis of the results obtained, the less effective families can be eliminated. The genetic quality of the varieties can also be improved by introducing new parent plants into the breeding population. The additional gains obtainable through cloning and **somatic embryogenesis** are currently being studied. The strategy is in conformity with the principles of genetic improvement, i.e. repeated cycles of selection, crossing and testing.

Black spruce cutting propagation is also practised in Ontario, Nova Scotia and New Brunswick. In Ontario, the program is aimed at producing **multiclonal varieties** through **serial propagation**, while in Nova Scotia it is used to propagate a superior provenance to compensate for occasional insufficient supplies of improved seeds.

2 OVERVIEW OF THE SYSTEM

The production of plants from cuttings involves a number of steps, described briefly in Figure 1. In the case of black spruce, the **stock plants** are first cultivated intensively in greenhouses, for approximately three years (Figure 1A), under continuous **forcing** conditions. They are **cut back** to obtain a short, bushy form that maximizes cutting yields. The cuttings, measuring between 5 cm and 7 cm in length, are harvested at the **semi-lignified stage**, every eight to ten weeks. They are planted in containers with 25 cm^3 or 50 cm^3 cavities (Figure 1B). During the rooting period, which lasts for eight weeks, the cuttings are placed in **mini-greenhouses**, with high relative humidity, low levels of artificial lighting and carefully-controlled temperatures. Once rooted, the cuttings are acclimatized in greenhouses (Figure 1C), and then, depending on the season, they are transferred outside or into cold storage (Figure 1D). In spring, they are transplanted in nursery beds or larger containers (Figure 1E), to obtain large-sized plants (LSP). Two years later, the stecklings are delivered for reforestation purposes.

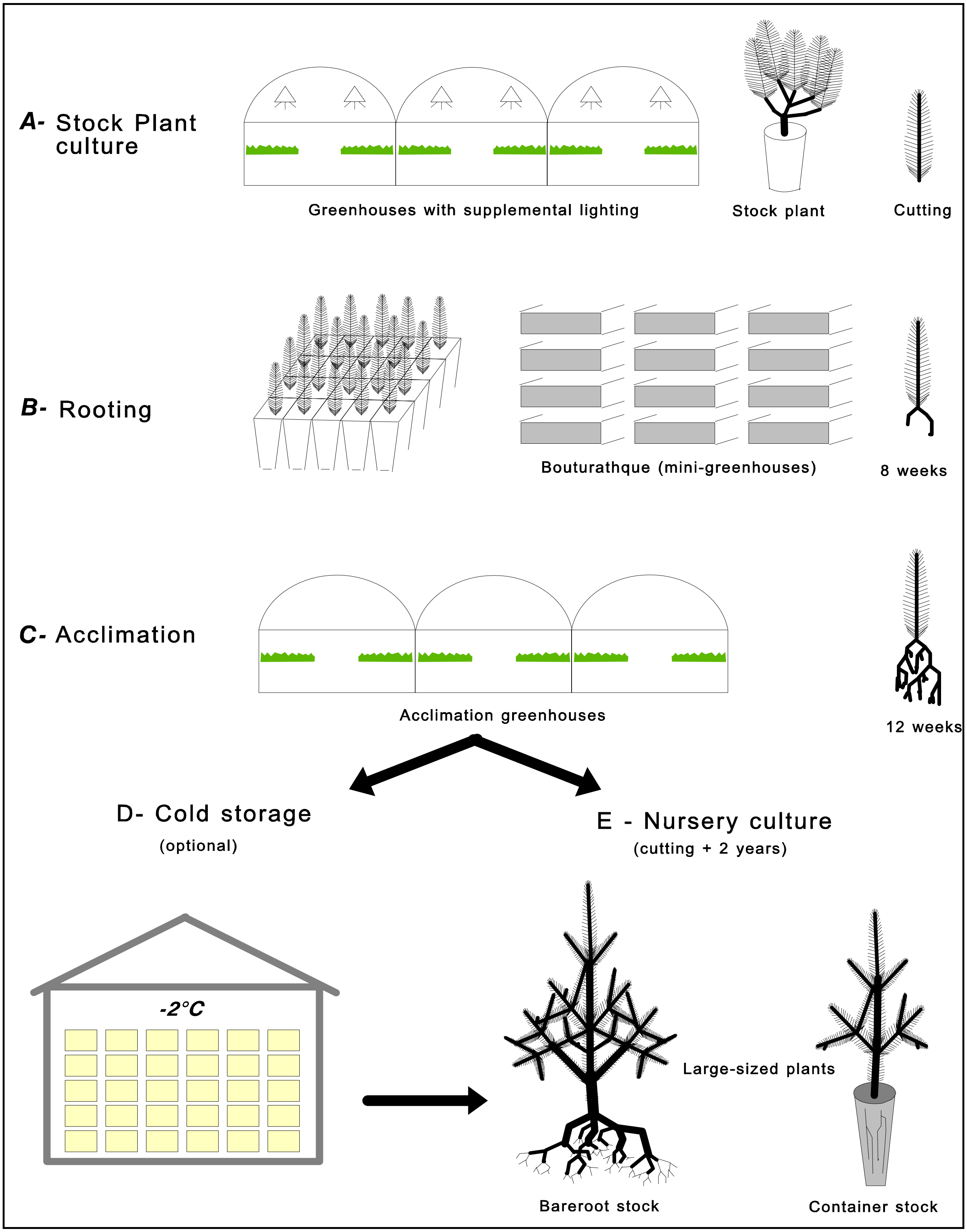

Figure 1. *Diagram of the system used to produce stecklings at the Pépinière de Saint-Modeste.*

3 STOCK PLANT CULTIVATION

Black spruce stock plants are cultivated intensively in greenhouses, under year-round forcing conditions. They are usually grown in containers comprising 25 200 cm^3 cavities. Regular pruning results in a short, bushy form that maximizes cutting yields.

When the stock plants are four or five months old, young softwood cuttings (semi-lignified stage) measuring between 5 cm and 7 cm are taken approximately every two months. After three years, the stock plants are transplanted into outdoor propagation hedges, where they continue to provide summer harvests of cuttings for several years.

The black spruce stock plant cultivation method developed at Saint-Modeste is unique. It differs from the other systems in its use of forced greenhouse cultivation of stock plants and the periodic harvesting of young semi-lignified cuttings over a three-year period.

3.1 Cultivation Techniques

3.1.1 Sowing and Growth Conditions

The seeds used to grow the stock plants are in short supply and generally expensive, because they are obtained through controlled crosses. It is therefore not possible to check the germination percentage before sowing. The seeds are sown manually : each one is placed in a cavity filled with a mixture of 80 % peat and 20 % vermiculite, and then covered with silica. After germination, the seedlings are grouped together to maximize container and greenhouse use. Lots and families are carefully identified and followed in progeny tests.

To encourage both vegetative growth of the stock plants and rooting of the cuttings, specific forcing conditions must be maintained in the greenhouses (Sy *et al*., 1996). The temperature is set to 23 °C during the day and 19 °C at night, and auxiliary lighting of 8,000 lux (140 $\mu mol \cdot m^{-2} \cdot s^{-1}$) is switched on automatically when the natural light drops below a minimum threshold (Photo 1, page 15). The auxiliary lighting is provided by the same high-pressure sodium vapour lamps that maintain a year-round photoperiod of 18 hours for the stock plants.

3.1.2 Stock Plant Pruning

As mentioned previously, the black spruce stock plants are cut back to obtain a short, bushy form that maximizes cutting yields (Photo 2, page 15). When they reach an average height of 8 cm (Figure 2a), the seedlings are pinched back to 5 cm to induce branch formation near the base of the stem. At the first harvest, which takes place approximately 14 weeks after sowing, it is usually possible to take between three and five cuttings measuring 5 cm to 7 cm from each stock plant. Subsequent prunings maximize branch formation and cutting yields, not only in the greenhouse but also later, in the **propagation hedges**. They also maintain the stock plants at a juvenile stage for a longer period, thus promoting higher rooting levels, **orthotropic** (vertical) growth and vigorous cuttings.

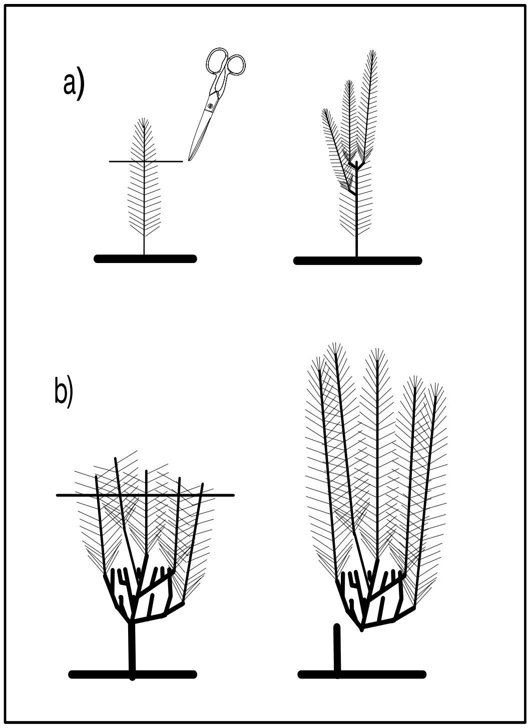

Figure 2. Stock plant pruning technique. (a) Initial pinching and results; (b) appearance of stock plant after systematic prunings.

Whenever cuttings are taken, the stock plants are systematically cut back to a pre-established height. After the first harvest, they are cut back to 5 cm, but during the following three years they are allowed to grow progressively to 10 cm or 12 cm (Figure 2b). Other pruning methods have been tried, but systematic cutting back was found to be preferable, even though it slightly reduces overall stock plant productivity, because it is the only method that allows continuous growth for three years.

3.1.3 Watering

In the period between cutting harvests, stock plant physiological activity and growth vary cyclically, and water requirements fluctuate accordingly. After pruning, the plants need very little water, but once they begin to grow again, their requirements increase. In the days preceding the harvesting of cuttings, the stock plants grow exponentially and their water requirements are at their highest. Because of their luxuriant foliage the young shoots are highly sensitive to water stress, which causes wilting. They must be watered frequently and copiously, but not to excess, since too much water can suffocate the roots and slow down plant growth. In fact, it is better to wait until the substrate is slightly dry before watering. This operation is generally performed using a mobile robot that transports spraying booms above the plants. The spray heads can be adjusted as required.

The most accurate method of assessing the amount of water in the substrate and determining water requirements is to weigh the containers. Standards have been established on the basis of the characteristics of the different stock plant lots (types of containers and substrate used, average stock plant mass, etc.). Watering must be carefully controlled if container mass is to be maintained within acceptable limits. A number of factors must be considered : stock plant growth rates, cavity size, environmental conditions, etc. As employees gain experience, however, they are able to assess water requirements without systematically weighing the containers. It is important to remember that drying rates will vary in different areas of the greenhouse, and some sectors must be watered more often — for example, those located along the aisles or above heating pipes.

3.1.4 Repression of Insects and Diseases

Integrated pest management helps prevent the diseases most likely to affect the stock plants, especially fungal infections such as grey mold (*Botrytis cinerea*). Excessive watering, which causes the foliage to remain wet for long periods, must be avoided and, when the foliage is too dense, the stock plants are trimmed to improve aeration. In addition, the plants are examined regularly to detect problems as early as possible, and steps are taken to reduce the risks of contamination (for example, regular disinfection and cleaning of the greenhouses, proper ventilation, etc.). A fungicide solution is also applied before the cuttings are taken.

Stock plants grown in greenhouses are particularly vulnerable to aphids and they are sometimes attacked by mites brought in with plant material from outside. As soon as pests such as these are detected, an appropriate insecticide or acaricide is applied to the sectors affected. Fungus gnats are often found in the greenhouses, but they rarely pose a serious threat.

3.1.5 Container Types

Several types of containers were tested to optimize the stock plant propagation factor (the number of cuttings obtained per plant and per greenhouse surface unit), including plastic containers comprising 25 200 cm^3 cavities (25-200), 4" diameter plastic pots and 23 l trays with a capacity of 50 stock plants (Figure 3). The pots were found to produce the highest individual stock plant yields, and the 25-200 containers, the best surface unit productivity. The performance achieved with the trays was intermediate in both areas. The principle is simple : when larger containers are used, the size of the stock plants increases, but their number per surface unit decreases.

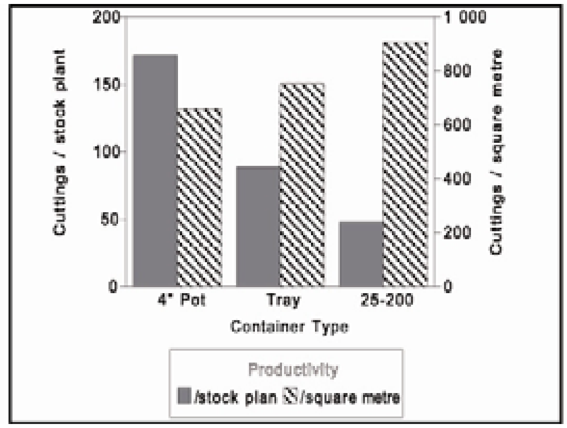

Figure 3. Comparison of stock plant yields per individual plant and per greenhouse surface unit, after approximately two cultuvation years.

Our present aim is to produce as many cuttings as possible in the space available, rather than increasing the number of cuttings per stock plant. We have therefore opted for the 25-200 containers for our standard cultures. This type of container is also easy to handle. If we were faced with a shortage of seeds, or if our production strategy were to change, we could use larger containers or adopt other cultivation methods. For example, we are currently considering the possibility of growing stock plants in one-litre or larger containers, and leaving them outside for a period of time to reduce greenhouse cultivation costs.

3.1.6 Fertilizing

Particular attention is paid to stock plant fertilization, which helps control development in the greenhouse. Our approach was inspired by the method developed by Langlois and Gagnon (1993) for the production of conifer seedlings. It is based on weekly plant nutrient requirements (nitrogen, phosphorus and potassium), and the maintenance of a minimum fertilizer level in the substrate. Stock plant requirements are assessed according to their biomass, the nutritional content of their tissues and seasonal variations. In winter, for example, the plants need less nitrogen because they receive less sunlight.

The fertilization program must take account of the forcing process and the repetitive growth/cutback cycles. Stock plant development obviously does not follow the same growth curve as other seedlings, because by harvesting cuttings before **summer lignification**, we deprive the stock plant of a large part of its biomass and provoke the constant formation of new shoots. Following periodical analysis of the substrate and plant tissues, we can make any adjustments required to maintain the nitrogen content of the cuttings at around 1.5%.

For many woody species, if the stock plants are overfertilized, the cuttings will not root properly (Henry *et al*., 1992; Moe and Andersen, 1988). In the case of black spruce, for example, nutrition too rich in nitrogen will produce cuttings that become too long and vigorous before reaching the optimal harvesting stage. The fertilization program must therefore be designed to maintain continuous stock plant growth while at the same time limiting cutting vigour, to maximize rooting potential.

Fertilizer doses are established on the basis of empirical results, according to the amount of nitrogen required by the stock plants to produce a given number of cuttings at regular intervals, i.e. approximately 3 mg N / week / cavity for 25-200 containers. Fertilization is adjusted to reflect analysis results, stock plant development and seasonal variations. Since the period between two cutting harvests is relatively short, nitrogen is administered only in the form of nitrates and ammonium. Urea is avoided because it can have a delayed effect on growth.

It is thus easier to control the quantities of nitrogen available and to modify the substrate content where necessary.

3.2 Harvesting the Cuttings

A key factor in propagation success is the development stage reached by the cuttings when they are taken from the stock plants. Development is judged by the length of the cuttings and the degree of **lignification**.

3.2.1 Length

The rooting percentage does not necessarily depend on the length of the cuttings. However, when they are less than 5 cm long, major cultivation adjustments are needed to produce large-sized plants. On the other hand, if they are between 10 cm and 12 cm long, they will have to be placed in larger containers, and system productivity will be reduced (584 cuttings per m^2). We therefore recommend the use of cuttings between 5 cm and 7 cm long, because they are easy to handle and allow maximum productivity (1,636 cuttings per m^2).

3.2.2 Lignification

The cuttings can be harvested when their base begins to lignify. The phenomenon of lignification becomes apparent through a whitish colour in the normal sectioning zone. It can also be measured more accurately, by establishing the percentage of dry matter in the cuttings (the rate increases as the tissues lignify) (Figure 4). This is done by obtaining the ratio of dry mass to fresh mass. When the cuttings reach the appropriate development stage (i.e. the semi-lignified stage), they contain between 28 % and 32 % of dry matter. However, this percentage is affected by growth conditions. For example, at a given apparent lignification stage, the percentage of dry matter will be higher in cuttings taken outside, from the propagation hedges, than in those taken from greenhouse plants.

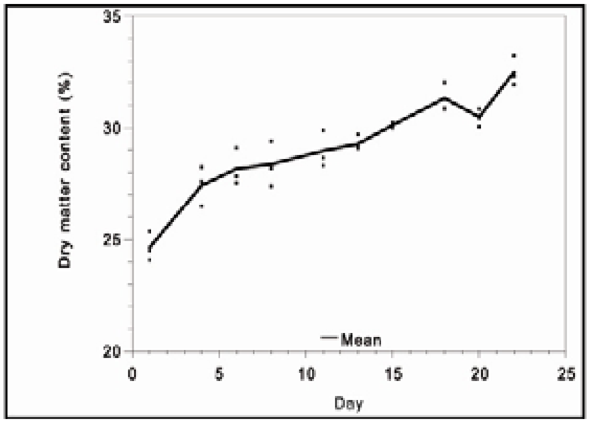

Figure 4. Increase in cutting lignification on the stock plant before harvesting. Measurement began (day I) when the cuttings were 5 cm long.

Although the dry matter content is not always directly related to the rooting percentage of the cuttings, it has a significant impact on their general behaviour during the rooting period (Tousignant, 1995). Insufficiently lignified cuttings are fragile, more difficult to plant in the substrate and more vulnerable to water stress and pathogen attacks. They also tend to grow in height, at the expense of root development, and they are more difficult to cultivate during the rooting phase. In contrast, cuttings that are sufficiently lignified produce larger root biomass (Figure 5).

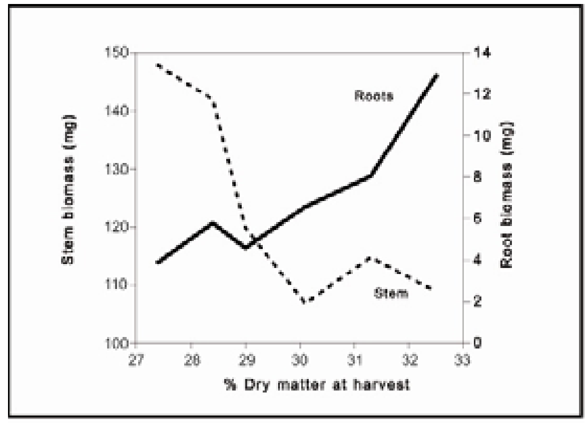

Figure 5. Relationship between the degree of lignification of cuttings at harvesting and biomass allocation between stem and roots, 12 weeks later

Even though greenhouse-grown stock plants are cut back frequently, they follow a seasonal cycle dictated by natural sunlight levels (Figure 6). In summer, growth is rapid and cuttings can be harvested at shorter intervals. It slows down during the fall, and the plants produce less cuttings. Reduced sunlight cannot be compensated by auxiliary lighting or additional fertilizer, but systematic pruning each time cuttings are taken will significantly reduce growth slow-down. Sunlight also influences the state of the cuttings at harvesting. Slow growing plants (fall and winter) lignify more quickly, and it is easy to find shoots that have reached the required length and lignification stage. In contrast, fast growing plants (spring and summer) lignify less quickly, and when they reach the right length they are often still highly turgid.

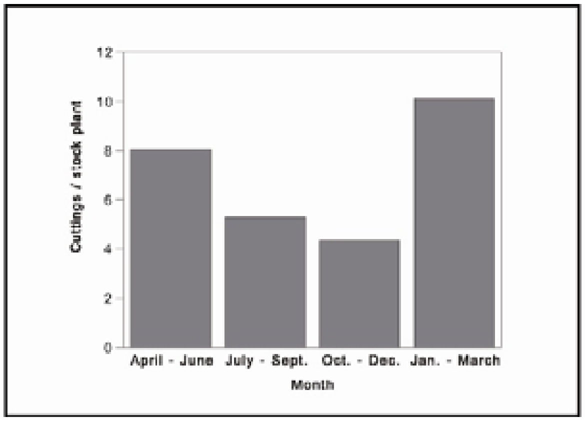

Figure 6. Seasonal variation in the yield of a lot of stock plants cultivated in 25-200 containers, during the first harvesting year (between 4 and 15 months) – The columns represent the total number of cuttings for each period.

It is rare for all the cuttings in a given stock plant lot to reach the same physiological stage at the same time, and the resulting variations can affect propagation results. We must therefore control cutting length and encourage even lignification. This can be achieved by adjusting nitrogen content and temporarily reducing the photoperiod to eight hours (**short day treatment**). A treatment of nine short days, prior to cutting harvesting, can easily be included in the production cycle without extending it. The cuttings are taken between three and six days after the treatment, and lignification continues in response to the signal given by the reduced photoperiod. They root better, and develop a larger root biomass (Figure 7). Once the cuttings have been taken, the stock plants are cut back, so that growth can resume without delay.

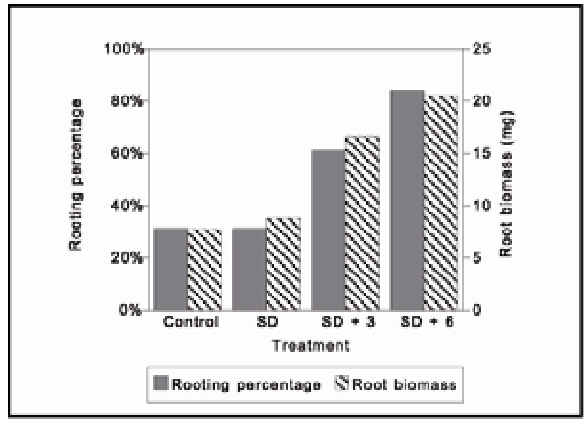

Figure 7. Effect of a short day treatment and the waiting period before harvesting on the rooting percentage and root prodution of black sprue cuttings, 12 weeks after harvesting. SD: 9 short days without waiting; SD+3: 9 short days and 3 waiting days; SD+6: 9 short days and 6 waiting days. Cuttings from the control batch were taken at the same time as those from the SD-6 treatment.

3.3 Cutting Yields

As mentioned in section 3.1.5, the stock plant propagation factor depends to a large extent on the container selected. The black spruce propagation program is presently directed towards bulk propagation of a set of families rather than cloning of a certain number of individuals. Since we have enough seeds, we use 25-200 containers to maximize overall system productivity, even though pot cultivation gives better individual stock plant yields.

When the stock plants are approximately three years old, they are transplanted outdoors, into propagation hedges, where they continue for a further three years to produce cuttings that root as well as those taken from younger plants (Photo 3, page 15). Because of the repeated pruning to which the stock plants are subjected in the greenhouses, the propagation hedges are very compact. Their productivity depends on plant size, and thus on the type of container used. The larger the stock plants when they are transplanted into the hedges, the higher the number of cuttings they produce.

Table 1 shows the potential yield of stock plants based on the example of a lot grown in a greenhouse for three-and-a-half years, mainly in 4" pots, and then transplanted into propagation hedges. If the stock plants were grown in smaller containers, such as the 25-200, for example, their individual yields would certainly be less. However, as they would also be smaller, more of them could be grown in the same space, and the total yield would be the same.

Table 1. *Example of a Stock Plant Lot Yield*

Year	**Age (Years)**	**Type of culture**	**Average yield (cuttings/plant)**	
			Periodic	**Cumulative**
1989	1	Greenhouse (sown in 45-100 containers)	7.5	7.5
1990	2	Greenhouse (repotted in 4" pots)	44.4	51.9
1991	3	Greenhouse (4" pots)	55.3	107.2
1992	4	Hedge (transplanted during summer)	71.5	178.7
1993	5	Hedge (1^{st} harvest)	61.1	239.8
1994	6	Hedge (2^{nd} harvest)	102.5	342.3

Plate 1

Cutting Production and Rooting

Photo 1
The black spruce stock plants are grown in greenhouses, in continuous forcing conditions, which enables cuttings to be produced year-round for approximately three years.

Photo 2
As a result of repeated prunings, this stock plant, which is one- and-a-half years old, has developed a short, bushy form which maximizes yields.

Photo 3
After three years of intensive greenhouse cultivation, the stock plants are transplanted into propagation hedges, and cuttings continue to be taken once every summer.

Photo 4
The *Bouturathèque* mini-greenhouses are individually lit. Conditions favourable to rooting are maintained throughout the year.

Photo 5
When the cuttings are planted in the 126-25 containers, each mini-greenhouse can receive over 40,000.

Photo 6
This container, which has 126 cavities of 25 cm^3 each (126-25), was developed specifically for rooting the cuttings.

1.

2.

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4 THE METHODOLOGY OF CUTTING PROPAGATION

If the work is planned properly, a team of 30 people can plant around 100,000 cuttings per day. In addition to the team leader and the technicians responsible for planning and quality control, each team is composed of employees who harvest the cuttings, transport them between the greenhouses and the propagation room, prepare the containers, plant the cuttings in the substrate and fill the mini-greenhouses.

4.1 Preliminary Steps

4.1.1 Data Collection

To plan cutting propagation work, we must establish the number of cuttings available, by species and by genetic improvement zone, as well as the capacity of the *Bouturathèque*s and acclimation greenhouses. This information is needed to fix the production goals, organize the staff and equipment and estimate the duration of the work. Once we know the length of the cuttings and their degree of lignification, we can establish in which order cuttings will be harvested in the various stock plant lots to optimize rooting and facilitate the work. The information required is generally collected three or four days before operations are due to begin.

4.1.2 Preparing the Stock Plants

Before each cutting session, a fungicide solution is applied to the stock plants to eliminate pathogenic fungi such as *Botrytis cinerea*. The solution provides good phytosanitary control and is more economic and safer than soaking the cuttings after harvesting. It must be applied at least 60 hours before work begins, to reduce the risk of worker exposure. The solution used contains a mixture of Benlate™ (benomyl) and Rovral™ (iprodione) (0.3 $g \cdot m^{-2}$ each).

Between 12 and 24 hours before the cuttings are taken, the stock plants must be watered generously to allow them to soak up plenty of moisture. This reduces the risk of water stress and increases the chances of rooting.

4.1.3 Preparing the Mini-Greenhouses

Before placing the cuttings in the Centre's 24 mini-greenhouses, the frames are covered with polythene sheets (Milrol™ type) 0.004" thick, to prevent loss of humidity.

A system of removable rails is installed inside the mini-greenhouses, to facilitate handling of the containers and the movements of the water robot. The robot, which is equipped with its own independent reservoir and a multinozzle spray boom, is remote controlled.

4.1.4 Filling the Containers

The containers used to cultivate the cuttings are filled mechanically, on the nursery's potting line. It is important to ensure that the substrate mixture is homogeneous, of the required density, and that it has an adequate moisture content (section 5.3).

4.2 Harvesting the Cuttings

The way in which the cuttings are harvested from the stock plants is an important factor in subsequent rooting and propagation success. The employees must consider the length and lignification stage of the cuttings. As mentioned previously, the ideal length is somewhere between 5 cm and 7 cm, and the cut must be made in the semi-lignified part of the shoot.

The cuttings are taken using scissors designed for pruning bonsais. They are light, small, easy to handle, and give excellent results. Before proceeding, the employees gauge the length of the cutting using a reference mark drawn on their index fingers, and cut the shoots in the semi-lignified section. The cuttings are then placed in plastic trays and sprayed manually with water.

The greenhouse conditions can be modified temporarily to facilitate harvesting, improve employee performance and reduce stock plant stress. In sunny weather, shades can be installed to reduce the risk of wilting and, if artificial lighting is in use, the lamps above the sectors where work is taking place should be turned off.

4.3 Work Organization

We have developed a working method that takes account of the variety of tasks to be performed. This method has optimized both the quality of the work and the overall performance of the Saint-Modeste cutting propagation centre.

4.3.1 Task Description

As mentioned at the beginning of the chapter, a propagation team is composed of approximately 30 people, together with a technician responsible for quality control. Figure 8 shows how the tasks are organized. The team leader *(a)* directs the employees and coordinates their work. Also, in cooperation with the technician, he or she ensures that work quality and overall performance are satisfactory.

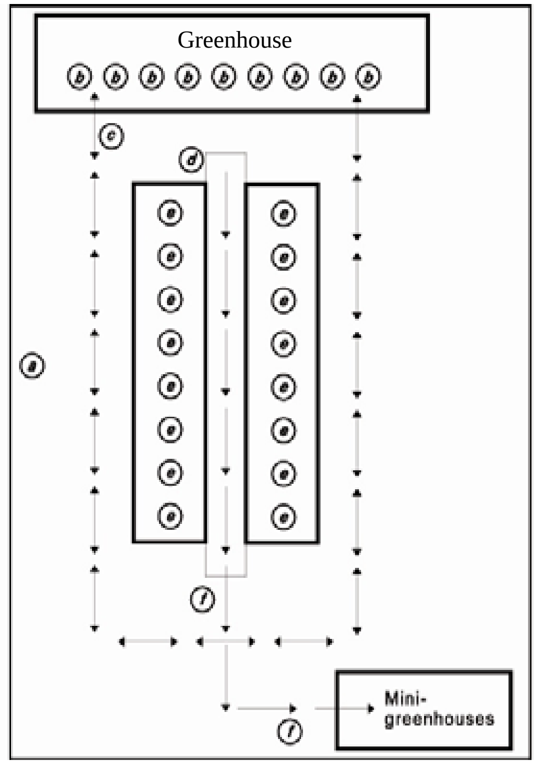

Figure 8. *Organization of black spruce cutting propagation work. See section 4.3.1 for explanations.*

In the greenhouses, approximately nine people *(b)* take the cuttings by hand, after ensuring that they satisfy the criteria. An employee *(c)* transports the cuttings from the greenhouses to the propagation room (a distance of between 10 m and 40 m), and distributes them to the planters. This person is also responsible for reassigning people to harvesting or planting when necessary. At the same time, another employee waters the containers *(d)*, weighs them and makes a hole in the substrate, before placing them on a conveyor belt that transports them to the propagation stations. This last activity employs around 16 people *(e)*, sitting around a table served by two superimposed conveyor belts. The upper belt transports the containers to the employees, who plant the cuttings, and the lower belt takes the filled containers to the following sector, where two containers to the following sector, where two employees place them in the mini-greenhouses *(f)*, registering the number of cuttings planted and the location of the different batches.

4.3.2 Performance

A team of 30 people is considered ideal, because it keeps production costs to a minimum. Based on a total of 400 minutes of work per day, the average daily performance of a team of this size is around 100,000 cuttings, or 3,300 cuttings per person (8.3 cuttings per minute). An employee can take around 11,000 cuttings per day (27.5 cuttings per minute) and plant around 6,250 (15.6 cuttings per minute).

The physiological state of the cuttings is the factor that has the greatest impact on employee performance. If the cuttings are insufficiently lignified, they are difficult to handle and plant in the substrate. Consequently, the process takes longer, the quality of the work diminishes and costs rise. Clearly, lack of experience can also have a negative effect on performance.

4.4 Management of Stock Plant Lots

Proper management of stock plant lots and cutting batches, by species, genetic improvement zone, age and location in the greenhouse or *Bouturathèque*, facilitates planning and monitoring of the propagation process. Computers have proved to be valuable in this respect. We have developed an address system and simple forms that enable us to locate stock plant lots and cutting batches quickly in the greenhouses and mini-greenhouses, as well as a database that is useful in the stock plant and cutting cultivation process, both during and after rooting.

5 ROOTING IN THE BOUTURATHÈQUE

The Saint-Modeste cutting propagation center uses the *Bouturathèque* system developed by the ministère des Ressources naturelles (Vallée et Noreau, 1990). This is a compact shelf system composed of superimposed, hermetic mini-greenhouses, individually lit by fluorescent lamps and placed in a room where the temperature is rigorously controlled.

The cuttings are planted in a mixture of peat and perlite, with or without vermiculite. Containers comprising 67 50 cm^3 cavities (67-50) or 126 25 cm^3 cavities (126-25) are used.

The cuttings are cultivated in the mini-greenhouses for eight weeks. They are sprayed once or twice a week with water or fungicide. In the fourth week, the first roots appear at the base of the cuttings without prior callus formation. However, most of the cuttings really root between the sixth and eighth weeks. They are then transferred to greenhouses, where they acclimatize to standard growing conditions.

The *Bouturathèque* system operates all year round, thanks to the forcing of the stock plants, which are grown in greenhouses in conditions of uninterrupted production. It is therefore highly profitable.

5.1 Description of the Saint-Modeste Bouturathèque

At Saint-Modeste, the *Bouturathèque* occupies two air-conditioned rooms. It comprises six sets of shelves measuring 2.5 m wide, 14.5 m long and 2.6 m high. Four 48 cm high mini-greenhouses are arranged on each shelf (Photo 4, page 15). The 24 mini-greenhouses, which can hold up to 47,000 cuttings each (Photo 5, page 15), depending on the type of container used, are covered with transparent polythene and lit individually from above by three rows of 75-watt fluorescent tubes, arranged lengthwise.

The cuttings are thus rooted in closed conditions, under artificial lighting. Movable trays able to hold up to nine containers of cuttings are placed on rails inside the mini-greenhouses.

The plants are watered by a robot with its own pressurized reservoir and spraying boom, which also moves along the rails.

5.2 Ambient Conditions in the Mini-Greenhouses

If the propagation process is to be successful, the heat, light and humidity conditions in the mini-greenhouses must be uniform and constant. These conditions depend to a large extent on the power of the fluorescent lamps, which radiate a lot of heat. The lamps emit both visible and thermal radiation (infrared rays) which pass through the polythene. The mini-greenhouses therefore have to be cooled, so that the heat does not threaten the survival of the cuttings. It is for this reason that the *bouturathèques* are installed in air-conditioned rooms.

The air conditioning cools the outside sheeting of the mini-greenhouses, and the resulting condensation creates a film on the inside surface. The water droplets act as a screen, filtering the infrared rays. The phenomenon is not uniform throughout the greenhouses because while the well-ventilated surfaces are entirely misted over, the warmer surfaces are not. When condensation levels drop, the cuttings transpire more and the substrate dries out more quickly. The temperature in the air-conditioned rooms, the material used to cover the enclosures and the ventilation all have a significant impact on the conditions inside the mini-greenhouses.

The temperature inside the mini-greenhouses varies less when air can circulate evenly and cool all the walls equally. Otherwise, water tends to evaporate in some areas and accumulate in others. In the warmer sectors the substrate dries out, while in the cooler sectors its moisture content increases, as water drips into the containers.

5.2.1 Lighting and Temperature

Daylight-type fluorescent lamps are used to provide the lighting required to cultivate the cuttings. The light intensity of around 2,000 lux (20 $\mu mol \cdot m^{-2} \cdot s^{-1}$) and the photoperiod of 18 to 20 hours were established on the basis of the heat emitted by the lamps. Since the centre was created in 1989, the lighting has been changed to standardize the ambient conditions and reduce the variations between the different sectors of the *Bouturathèque*. The lighting is now more even but lower in intensity, and temperatures are easier to manage.

The temperature inside the mini-greenhouses depends on both the lighting and the temperature of the air-conditioned room in which the system is installed. It is generally maintained at 20 ^oC, because research on black spruce has shown that where light levels are low, photosynthesis exceeds respiration, provided the temperature is low enough (Yue and Margolis, 1993). Consequently, when average light levels are 20 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the temperature should not exceed 20 ^oC.

5.2.2 Relative Humidity

Before root initiation, cuttings cannot absorb enough water to compensate for the moisture lost through excessive transpiration, which occurs when the air is not humid enough or the temperature is too high. This produces wilting. The less lignified the cuttings, the higher the risk of wilting. A cutting propagation system should thus be designed so that the plants do not lose too much moisture, and it should be possible to maintain a water vapour pressure in the ambient air equal to that of the needles.

This can be achieved in two ways: first, by increasing the relative humidity rate of the air, and second, by reducing the foliage temperature (Loach, 1988). In the former case, propagation in an enclosure can be used; in other words, the cuttings can be grown in a closed environment which imprisons the water vapour. In the latter case, if the cuttings are placed in greenhouses during rooting, they can, for example, be misted intermittently; when the water spray evaporates, the foliage cools down. These two methods use different mechanisms to produce the same result, i.e. reducing transpiration by minimizing the water vapour pressure gradient.

In the *Bouturathèque* system, which uses propagation in an enclosure, relative humidity is maintained between 90 % and 95 % - in other words, close to saturation. Even so, light and heat levels must be watched carefully, because radiation from the lamps can increase transpiration. When the environmental conditions are properly controlled, between one and three mistings per week are sufficient to maintain the relative humidity at an acceptable level and prevent the cuttings from wilting.

5.3 Container and Substrates

As mentioned earlier, cutting propagation can be performed in different types of containers. At the Saint-Modeste centre, we generally use 67-50 or 126-25 containers (see section 6.3). The latter (126-25) were specifically designed for the production of cuttings, and are used for all batches to be transplanted into larger containers (Photo 6, page 15). They enable us to make maximum use of our premises and equipment, and to obtain quality cuttings. Cuttings used to produce bareroot stock can be planted in any of the commonly-used containers. We sometimes use other containers, such as the 45-110s, to cultivate stecklings for progeny tests.

The rooting substrate is a mixture of peat and perlite, to which vermiculite is added in some cases. We use superior quality peat which has long fibres and contains little debris, because it facilitates cavity filling. Moreover, peat bulking (volume increase) and thus substrate porosity increase with fibre length. When we mix the substrate, we dampen it by adding a volume of water equal to approximately 20 % of the substrate volume. Water content should be around 60 % of the saturated mass.

Substrate aeration, which depends on both its porosity and its water content, has a significant impact on rooting. If aeration is insufficient, the cuttings will not root properly. Porosity depends on the substrate components and the characteristics of the containers (cavity height, shape and volume). Fine perlite is added to the mixture to enhance porosity. This helps increase the rooting rate for black spruce cuttings (Figure 9).

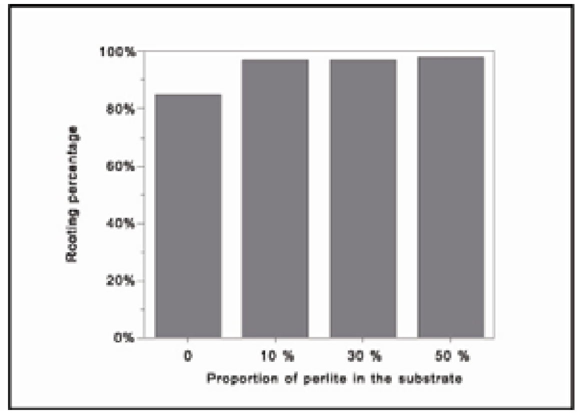

Figure 9. *Increased rooting percentage of black spruce cuttings with the addition of perlite to the substrate.*

The 67-50 containers are filled with a mixture of peat, vermiculite and fine perlite (P:V:FP), in a ratio of 2:1:1 and with a density of 0.07 $g \cdot cm^{-3}$ to 0.08 $g \cdot cm^{-3}$. The results obtained in these conditions are between 10 % and 30 % superior to those obtained with the 126-25 containers (Figure 10). The difference is undoubtedly related to the cavity volume - the smaller the cavity, the less air the substrate holds. To counter this problem inherent in the 126-25 containers, we have developed a new mixture composed of three parts perlite to one part peat (P: FP,1:3). The results obtained so far are very positive, and the new mixture will shortly be tested in 67-50 containers. It may eventually become the standard mixture for cutting propagation.

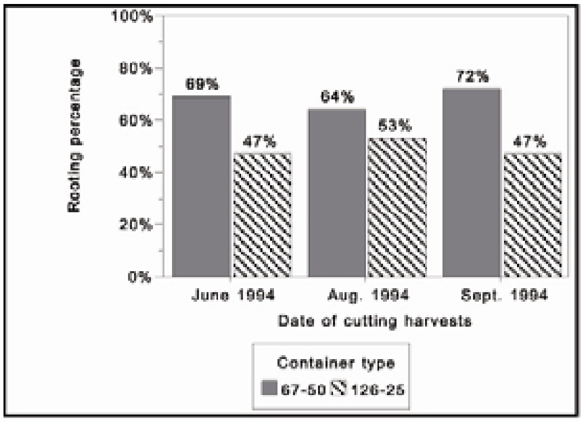

Figure 10. Comparison of the average rooting percentage of black spruce cuttings in 67-50 containers and 126-25 containers, for three consecutive cutting propagation operations.

5.4 Processing the Cuttings

5.4.1 Planting

The cuttings do not receive any special treatment, and they are not stripped of their needles. To avoid wilting, we try to minimize the time between harvesting of the cuttings and installation in the mini-greenhouses (around 20 minutes). If work is interrupted, at mealtimes for example, the cuttings are placed in hermetic containers. Cold storage is avoided.

Just before planting, 1.5 cm holes are made in the substrate using a nail template, and the cuttings are pushed gently but firmly into the holes. The containers are then sprayed with water to swell the peat, which closes up the holes.

5.4.2 IBA Treatment

At Saint-Modeste, the cuttings do not usually receive hormone treatment, and **auxins** are therefore not normally used. However, a number of tests have been performed to assess the effect of **indolylbutyric acid (IBA)** on rooting percentages. We found that this growth hormone does not necessarily improve the rooting rate of cuttings taken from young conifer stock plants. In the case of black spruce, for example, the results are not conclusive (Figure 11). In fact, we found that, when weak doses were applied (a five-second dip in a 1,000 ppm solution), the treated cuttings did not root any better than the control cuttings. When the concentration was increased (up to 5,000 ppm or 8,000 ppm), the average number of roots per cutting increased, but the rooting rate dropped significantly. The effect of the treatment did not vary with stock plant age or cutting lignification stage.

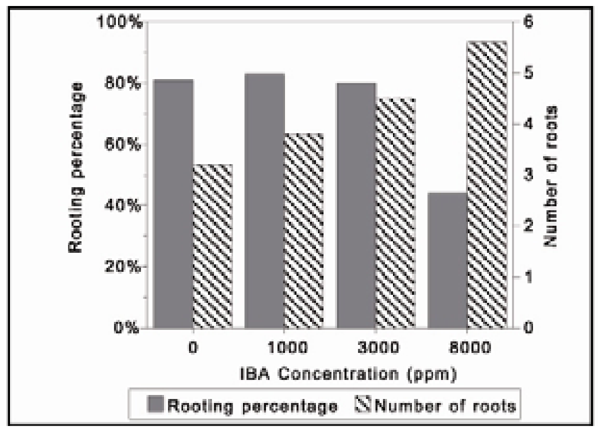

Figure 11. *Effect of different concentrations of IBA on the rooting percentage and the number of roots for black spruce cuttings. The treatment is carried out by briefly dipping the base of the cuttings into a concentrated solution.*

However, we have found that if IBA is sprayed onto the cutting needles in the form of potassium salt (K-IBA) dissolved in water, the number of main roots may increase slightly, while the rooting rate remains unchanged. In the mini-greenhouses, this type of treatment is easy and fairly inexpensive, because it can be performed using the water robot. Very weak doses of

K-IBA are used (between 2 µg and 4 µg per cutting) to avoid deformation of the tips of-non-lignified stems.

5.4.3 Watering, Fertilizing and Phytosanitary Control

As we saw earlier, water is a key element in the success of cutting propagation. Before placing the cutting containers in the mini-greenhouses, the water robot is used to spray all the surfaces. In the first few weeks, the operation is repeated every two or three days, depending on the condition of the cuttings. From the fourth week onwards, spraying is required only once or twice a week. Moistening the foliage and the surface of the cavities increases relative humidity in the mini-greenhouses. Spraying is not systematic; air humidity is measured daily, and the substrate surface and condition of the cuttings are also examined.

During the eight weeks of rooting, approximately 75 litres of water (1.6 ml per cutting) are sprayed into each mini-greenhouse. At each watering, the robot sprays 3.5 litres or 100 $ml \cdot m^{-2}$ of water into each enclosure.

Fertilizer is not applied in the mini-greenhouses, partly to avoid stimulating vegetative growth of the cuttings at the expense of root development, and partly because we have, in the past, observed negative effects, probably due to an increase in the osmotic pressure, which seems to hinder water absorption by the cuttings. However, once transferred into the acclimation greenhouses (see section 6.1), the cuttings are fertilized regularly.

To prevent the growth of mold and other fungi in the mini-greenhouses, weekly 0.2 $ml \cdot m^{-2}$ doses of Daconil™, a fungicide, are applied during the first four weeks of rooting.

5.5 Rooting Rates

In experimental conditions, between 80 % and 100 % of the black spruce cuttings root. Since the Saint-Modeste cutting propagation centre was created, we have obtained an average success rate of 70 %, although this percentage varies according to the state of the stock plants and the cultivation conditions. The rooting rate is at its highest at the first harvest, when the stock plants are between four and five months old. It then drops slightly, but does not seem to be seriously affected by stock plant ageing.

Despite all the attention given to cultivation of the stock plants and cuttings, the rooting rate can sometimes be unpredictable. For example, we might obtain a rate of 80 % in one batch and 50 % in another. During the last five years, we have identified several reasons for the fluctuations, and significant improvements were made to the system. We have, for example, modified the mini-greenhouses to make conditions more uniform. In addition, after identifying substrate aeration and the condition of the cuttings as the two factors with the greatest impact on rooting, we developed a new, more porous substrate better suited to the 126-25 containers, and we now subject the stock plants to a short day treatment to produce more standard cuttings that root better.

In continuous forcing conditions, seasonal variations sometimes make it difficult to control stock plant growth and predict the rooting percentage of the cuttings. The challenge presently facing the Saint-Modeste cutting propagation centre is to make black spruce propagation profitable by enhancing stock plant yields while at the same time standardizing the quality of the cuttings harvested in different lots at different times of the year.

6 STECKLING PRODUCTION

At the end of the rooting period, the cuttings are placed in greenhouses so that they can adapt to standard growth conditions and continue their development. This eight-week acclimation period is divided into two phases : an acclimation phase, during which the cuttings adapt to greenhouse conditions and, depending on the season, a growth or hardening phase.

Once acclimatized, the cuttings are transplanted. This operation is always performed in spring, so that the young plants have as long a period of growth as possible before winter. Cuttings that complete their acclimation between February and April are transplanted as soon as possible. The others are left in containers until they can be transplanted the following spring.

If the season permits, the batches of cuttings awaiting transplantation are placed in tunnels. During the cold season, they are left outside if they have reached the desired development stage and if their root biomass is sufficient. Otherwise, they are kept in cold storage, as are the cuttings that complete their acclimation in winter.

The genetically-improved cuttings cultivated at the Pépinière de Saint-Modeste are used to produce large-sized plants (around 40 cm high and 5 mm in diameter). These plants are reserved for the best forest sites — in other words, the most fertile sites where competing vegetation is strongest and poses the greatest threat to the growth and survival of conventional plants (18 cm to 25 cm high, 2.3 to 3.3 mm in diameter). To obtain large-sized plants, the cuttings are kept in the nursery for two years after transplanting.

6.1 The Acclimation Period

After the eight-week rooting period in the *Bouturathèque*, the cuttings are transferred to so-called acclimation greenhouses, where they remain for a further eight weeks (Photo 1, page 31).

Acclimation is divided into two phases. The first, which lasts between one and four weeks, allows the cuttings to adapt to standard growth conditions. During this phase, relative humidity in the greenhouses is maintained at over 80 % by misting, and then reduced gradually to between 60 % and 70 %. If sunlight is excessive, shades are installed to protect the cuttings, especially in the early stages. No artificial lighting is used to prolong the photoperiod or increase light intensity. Finally, 5 mg of 20-20-20 type fertilizer are applied per cutting.

During the fourth week of acclimation — twelve weeks after planting — rooting of the various batches is assessed and any reddening or rotting plants are discarded, since they have not rooted.

After the initial acclimation phase, the cultivation program is modified according to the ulterior destination of the cuttings. For example, the growth of plants that complete their acclimation between February and April is promoted because they will be transplanted as soon as they leave the greenhouses. The same applies to cuttings that complete their acclimation between April and September, because they will be transferred to tunnels, where they will remain until the end of the fall and even throughout the winter, if they are sufficiently developed (summer lignification and cold hardening occur naturally). Specific fertilization programs are implemented to promote the growth of these two categories, since the cuttings must develop a root biomass of at least 20 mg before they are transplanted (Photo 2, page 31).

Cuttings that complete their period of acclimation between October and February are placed in cold store. They are prepared by means of a short day treatment (8-hour photoperiod for 14 days), which induces dormancy, and then by a gradual reduction of temperature (from 23 °C to 5 °C), which hardens them to the cold. When they are transferred to cold storage, they have generally developed a root biomass of at least 20 mg.

6.2 Cold Storage

Cold stores are used from October to mid-April. Depending when the cuttings leave the acclimation greenhouses, they remain in the cold stores between one and six months. Before storing the cuttings, we water them copiously and apply a fungicide (a mixture of Benlate™ and Rovral™, 0.3 $g \cdot m^{-2}$). To rationalize the use of space, the containers are placed on pallets, which are grouped together in blocks of approximately 80 m^3 and then covered with polythene to reduce the risk of drying. A humidifier is also installed in the cold stores to maintain adequate humidity.

The hardening process begun in the greenhouses continues in the cold store. For the first week, the temperature is set at 2 °C, and then lowered to 0 °C and -2 °C in the following two weeks. It is maintained at this level until the last two weeks of storage, when it is gradually brought back to 2 °C.

6.3 Transplanting

In early May, as soon as the temperature permits, the cuttings are taken out of cold storage and transplanted in nursery beds as soon as possible. This reduces the risk of frost heaving later on. The cuttings reserved for container cultivation do not face this problem, and can be transplanted later, up to the end of June. They can also be smaller than the former when they are trans-planted.

The containers used for rooting determine subsequent cultivation methods. For example, cuttings grown in 67-50 containers form a root ball that is too large to be transplanted easily into other containers. They are therefore used exclusively for bareroot production. In contrast, the cuttings rooted in 126-25 containers can be transplanted either into larger containers or nursery beds, for bareroot production.

At Saint-Modeste, the cuttings to be used for bareroot production are shaken to remove the substrate before transplanting, since freeing the roots reduces the risk of malformation. The other cuttings are transplanted into containers with 350 cm^3 cavities (Photo 3, page 31). This is performed on the potting line, to maximize performance.

The containers are filled mechanically and then transported to a machine that makes a hole shaped like the rooting cavity in the substrate. The cutting and root ball are placed in the hole by hand, and the substrate is then covered mechanically with a layer of silica approximately 1 cm thick. We are currently looking for a way to avoid compacting the substrate when making the holes, as this hinders subsequent root system development.

6.4 Growth in the Nursery

Because the cuttings are produced throughout the year, they are not all subjected to the same conditions (seasonal variations in temperature, sunlight, photoperiod, etc.), and they may therefore not have reached the same physiological development stage when they are transplanted.

The dormancy release provoked by exposure to cold brings all the batches of cuttings to the same development stage. In fact, the dormancy cycle encourages root biomass development, bud formation and regular growth of the plants after transplanting. In addition, exposure to cold seems to allow the shoots to resume normal growth after transplanting. Plants not exposed to cold may exhibit uneven budbreak and reduced growth, and they may produce lateral shoots instead of a leader which causes stem malformations.

The techniques used to cultivate stecklings and seedlings are identical (Photo 4, page 31). However, when the former are grown as bareroot plants, they generally meet LSP standards at the age of two-and-a-half or three years (Photo 5, page 31), while seedlings take four years to reach the same point. The cuttings transplanted into containers often exceed current standards after two growing seasons. This problem arises because we presently have only one production schedule for both stecklings and seedlings. However, we are now attempting to establish production schedules better suited to container cultivation of cuttings. We are also beginning work on the development of containers better suited to cuttings.

Plate 2

Production of Large-Sized Plants from Cuttings

Photo 1
After the rooting phase in the mini-greenhouses (eight weeks), the cuttings are placed in conventional greenhouses where they are left to acclimatize. Those shown here are twelve weeks old.

Photo 2
The roots of the cuttings continue to develop until transplantation.

Photo 3
The cuttings are transplanted manually into 350 cm^3 containers. The root ball is placed into a hole made in the substrate.

Photo 4
Two years after being transplanted at the nursery, the black spruce stecklings have grown to large size. The plants shown here were transplanted a year ago in a nursery bed.

Photo 5
Black spruce stecklings, bareroot (RN) and container (340 cm^3) grown (RC). The ruler is 1 m long. Because of their large size, they are ready to face competing vegetation that is often vigorous in forest sites.

Photo 6
Five-year old plantation of black spruce stecklings. The genetically improved trees are much sturdier than those grown from unimproved seed.

1.

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CONCLUSION

The cutting propagation centre at the Pépinière de Saint-Modeste produces nearly two million black spruce stecklings each year. To do this, it has adopted an innovative and original method which, when combined with stock plant forcing in greenhouses, allows propagation to continue throughout the year, thus maximizing infrastructure profitability. The method is known as the *Bouturathèque* system. Since the centre was created, in 1989, we have developed a number of new techniques that may prove to be useful in horticulture as well as in forestry. One of the centre's main challenges was to move the *Bouturathèque* system from the experimental stage to the commercial stage. Major efforts were, and are still, poured into the development of operational methods.

Currently, depending on the production method selected, the cost price of a steckling is 1.5 to 2 times higher than the cost price of an LSP grown from seed. However, if we can continue to improve the rooting rate, presently 70 %, and to enhance the different stages of the propagation system, production costs will be reduced. Moreover, the higher the genetic gains, the more advantageous it will be to reforest with plants grown from cuttings.

In the next few years, our cutting propagation centre will have provided plants for the reforestation of several thousand hectares of forest with high quality trees (Photo 6, page 31). We will thus have made major genetic gains, which will translate into tangible benefits when the timber is harvested. In the case of black spruce, for example, the first progeny test established in the nursery showed, after five years, that the ten best of the seventy families tested had achieved height gains of around 32 %. We can therefore anticipate height gains of around 25 % (or 40 % in volume terms) after 45 years.

The main advantage of cutting propagation lies in the fact that it allows propagation of genetically improved seeds that are expensive to produce. When the seeds produced by controlled crossing are used to grow stock plants, we obtain a large number of stecklings from each improved seed, whereas when they are sown directly, they are obviously never able to produce more than one seedling each.

In addition, cutting propagation considerably accelerates the introduction of the new varieties obtained through genetic improvement work. We have seen that it can be used to propagate full-sib seeds and to obtain plants ready for use in reforestation after only four years. To produce the same number of improved plants without cutting propagation, the parent plants would have to be propagated by large-scale grafting, and then bred when the scions are ready to flower. We would thus have to wait between five and ten years for the seeds, and between two and four additional years for the improved nursery-produced seedlings.

The information obtained from early progeny tests, established in 1990, allowed us, five years later, to select the families to be sown as stock plants to improve the genetic quality of the varieties. In addition, the propagation of second generation trees will enable us to obtain even more signi-ficant genetic gains in the future.

A number of research and development projects aimed at improving the performance and profitability of the system are presently underway. The projects address both plant quality and the production capacity of the premises and equipment, and include consideration of cultivation scenarios that would increase the cutting yields of stock plants, automation of some stages of production, such as transplanting into containers, and so on. We are also continuing to adapt the *Bouturathèque* system for use with other species, in particular white spruce, Norway spruce and hybrid larch. In addition, we are studying mixed planting strategies, combining stecklings and conventional LSPs, to maximize the areas planted with genetically-improved stock. Finally, we intend, in the near future, to analyze the gains associated with clonal forestry.

GLOSSARY

Auxins : Natural or synthetic organic molecules that regulate plant growth (phytohormones) and are involved in controlling cellular growth, apical dominance and adventitious root formation.

Bouturathèque : Four-level shelf containing artificially-lit mini-greenhouses in which the cuttings are placed for the rooting phase. The cutting propagation system at the Pépinière de Saint-Modeste is known by extension as the "*Bouturathèque* system".

Bulk propagation : Large-scale reproduction of a given population, which does not consider individual identity.

Cloning : Large-scale reproduction, with tracking, of relatively few tested genotypes, to capture the performance gain of the very best individuals (after Ritchie, 1994, and Bentzer, 1993).

Controlled cross : Artificial mating of two individuals.

Cutting : Part of a stem, branch, root, etc. taken from a stock plant and used to produce a new plant of the same genotype (after Lamontagne and Corriveau, 1982).

Cutting back : Radical trimming of a plant to a pre-established height.

Cutting propagation : Vegetative propagation by rooting of plant fragments.

Family : A group of individuals with at least one common parent. The individuals produced by controlled pollination form a full-sib family (after Lamontagne and Corriveau, 1982).

Forcing : Cultivation of plants in conditions that allow them to continue to grow outside their normal seasonal cycle. Forcing is generally practised in heated greenhouses equipped with an artificial lighting system.

Genetic gain : Average genetic improvement of the descendants of selected individuals over their parents' generation. This depends on the selection intensity, variation and heritability of the trait concerned (Lamontagne and Corriveau, 1982).

Indolylbutyric acid (IBA) : Synthetic auxin commonly used in horticulture to stimulate rooting of cuttings.

Large-sized plant (LSP) : Plant whose height, root collar diameter and root system are superior to standards, allowing it to overcome competing vegetation without the need for phytocides (J. Ménétrier, pers. comm.).

Lignification : Modification of the cell wall through deposition of lignin on the cellulose. This phenomenon is responsible for the formation of wood in ligneous plants.

Mini-greenhouse : An enclosure, covered with transparent polythene and lit by fluorescent lamps, used to root the cuttings.

Multiclonal variety : A group of selected clones to be deployed in a specific genetic improvement zone.

Orthotropic : Having a vertical growth habit, e.g. a leader. Antonym: **plagiotropic**: having a branch-like growth form.

Progeny test : Plantation established according to an appropriate experimental design to assess the genetic value of certain parents on the basis of the performance of their descendants.

Propagation hedge : A group of stock plants grown outside and cut back regularly to maintain them at a juvenile stage and maximize the production of cuttings.

Provenance test : Plantation established according to an experimental design to assess populations of the same species with various geographical origins.

Semi-lignified stage : Development phase of a young stem whose tissues are in the process of lignification.

Serial propagation : Method of vegetative propagation based on a series of propagation cycles, where the last cuttings to be rooted become cutting donors for the next cycle.

Short day treatment : Procedure used to change a plant's phenology by exposing it to a shorter photoperiod for a given number of days.

Somatic embryogenesis : The formation of embryos from somatic (i.e. non-reproductive) cells, without fecondation. The process can be used to produce large numbers of copies of a clone.

Steckling : A plant produced through cutting propagation and ready for outplanting.

Stock plant : Plant grown for cutting production.

Summer lignification : Lignification of young plant shoots and formation of terminal buds, at the end of summer.

Vegetative propagation : Asexual reproduction of a plant, i.e. by grafting, cutting, layering, *in vitro* culture, etc. The genotype of the plants obtained in this way is theoretically identical to that of the mother plant (Lamontagne and Corriveau, 1982).

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