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Production of Genetically Improved Stecklings of Interior Spruce A Grower's Manual

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Production of Genetically Improved Stecklings of Interior Spruce

A Grower's Manual

by
J. Russell and C. Ferguson

March 1990

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT

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1 INTRODUCTION

This manual describes the techniques needed for producing good quality interior spruce (*Picea glauca* and *P. engelmannii*) stecklings (plantable rooted cuttings). It is intended to guide forest nursery growers and forest science researchers in growing and using stecklings of interior spruce. Stecklings can be used to provide immediate genetic gains for operational plantings, and to increase the efficiency and precision of research trials.

Genetic Gains

An effective technique for producing good quality stecklings of interior spruce would result in the early availability of genetically improved stock for reforestation. The interior spruce tree improvement program, for example, has achieved a 10-15% gain in height by selecting families of trees with an increased rate of growth over a 12-year test period. These gains in productivity will be transferred to the field through the use of seed collected from 1.5 generation seed orchards now being established. Unfortunately, appreciable amounts of quality seed from these orchards will not be available until the late 1990's. Stecklings propagated from superior seedlings are an effective alternative to the immediate transfer of genetic gain to reforestation.

Stecklings are not meant to compete with seed orchard seed for realizing genetic gain in reforestation. Rather, their use is meant to complement the gain that is possible through genetic testing. As seed orchards start to produce good quality seed in sufficient quantities, the need for stecklings may decrease. It still may be feasible, however, to use stecklings for bulking-up the most elite, full-sib families. As well, if clonal forestry – the testing, selection and deployment of clones – becomes a practical option for interior spruce, then the protocol for the production of stecklings for multiplying the selected clones will already be in place.

Research Trials

The use of clones for forest research trials can increase both the efficiency of obtaining information, and the precision of the information itself, by reducing the amount of variability or "genetic noise." By controlling the amount of variability within a treatment, the number of trees per treatment can be reduced and the precision with which treatment differences are measured can be improved.

2 PRODUCTION TECHNIQUE

2.1 Overview

The technique for producing stecklings of interior spruce is described here and outlined in Figure 1. For each activity, an optimum method for maximizing the number of quality stecklings is described. As with most nursery techniques, some methods should be done in one particular way, whereas other activities may have alternative methods. The alternative methods may simply be biological options, or they may involve economic tradeoffs between production and nursery costs. Some activities have not been adequately researched, so the best method is not even known yet. Thus, for each "optimum" activity described, alternatives, essentials, and unknowns will also be discussed (in the shaded areas).

There are essentially two separate but related activities in the production of stecklings: the production of cutting-donors, and the production of stecklings. For the cutting-donors, seed from genetically improved families are sown in the greenhouse and grown under high light intensity and wide spacing. The newly developed shoots are pruned regularly. After approximately 9 months of growth, the supplemental lights are turned off and the air temperature is reduced to harden-off the seedlings. After 1-3 months of hardening, cuttings are detached, set into standard seedling containers, and placed into a rooting environment. After 6-8 weeks, the cuttings have rooted, and can be treated the same as rising 1-year-old seedlings.

Under this optimum regime, the cutting-donors produce an average of 65 cuttings each in one growing season. Rooting success is 90% with a 15% cull rate. The cutting-donors are used for only one growing season.

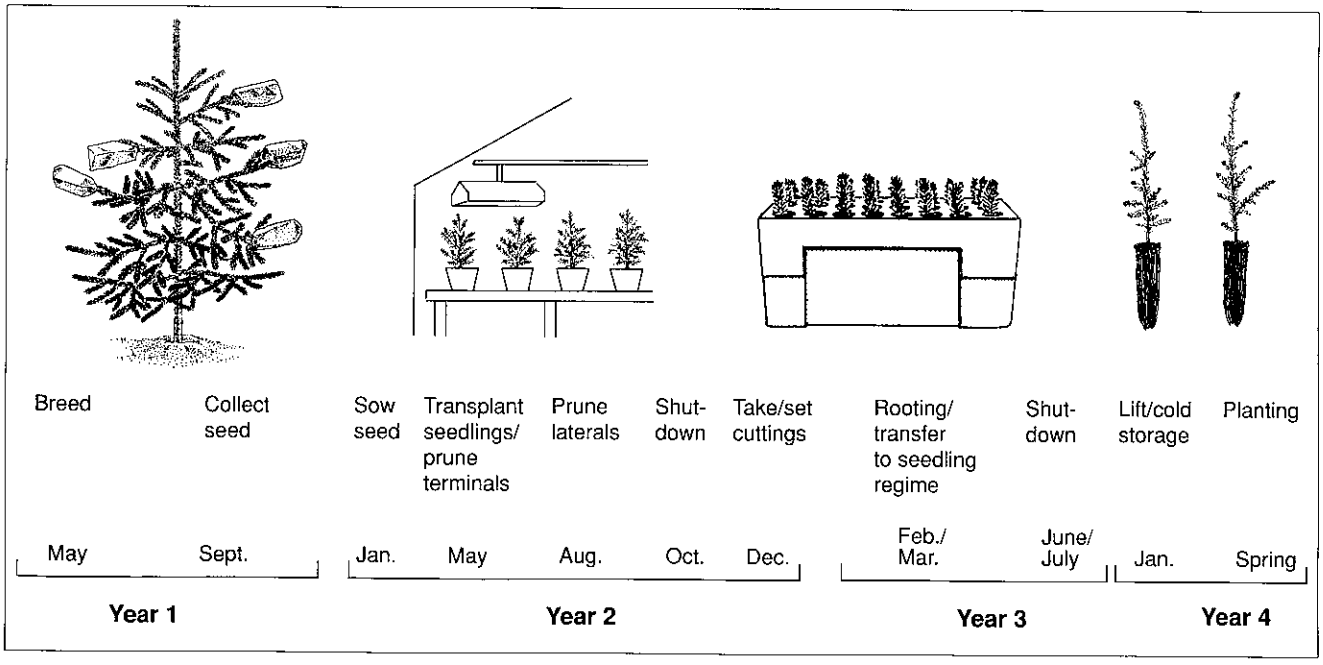


FIGURE 1. Production of genetically superior stecklings.

This method effectively multiplies an expensive seed source while avoiding or minimizing maturation-related problems which could hamper rooting success and reduce the quality of the subsequent stecklings. There are other techniques that will provide more cuttings at a cheaper cost over many years — hedge orchards, for example, in which seedlings are grown under normal conditions and pruned annually to delay maturation, and serial propagation, in which cuttings are rooted from previously rooted cuttings. However, neither hedging nor serial propagation of interior spruce has yet proven to be able to delay maturation successfully.

The following description of the technique for rooting cuttings is divided into cutting-donor production and steckling production.



Controlled crossing of interior spruce to produce genetically improved seed.

2.2 Cutting Donor Production

Seed source

If the reason for producing stecklings is to attain genetic improvement in planting stock, then genetically improved seed must be used. For interior spruce, the best material available would come from controlled matings among superior clones as identified in progeny trials. These clones are currently in clonebanks at Kalamalka Research Station in Vernon, B.C.

To determine the number of seed needed, multiply the number of stecklings by .022 (see Table 1 for details). Thus, to produce 1 million stecklings, a minimum of 22 000 seed would be needed. To maintain genetic diversity in artificial forests using stecklings, a minimum of 30 families, with at least 10 unrelated families, should be used. Thus, 750 seed are needed from each of 30 families to produce 1 million stecklings.

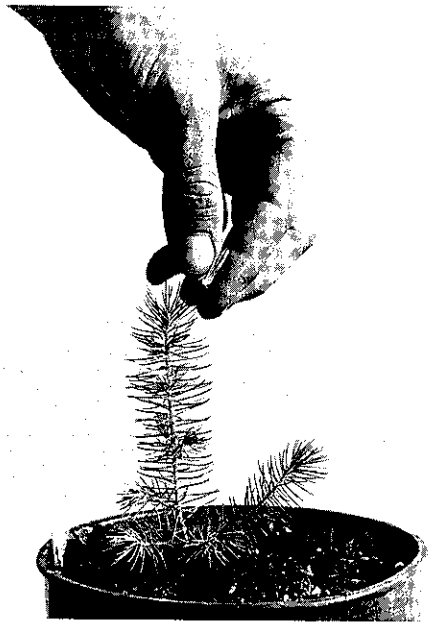
TABLE 1. Calculations for determining the number of seedlings needed per family to produce 1 million stecklings

1. Germination/cull rate (seed)	90%
2. No. of cuttings/donor	65
3. Percent rooting	90%
4. Cull rate (% of rooted)	15%
5. Minimum number of families	30

Example: 65 cuttings/donor x 90% rooting x 15% cull rate = 50 stecklings/donor. One million stecklings / 50 / 90% germination rate = 22 222 seed / 30 families = 750 seed per family.

Sowing to transplanting

Genetically improved seed is sown in January in Spencer Lemaire Hillson containers. The emerging seedlings are grown under a normal greenhouse nursery regime, except light duration should be 20-22 hours, and light intensity set at a minimum of 10 000 lux using 400 watt high pressure sodium lamps[1]. After 4-5 months, the seedlings should be transplanted into 5-L pots and the terminals pinched back by hand, using the fingernails only, to the first major set of lateral shoots or buds. Table 2 describes the various growing media and fertilization regimes used to grow cutting-donors.



Pinching off of leader in newly transplanted seedlings to be used as cutting-donors.

[1] This is equivalent to 122 μ moles. sec^{-1} m^{-2} of photosynthetic active radiation.

Essentials

1. ***Spencer Lemaire Hillson containers:*** *"Hillson" containers are used to minimize transplanting shock by reducing the handling and tearing of the root systems. By using Hillson containers, each book in a tray can be opened separately, and each seedling eased out of the container and into the pot. Hillsons are used rather than a smaller cavity size (i.e., Spencer Lemaire Five's) to maximize the space available to each seedling and so promote sturdy lateral growth during the first few months.*

2. ***Growing regime:*** *Although this may seem obvious, it is extremely important that the seedlings receive the optimum regime prescribed for interior spruce. If the seedlings set bud because of lack of water or light, they will not be able to grow enough after reflushing to produce a suitable number of cuttings.*

3. ***Transplanting:*** *All of the cutting-donor growing activities are geared towards maximizing the number of good quality cuttings. By transplanting the seedlings to large pots, space is increased for the production of sturdy laterals.*

4. ***Pruning at transplant:*** *Pruning is done to promote lateral production and to minimize height growth. Figure 2 shows the results of a trial in which cuttings were taken from the bottom, middle, and top portions of an unpruned, 1-year-old donor. Cuttings which came from the bottom and middle of the donors had better rooting success and increased growth after rooting.*

   Pruning the terminal shoot at transplant encourages more lateral production and reduces the height of the donor. This increases the overall quality of the cutting material.

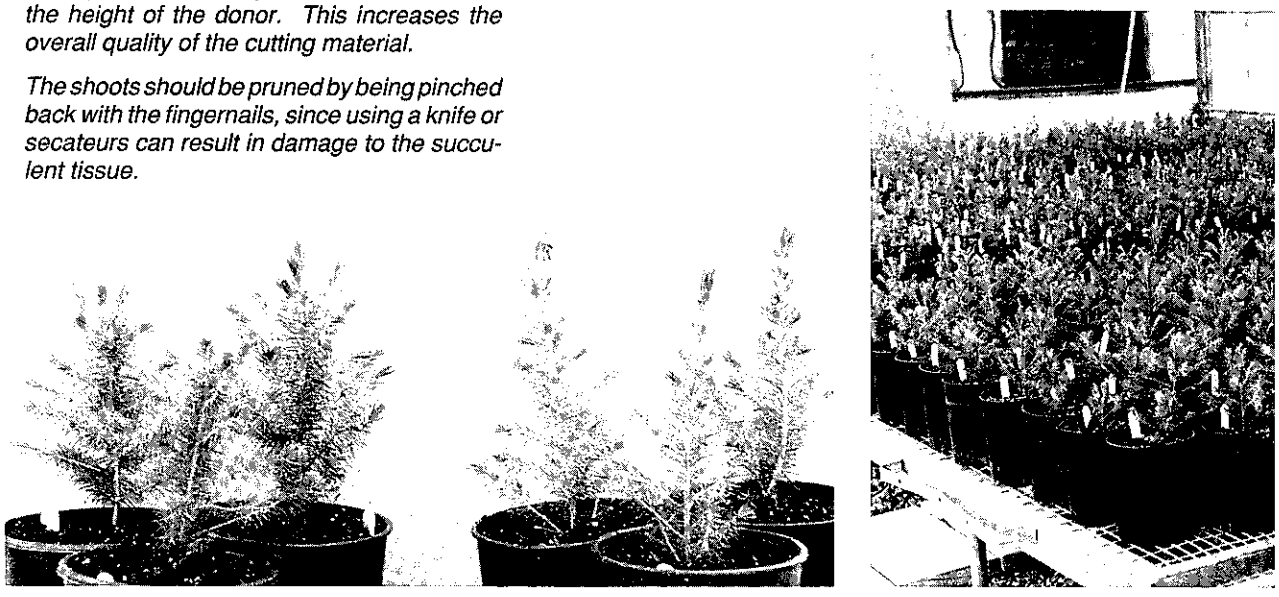
   The shoots should be pruned by being pinched back with the fingernails, since using a knife or secateurs can result in damage to the succulent tissue.

Transplanting to hardening-off

The transplanted seedlings are placed back in the greenhouse where they continue to receive 20-22 hours of high intensity light. The donors are spaced as needed to prevent laterals from touching. All of the laterals are pruned with the fingernails to the first whorl of either buds or shoots 8 weeks prior to hardening-off.

TABLE 2. Growing media and fertilization regimes for the production of cutting-donors

Event	Details
a. Sowing: media	0.72 m^3 peat 0.12 m^3 perlite 0.12 m^3 vermiculite 2.5 kg dolomite lime 1 kg gypsum 1 kg micromax 2 kg Osmocote 18-6-12
b. Sowing: fertilizer	high soluble 20-20-20 @ 0.5 g/L biweekly for 2 weeks, increase to 1 g/L applied biweekly, plus STEM @ 0.5% of fertilizer by weight
c. Transplant: media	0.6 m^3 hog fuel 0.12 m^3 peat 0.12 m^3 vermiculite 5 kg Osmocote 18-6-12 2 kg dolomite lime 1 kg gypsum 1 kg 0-25-0 1 kg micromax
d. Transplant: fertilizer	maintain levels at pre-transplant
e. Hardening: fertilizer	high sol 20-20-20 @ 0.5 g/L when watering is required



Six-month-old cutting-donors with hedged terminals.

The cutting-donors are kept growing for approximately 9 months after which time the supplemental lights are shut off, the soluble balanced fertilizer reduced, and the temperature reduced (if supplemental heating is being used) to induce bud-set. During the hardening-off period, the donors are watered as needed.

After the supplemental lights are shut off, the laterals will grow between 1 and 2 cm in length. Cuttings are taken from the donors after 1-3 months of hardening-off. Table 2 describes the fertilization regime during hardening-off.



Nine-month-old cutting-donors with laterals pinched back, and ready for shut-down.



Eight-month-old unhedged accelerated–grown cutting-donor compared to a normal seedling.



Eight-month-old hedged versus non-hedged accelerated-grown cutting-donor.

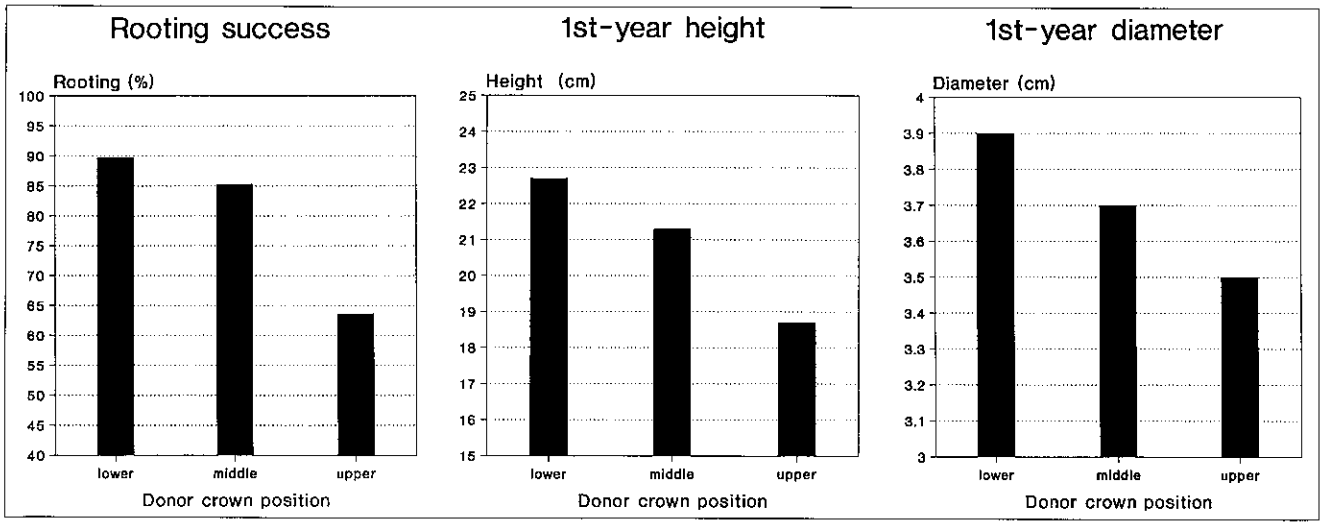


FIGURE 2. Effect of donor crown position on cutting rooting success and steckling stock quality. (See text for details.)

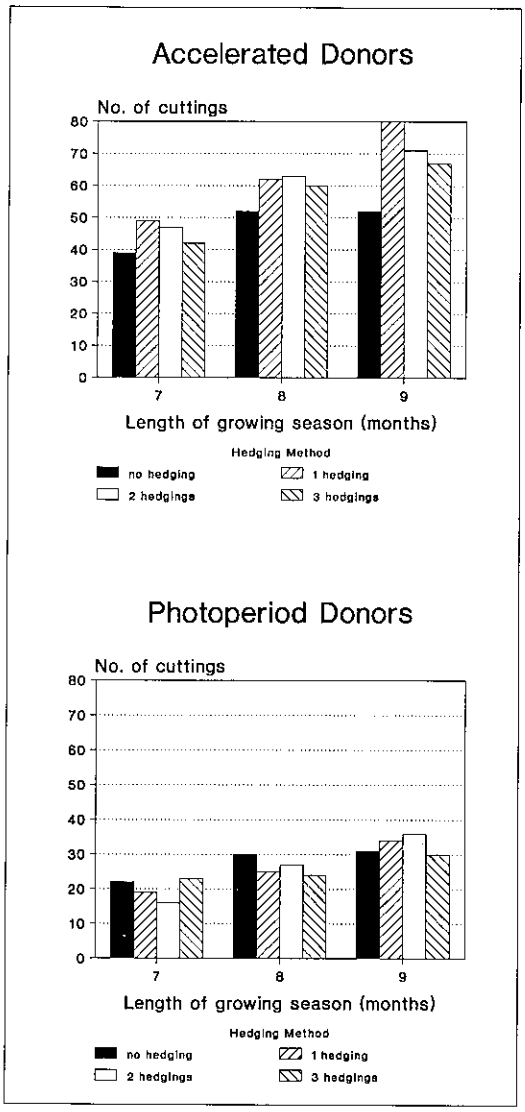


FIGURE 3. Effect of cutting-donor cultural regimes on production of cuttings. (See text for details.)

Essentials

1. ***Pruning of laterals:*** *A second pruning of the cutting-donors is only essential to maintain a low, bushy crown. Pruning to increase the number of cuttings is discussed under options.*

2. ***Length of hardening-off:*** *The time between turning off the lights and taking cuttings should be between 1 and 3 months. Cuttings taken during the active growing phase are very succulent. Although they have good rooting success, they are also susceptible to mortality due to desiccation, rotting, or fungal disease.*

   If the cuttings are taken after the lateral buds have reached the resting stage (i.e., the plants require chilling before reflushing), there is a significant reduction in rooting success.

3. ***Timing:*** *It is important that cuttings be available from the donors by mid-winter. Not only is this the easiest time to root cuttings, it also ensures that the cuttings will be on the same schedule as seedlings germinated in early spring. This will allow consistency within the nursery for watering, fertilizing, acclimatizing, and lifting.*

4. ***Hardening-off:*** *Moisture stress should not be used as a method to induce bud-set. Cuttings taken from donors that are under moisture stress can result in 20% less rooting.*

Options

1. ***Cutting-donor cultural regime:*** *A grower has a number of options in choosing length of growing season, intensity of light, and pruning technique. All of these variables affect the number of cuttings a donor can provide. Although moderate changes in length of growing season and light intensity will not influence the rooting success and quality of the cutting material, pruning technique, as previously noted, will.*

   Figure 3 shows the results of a trial in which seedlings were grown under two light intensities, three growing season lengths, and four hedging techniques. The first obvious result is that donors grown under low light intensity (photoperiod extension) produce one-half the amount of cuttings as those grown under high light intensity (10 000 lux). Use of high light intensity, however, does impose an additional cost.

   Also apparent, is that the longer the growing season, the greater the number of cuttings. Again, however, the longer the growing season, the greater the expense for labour and heating the greenhouse.

   The number of times a cutting-donor is pruned also affects the number of cuttings produced. In this trial, the four treatments were: 1) no pruning; 2) one pruning at a minimum of 8-10 weeks prior to hardening-off; 3) one pruning at transplanting plus one pruning at a minimum of 8-10 weeks prior to hardening-off; and 4) one pruning at transplant plus two prunings between transplanting and 8 weeks prior to hardening-off.

Although the best treatment for producing high numbers of cuttings is one pruning, this treatment wll result in a tall plant because the terminal is not pruned at transplant. This in turn will result in poorer quality cuttings. The second best treatment, two prunings, produces almost the same number of cuttings as the one pruning, but results in a low, bushy cutting-donor, which produces better quality cuttings. The one pruning of the terminals at transplant requires very little additional time.

Different pruning techniques will also produce different proportions of small and large cuttings. The size of the cutting, however, does not affect rooting success and subsequent stock quality of the stecklings.

A trade-off between the number of cuttings produced and the additional cost of certain methods must be weighed by each grower before he or she decides on the exact technique.

2. ***Length of hardening-off:*** *As mentioned above, there seems to be a window of 1-3 months in which cutting-donors can be hardened-off without any change in rooting success or survival. Cuttings from these donors are sufficiently lignified to minimize rotting and disease, but have not reached the resting stage. During the hardening-off period, temperatures in the greenhouse should be maintained above freezing.*

Unknowns

1. ***Cutting-donor fertilization:*** *The few trials that have investigated the effect of increased nitrogen on the number of cuttings, and the subsequent rooting success and stock quality of the cuttings, have been inconclusive. The best results indicate that 1 g/L of high soluble, balanced fertilizer along with Osmocote 18-6-12 mixed in the transplant soil at 5 kg/m³ of potting mix, produces the greatest number of quality rooted cuttings per donor (Table 3).*

TABLE 3. Effect of nitrogen level applied to cutting-donors on subsequent number of cuttings, rooting success, and steckling quality

	Rate of fertilizer (g/L nitrogen)		
Trait	**0.5**	**1.0**	**2.0**
Cutting-donor			
No. cuttings/donor	53	62	55
Percent rooting	70%	70%	63%
Stecklings			
Height (cm)	23.2	24.3	23.1
Diameter (mm)	3.8	4.1	4.0
No. main roots	8	8	7
Root dry weight	1.42	1.35	1.23
Shoot dry weight	3.59	3.72	3.65



2.3 Stecklings

Taking cuttings

As already mentioned, the donors should be hardened-off for 1-3 months. At this time, the laterals will be semi-lignified and buds just formed. Since the donors are only used as a source of cuttings once, the easiest way to collect the cuttings is to cut off the complete donor at the base of the stem. The detached seedlings can be collected by family and stored in plastic garbage bags. The cutting material can be cold-stored at 2-4°C for at least 1 week, as long as the bags are properly sealed.

Setting cuttings

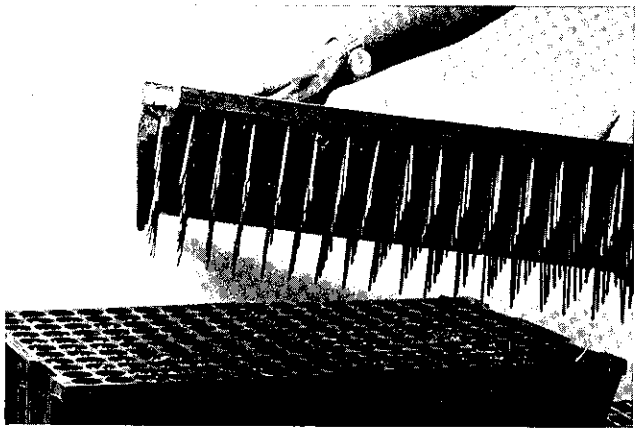
Cuttings can be taken from all over the hedged donor, as long as they are sturdy. The cuttings should be grouped into two sizes – large, 6-8 cm; and small, 3-5 cm – and they should be set in containers by size as well as by family.



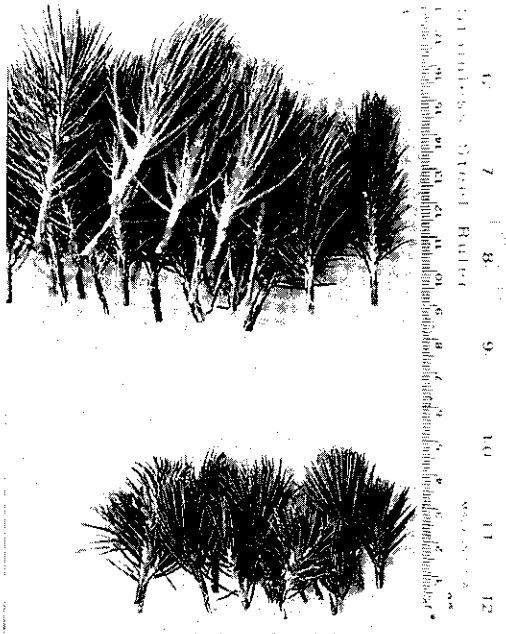
Collection of cuttings in the green house achieved by decapitating the complete donor.

The Technique for Setting Cuttings

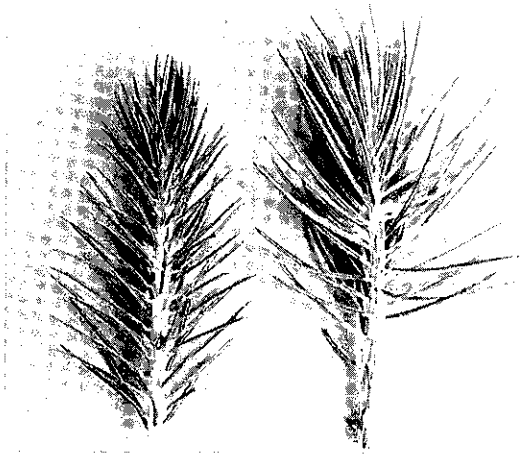
a) nail template for making holes in the soil in containers



b) large and small stripped cuttings

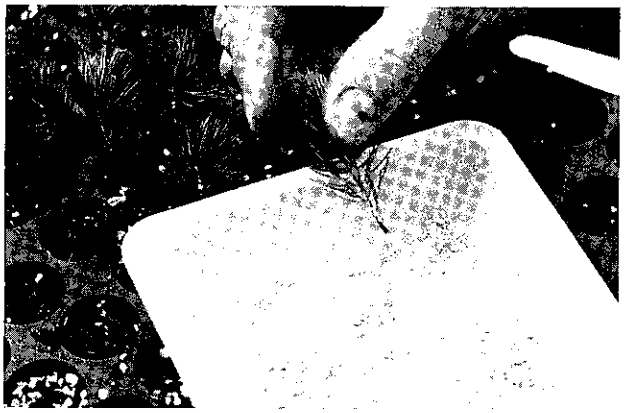


c) stripped and nonstripped cuttings



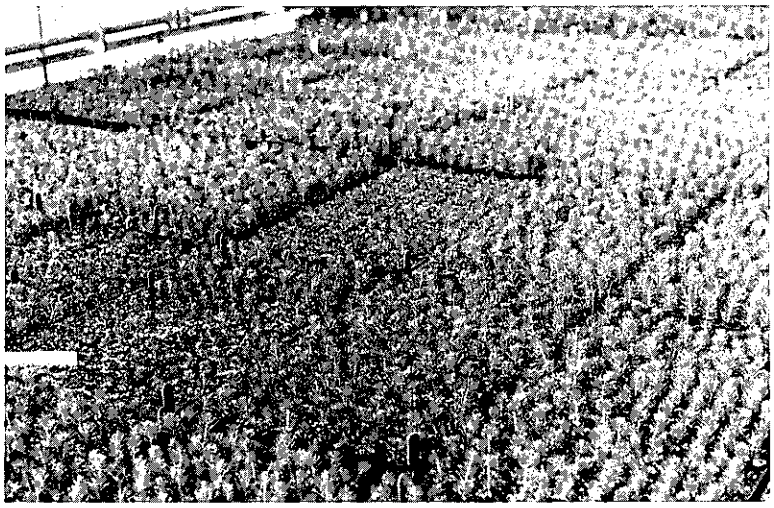
If the whole cutting-donor is collected, then cuttings can be cut to standard size as they are removed from the donor and set directly. However, if individual cuttings are taken before setting, then the cuttings must be recut. The bottom one-quarter to one-third of the cutting is stripped of its needles, and then the cuttings are quick-dipped in a powder solution of talc and I.B.A. at 0.08% (Stimroot #3) and stuck into the containers to the depth of the stripped needles. The containers are usually styro 313 or capilanoes (soil volume of 59 cm^3), with a growing media of 1:1 peat to perlite by volume. Holes are preformed into the media in the containers using a nail template. After setting, the containers are placed in a rooting environment in the greenhouse.

d) dipping the cuttings in talc preparation of I.B.A.



e) setting the cutting into the container





Cuttings in the rooting environment just after setting. Note cuttings have been set by family and size.

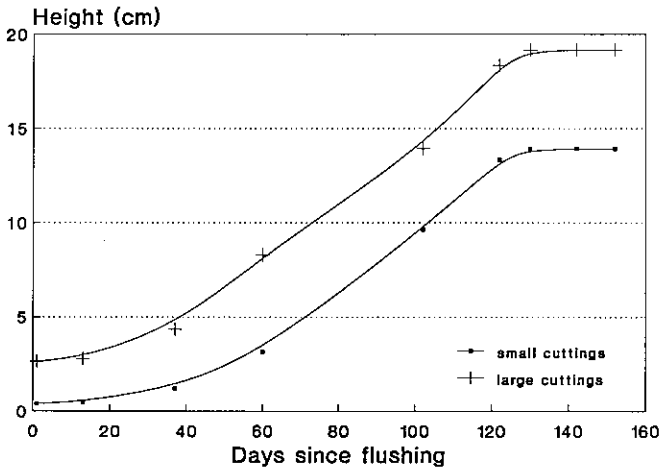


FIGURE 4. Comparison of first-year nursery growth rates for large and small rooted cuttings.

Rooting to lifting

The containers are placed in a greenhouse with a standard rooting environment: 15-20°C bottom heat, intermittent misting to maintain a high relative humidity, and ambient air temperatures (temperatures are maintained above 12°C).

The cuttings will begin to root after 6-8 weeks. At this time they will begin to flush and photoperiod lights should be turned on for 21-22 hours per day. Once rooting is under way, a fertilization regime – similar to that for newly emerging seedlings – should be started (see Table 4).

The rooted cuttings can be acclimatized using the same methods as for seedlings. One method is to remove the rooted cuttings from the greenhouse and place them in an outdoor compound under shade cloth for 2-3 weeks, after which the

Essentials

1. *Sorting cuttings by size and genetic family: Larger cuttings will reach target height before the smaller cuttings. Cuttings from different families (seed from one full-sib cross), also grow at different rates (see Figure 4). Thus, to attain target specifications, the rooted cuttings must be removed from the greenhouse at different times so they can be shut down. This is possible to do if families and the two sizes of cuttings are placed in separate containers. (The task is made easy if seed are sown by family, cuttings are collected by family, and the sizes within family are sorted into two different bags at the time of collection.)*

2. *Preformed holes: Holes are necessary since the cuttings are not completely lignified and do not push into the soil very well. This task is simplified if a nail template is used.*

Options

1. *Stripping the needles: Rooting success does not change significantly if the needles are not stripped from the bottom of the cutting. Not stripping the cuttings saves labour costs when the cuttings are set.*

   However, the cuttings must be secure in the soil or they may be washed out. This can be a problem if the cuttings are not stripped, especially for the smaller cuttings. As well, unstripped cuttings may be more prone to rotting and fungal disease.

2. *Rooting hormone: Applying rooting hormone to the cuttings at the time of setting does not increase rooting significantly; and it is not yet known whether it increases the quality of the root system.*

TABLE 4. Growing media, fungicide treatment, and fertilization regime for rooting cuttings

Event	Description
a. Media	1:1 peat:perlite by volume
b. Fungicide	Drench cuttings after settting with mix of 0.5 g/L benlate and 2 g/L captan. Repeat during growing season as needed to control botrytis.
c. Fertilizer	1. Initiate fertilizing when roots first appear using a high soluble 20-20-20 @ 0.25 g/L or 10-52-17 @ 0.5 g/L plus STEM @ 0.5% of fertilizer rate once a week until bud flush.
	2. At bud flush increase high soluble 20-20-20 to 1.0 g/L applied biweekly plus STEM at same rate.
	3. At shut-down, reduce 20-20-20 to 0.5 g/L.

Essentials

1. ***Early photoperiod lights:*** *If a 22-hour photoperiod is not initiated as soon as the cuttings begin to flush, then they will set bud. Although the cuttings will reflush given the proper conditions, the growth and form of the resultant stecklings are poorer than if they had grown continuously without setting bud.*

Options

1. ***Fertilization regime:*** *No one grower uses the same fertilizer regime for growing seedlings. The same is true for stecklings of interior spruce. Target specifications for height and diameter are the same for seedlings and rooted cuttings, so whatever regime produces quality stecklings that meet target specifications will do the job. One unknown, however, is when to start fertilizing.*

Unknowns

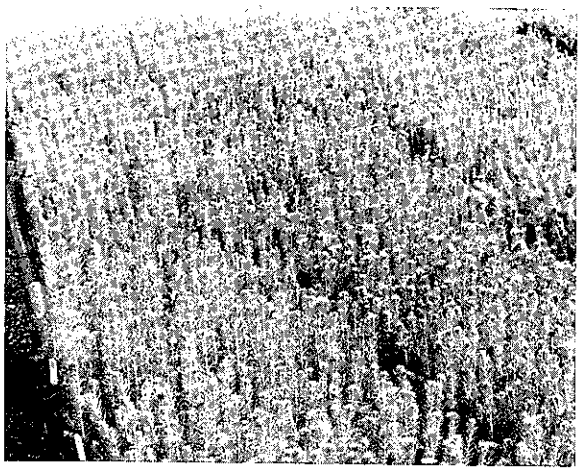
1. ***Time of fertilization:*** *A trial was initiated in which a standard high soluble fertilization regime was used on cuttings starting at four different times: when the cuttings were set; when 50% of the cuttings were callused; when 50% of the cuttings had rooted; and when 50% of the rooted cuttings had flushed. Results to date indicate that time of initiating a fertilization regime has no significant effect on rooting success, though information is not yet available on the quality of the subsequent stecklings.*

shade cloth is removed. A balanced, high soluble fertilizer can be applied at a reduced rate during this period. Stecklings will typically grow only 5-20% more in height during acclimatization.

The resultant stecklings can be handled exactly the same as seedlings for lifting, cold storage, and planting.



Seven-month-old rooted cutting.



Seven-month-old rooted cuttings two weeks after removal from the greenhouse.

3 ECONOMICS

A steckling can be produced for 25 cents. This includes the production cost of the cutting-donors, but not the cost of producing the genetically improved seed from controlled crosses, nor any capital costs. Each cutting-donor costs $1.00 to produce, and with 50 shippable stecklings produced per donor, this cost represents a small fraction of the total nursery costs. (For example, if 1 million stecklings were produced, the donors would cost $22 000 and the stecklings $228 000.)

If the cutting-donors are grown under low light intensity (photoperiod extension), then only 25 shippable rooted cuttings would be produced per donor. This raises the price of the steckling to only $0.27, and substantially reduces capital, operating, and maintenance costs for lighting (approximately 65 high-density 400-watt sodium lights would be needed in a 12 x 42 m greenhouse to achieve the high light intensity needed to produce 50 shippable rooted cuttings per donor).

Table 5 outlines the number of man-hours needed to perform key tasks in the production technique.

Assuming a 15% increase in volume of wood produced by using stecklings from selected full-sib families, an increase of 9–11¢ per propagule, over the cost of seedlings, is justified. As shown by cost:benefit analysis, the increased benefits at rotation surpass the extra initial costs in stock production. This results in a greater rate of return using genetically improved stecklings over seedlings from untested seedlots.

TABLE 5. Time to complete key tasks in the production of interior spruce stecklings

Event	No. per man-hour
Cutting donors:	
1. Transplanting/pruning	100 seedlings
2. Pruning laterals	60 seedlings
3. Collecting cuttings	600 cuttings
Stecklings:	
1. Setting cuttings (cutting, stripping, dipping)	200 cuttings

4 GENETIC VARIABILITY

Genetic variability among traits affecting the production of the improved stecklings presents small but solvable problems with the technique described above. There is significant variability, for example, among families of interior spruce for the average number of cuttings produced for each donor, the rate of height growth, first-year height and root collar diameter, and root:shoot dry weight ratio of the stecklings. As well, interactions between nursery cultural treatments and families can produce a wide range of results.

In a study using 10 full-sib families, seed grown under the optimal regime produced an average of 65 cuttings from each donor. As shown in Figure 5, however, the average number of cuttings per donor for each family ranged from 46 for Family 11 to more than 90 for Family 9. Obviously, if the objective is to produce equal numbers of stecklings from each family to avoid a narrowing of genetic diversity in outplantings, twice as many seed should to be sown for Family 11 than for Family 9.

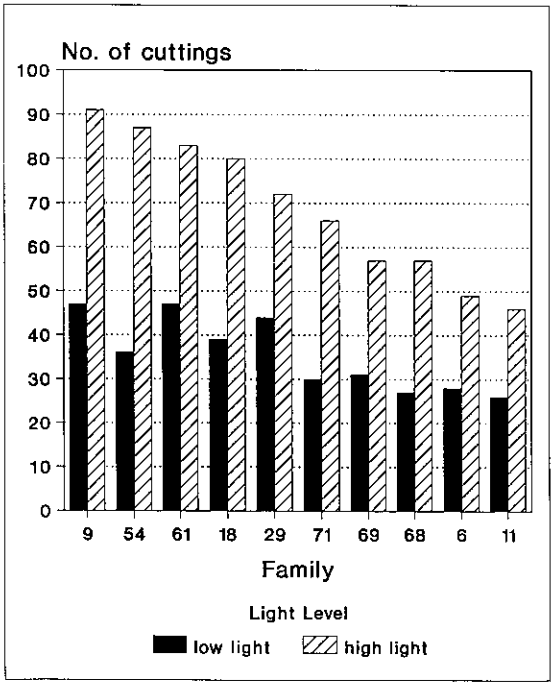


FIGURE 5. Family variability in the production of cuttings.

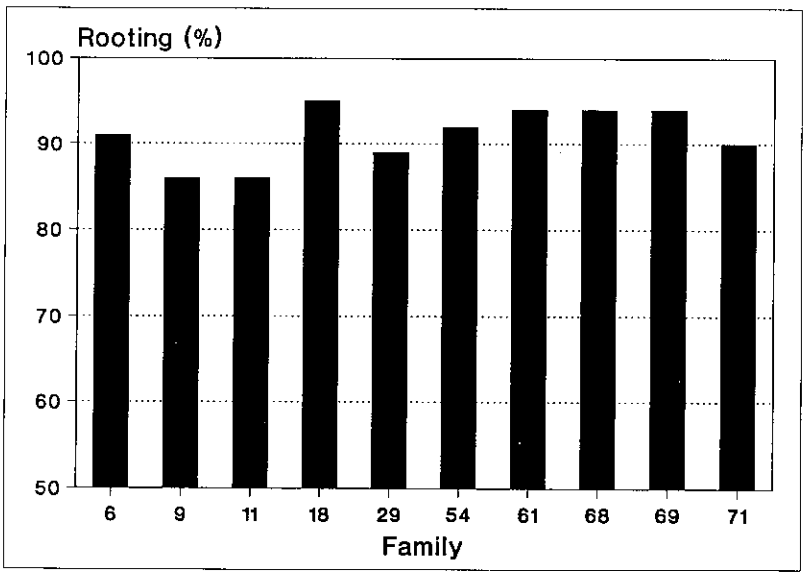


FIGURE 6. Family variability in rooting success.

There is no significant interaction between family and light intensity, as shown in Figure 5, with respect to the number of cuttings produced on average per donor. Those families that produce abundant cuttings per donor under high light intensity also produce the greatest number of cuttings under a lower light intensity.

Genetic variability is also minimal in rooting success among full-sib families as shown in Figure 6. Thus, families selected for the cutting program according to increased growth in the genetic field trials will not be lost due to poor rooting.

There is, however, a difference in growth rate during the first year. This could be a result of differences in speed of rooting as well as inherent genetic differences for growth rate among families. There is also an interaction between family and cutting size that affects rate of growth. Figure 7 shows that small and large cuttings from Family 71 grow at the same rate, whereas those from Family 16 grow at different rates. As mentioned earlier, to attain the desired target height, cuttings should be sorted by family and size and removed from the greenhouse for acclimatization accordingly.

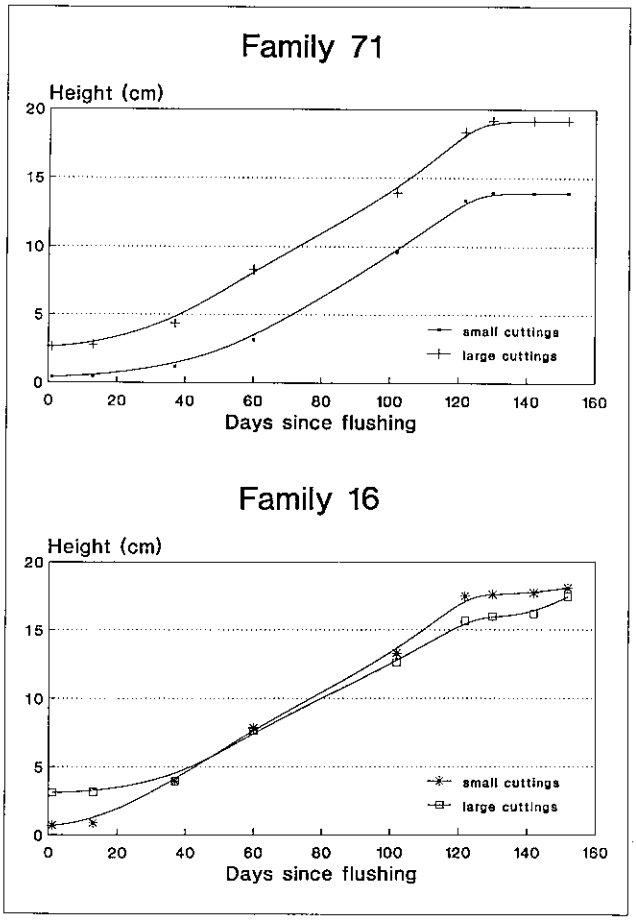


FIGURE 7. Family variability in first-year nursery growth rates of large and small cuttings. (See text for details.)

Not surprisingly, there is a significant difference in first-year height, root collar diameter, root morphology, and root:shoot dry weight. Figure 8 shows the differences among families in root collar diameter and root:shoot dry weight ratio, as well as the difference between seedlings and stecklings. Both propagule types were grown in styro 313's.

5 SEEDLING:STECKLING COMPARISONS

It is anticipated that there will be no significant difference in survival, growth, and form in the field, between seedlings and stecklings grown from juvenile cutting material. As well, it is hypothesized that seedlings and stecklings from the same families will grow at the same rate. In other words, if a set of families was ranked for 10-year height growth, this ranking would be the same whether the trees were seedlings or stecklings.

Observations from 1-year-old nursery trials involving seedlings and stecklings, show some interesting differences in growth and form. The seedlings are consistently better in total height, whereas stecklings have a greater root collar diameter and a higher root:shoot dry weight ratio (Figure 8). Whether these differences will persist in the field is doubtful. Nevertheless, a 1-year-old steckling more closely approaches the stocktype desired by foresters – fat and stubby with a good root system – which may result in better survival in the field.

Five field trials are currently underway in the interior of British Columbia, comparing the growth and form of seedlings and stecklings from the same families. As the oldest trials are only 2 years old, no meaningful growth data are available yet. In two of the trials that experienced the cold snap in February 1989, no difference in survival or frost damage occurred between the seedlings and stecklings.

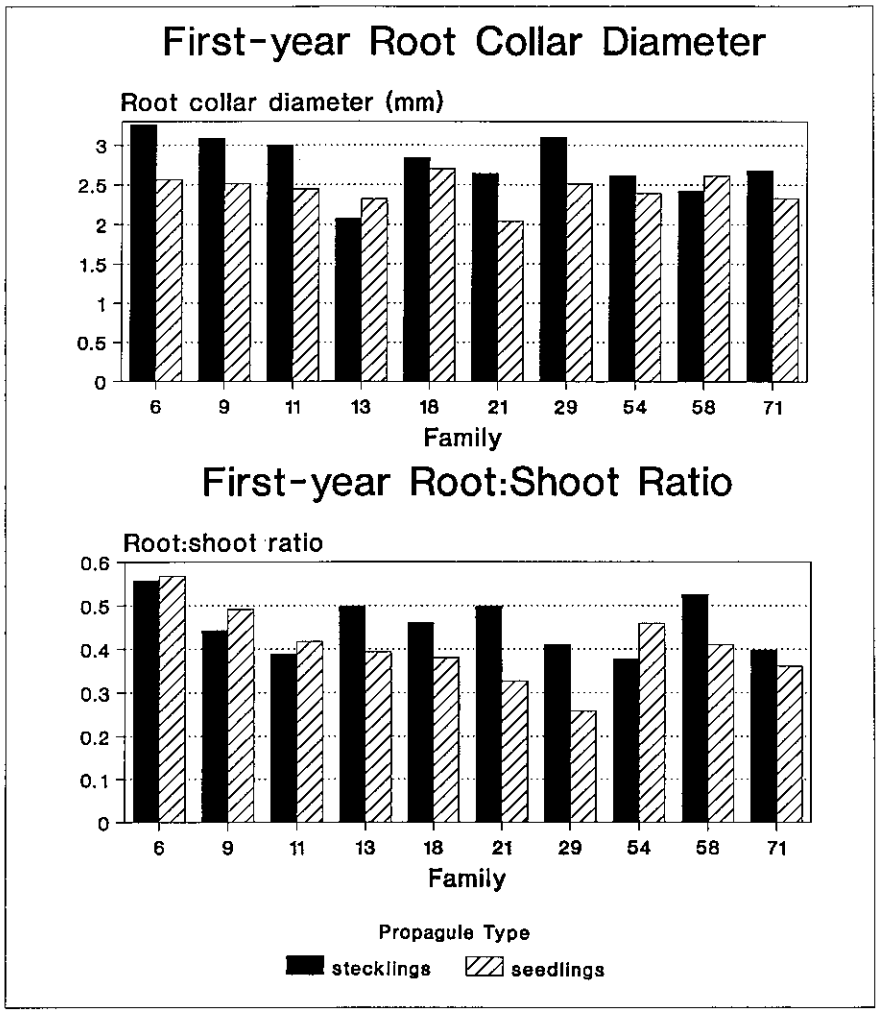
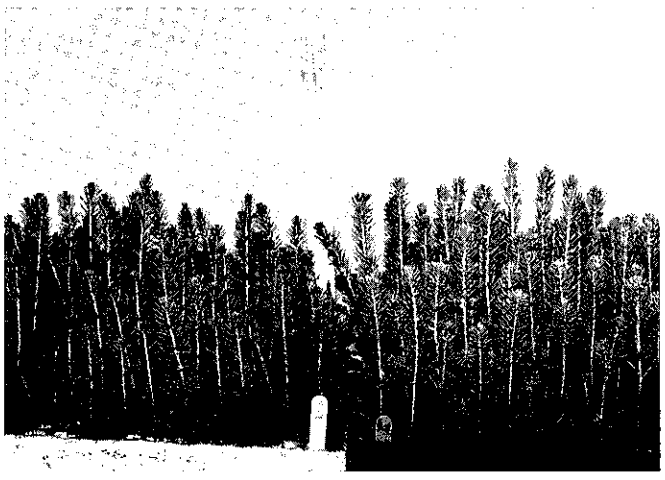
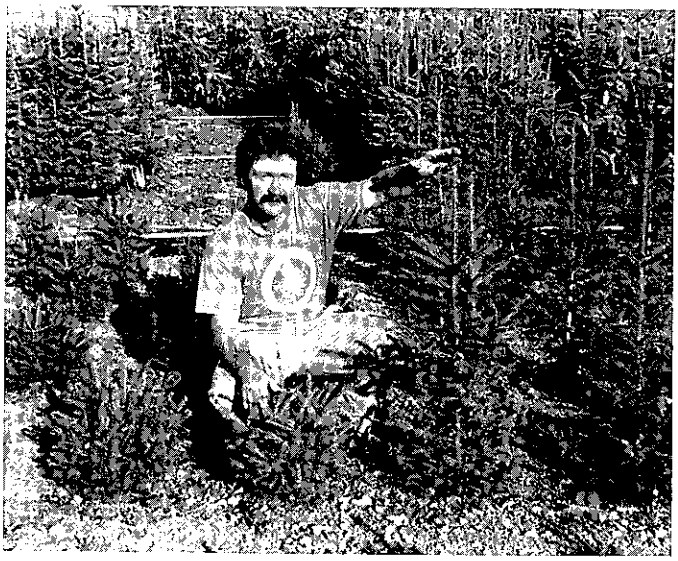


FIGURE 8. Seedling:steckling comparisons of first-year stock quality.





One-year-old stecklings and seedlings from the same family (above and right).



Four-year-old hedge orchard. The plants on the left have been pruned annually.

6 CLONAL FORESTRY: A FUTURE POSSIBILITY?

The variability in growth that exists within a family can be exploited to capture additional genetic gain. To realize this gain, however, individual seedlings from each family must be cloned (via rooted cuttings or tissue culture), tested, and then multiplied for reforestation.

Unfortunately, it takes years to test the clones (a minimum of 10 years), and meantime the original donors will be aging. When cuttings are repropagated from these older donors, rooting success can decline, and subsequent growth and form can be inferior compared to that in stecklings from younger, more juvenile donors.

Two methods of alleviating this problem are (1) to prune cutting-donors annually; and (2) to repropagate cuttings continually from previously rooted cuttings (serial propagation). Both methods are now being investigated, with the objective of delaying the maturation of the cutting-donors, such that the growth of stecklings from older donors is comparable to that of seedlings.

7 SUMMARY

The technique described in this manual can be successfully applied to produce genetically improved stecklings at an economical price. Although field trials are still young, stecklings show every indication of performing the same as seedlings. This is not surprising, since this has been the result for a number of species around the world including Norway, black, and Sitka spruce.

The method for producing interior spruce stecklings has been developed to maximize the number of shippable propagules per genetically improved seed, while minimizing nursery costs. The result is an efficient system which is compatible with the present seedling production system in British Columbia. It is flexible enough to accommodate changes and improvements which are inevitable as experience in growing stecklings of interior spruce is gained.

Currently 20 000-30 000 genetically improved stecklings are being produced annually. These are being planted alongside operational plantings of seedlings in the Prince George area. As more confidence is gained in the production and use of these new propagules, the numbers can be expanded to help meet the demand for genetically improved stock.

The uses of stecklings are many, however, and go beyond their use as a stop gap measure in producing improved stock until seed orchards come into full production. For example, the most elite families can be produced in large numbers by stecklings; the efficiency of forestry field trials can be improved using clonal replicates; and the demonstration of realized gain can be more effective using clonal blocks. Finally, if maturation can be successfully delayed in cutting-donors, then genetic gains in growth can be improved with the practice of clonal forestry.

8 GLOSSARY

Clonal test: a plantation consisting of clones and established primarily to determine genetic differences among clones.

Clone: plants (ramets) reproduced asexually from a common ancestor (ortet) and having identical genotypes.

Cutting-donor: plant material (seedling or steckling) grown for the purpose of providing cuttings for rooting.

Family: the offspring of a single tree.

Full-sib: the offspring of a single tree in which the male parent is also in common.

Hardening-off: the process of acclimatization to stress.

Hedges: cutting-donors, usually established in soil, annually pruned to delay maturation of plant tissue.

Maturation: the transition from the juvenile (vegetative) stage to the mature stage (reproductive).

Progeny test: a replicated experiment established to compare the offspring of different parents.

Resting stage: the condition of plant material (seed, buds) when it fails to grow due to internal conditions, even though external conditions are suitable.

Seed orchard: a plantation established for the production of seed.

Seed orchard (1.5 generation): a seed orchard composed of genetically improved clones as tested in first-generation progeny tests.

Serial propagation: the continual rooting of cuttings from previously rooted cuttings.

Steckling: a plantable (shippable) rooted cutting.

Target specifications: ideal height, diameter, and root mass measurements for nursery-grown seedlings set by the Ministry of Forests.