leaf so the bud can utilize material stored in the leaf and also manufacture food.

LARGE-SCALE PRODUCTION OF BLACK SPRUCE CUTTINGS FOR PROGENY TESTS

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A program for the large-scale production of spruce cuttings has been ongoing in Ontario for 4 years. This work has been based on preliminary studies by Rauter (7), Armson, et al. (1), Perez de la Garza (4), and Fung (3). The program was initiated in 1979 when approximately ½ million rooted cuttings were produced for operational outplanting (1). This program was so successful that in 1980, it was decided to build a new facility for the production of spruce juvenile cuttings for the Ontario Tree Improvement Program.

The purpose of this new program is to clone spruce seedlings for progeny testing. Seedlings of full-sib origin are grown and, as they develop, cuttings are taken from them and propagated. New cuttings are later taken from the original seedlings and also from the first rooted cuttings. This cycle is repeated until 140 ramets of the same age are produced from each clone. After rooting, these last cuttings are used for progeny outplanting tests in Northern Ontario. Presently both black spruce (*Picea mariana* [Mill.] BSP) and white spruce (*Picea glauca* [Moench.] Voss.) juvenile cuttings are propagated. The 140 ramets per clone can be achieved more rapidly with juvenile black spruce seedlings because they grow faster and cuttings taken from them root faster than juvenile white spruce seedlings.

The objective of this paper is to outline the cultural techniques by which the 140 black spruce ramets per clone are produced.

Production cycle. The first attempt at production of black spruce cuttings for progeny tests in 1980 required 5 cycles of cuttings and nearly 3 years to achieve the 140 ramets per clone objective. Since then our growing techniques have been improved and we have been able to reduce the length of the production cycle. In the cycle described here, 1900 seeds were sown in October 1981 for one progeny test (Table 1). One month later a germination survey showed 45% survival or 850 ortets. A germination rate of 45% for spruce seeds produced by artificial techniques is not unusual. The seedlings were grown

until March, 1982, when the first cuttings were taken from them. The cuttings were rooted by mid-May and were then grown until August, 1982. The seedling ortets were also grown until August and a second set of cuttings were taken from both the seedling ortets and the first cuttings to produce the 140 cuttings per clone.

Table 1. Production cycle of black spruce cuttings for progeny tests in 1981-82.

Date	Activity	Total Number	Number/Clone
October, 1981	Seed Sown	1,900	
November, 1981	Germination Count[a]	850	1
March, 1982	First Cutting[b]	35,700	42
August, 1982	Second Cutting[b]	119,000	140

[a] Seedling ortets grown in standard round 130 mm pots until June, 1982, then repotted to standard round 150 mm pots.

[b] All cuttings in Fir Cell Leach Containers.

Ortet propagation. The operation of this program is carried out in two gutter-connected greenhouses with an approximate bench capacity of 660m^2. With this bench space we can sow approximately 4350 black spruce seeds and with 50% viability, we expect to produce 2150 clones with at least 140 ramets per clone for progeny planting tests. Since each progeny test includes approximately 800 to 1000 clones, we can produce black spruce cuttings for 2 separate progeny tests in a one-year period.

Seeds were sown in mid-October, 1981, in Jiffy 7 pots and, after germination, the 850 seedlings were potted into standard round 130 mm pots. The growing medium consisted of sphagnum peat and vermiculite (1:1 v/v) amended with Unimix[1] and dolomitic limestone added at the rate of 2.4 and 4.5 kg/m^3, respectively. The seedlings were grown for 19 weeks under a 24-hour photoperiod supplied by natural sunlight supplemented by artificial lighting at 5000 lux intensity.

The supplemental light was supplied from 4:00 pm to 8:00 am daily with high pressure sodium lamps. The greenhouse temperature was artificially maintained at 21°C minimum throughout the growing period; at times the temperature did reach 30°C during the day. The seedlings were fertilized with balanced nutrient regimes usually twice per week at 100 ppm nutrient concentration based on N.

[1] Unimix is a potting fertilizer formulated for peat/vermiculite mixtures and sold under the trade name, Peter's Soluble Fertilizers.

The fertilizers were provided as follows:

Weeks 1,2,3	Seed germination
Weeks 4,5,6	N-P-K (9-45-15)
Weeks 7,8,11,12,15,16,19	N-P-K (20-20-20)
Weeks 9,13,17	N-P-K (15-15-18)
Weeks 10,14,18,20	Leached, no fertilizers
Week 21	N-P-K (15-15-30)
Week 22	N-P-K (9-45-15)

The trees were grown actively for 19 weeks after which they were conditioned for cutting. The supplementary lighting was then turned off and the growing medium was leached of all fertilizer salts. In the 21st week, a fertilizer high in potassium, N-P-K (15-15-30), was applied to the seedlings to increase their sturdiness. A fertilizer high in phosphorus (9-45-15) was applied to the seedlings in the 22nd week to promote better root development in the cuttings. Twenty-two weeks after sowing, the seedling ortets averaged 34.8 cm in height and 5.2 mm in root collar diameter (Figure 1).

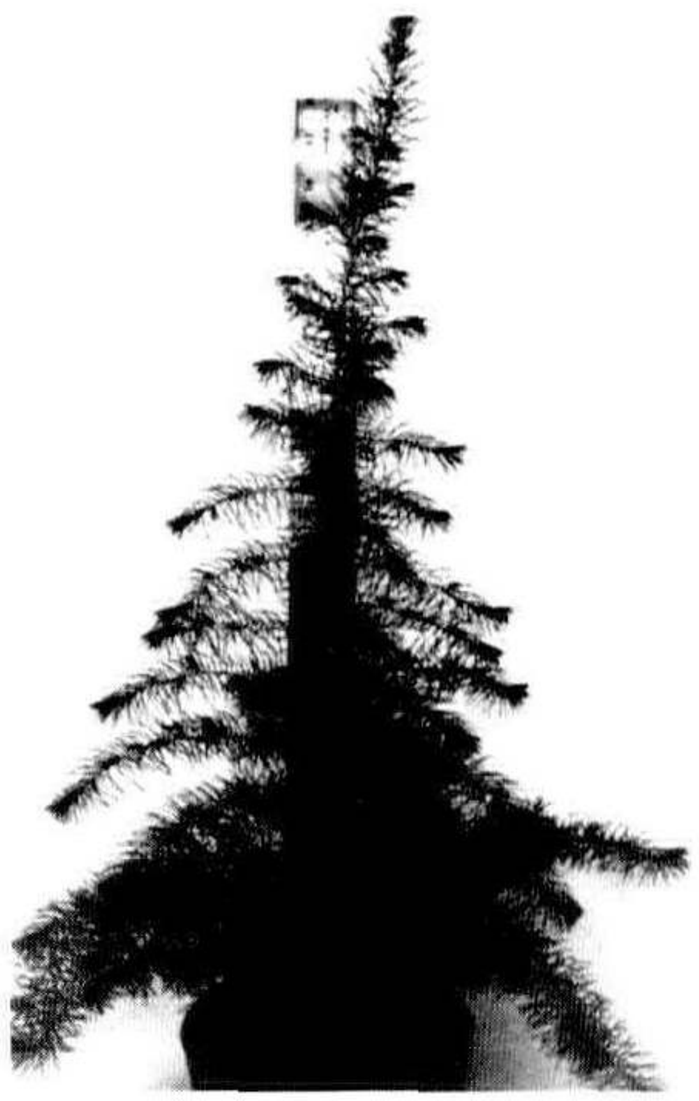

Figure 1. Typical black spruce seedling just prior to taking cuttings at 23 weeks.

Cutting production. In the 23rd week (March 22 to 26, 1982), the first cuttings were taken from the ortet seedlings. Two people working together prepared and planted the cuttings. With a razor blade, one person excised all of the cuttings off each seedling. Cuttings consisted of all the growing tips including leader and lateral branches; they averaged 4.5 to 5.0 cm in length and 1.0 to 3.0 mm in basal diameter. The other person planted the cuttings with a stick so that the cuttings were inserted about 1 cm into the soil. The stick had a pointed end which was used to make a hole in the rooting medium to

insert the cutting and a blunt end which was used to pack the soil down around the base of the cutting.

Until recently, the process of rooting juvenile black spruce cuttings at Orono involved plucking the lowermost needles from the base of cuttings prior to planting. Plucking the needles by hand was very time consuming and expensive in manpower. The needles were pulled off very carefully in order not to strip the stem bark in the process. When the cuttings were damaged in this manner, they often rooted, but they usually took longer and rooted from above the damaged portion of the stem. It has recently been shown (6) that the removal of the lowermost needles from the base of black spruce cuttings prior to planting is unnecessary and is often detrimental to their rooting ability. The same study showed that planting depths between 0.5 and 2.5 cm into the rooting medium had little effect on rooting as long as the cuttings were well-planted initially.

Root promoting substances were not required to root the juvenile black spruce cuttings. The cuttings were planted into a moist mixture of 1:1 shredded sphagnum peat moss and medium grade vermiculite in Leach Fir Cell Containers[2]. These were used for two reasons: 1) The perfectly aligned rows of cells provide an easy way of maintaining clonal identity; and 2) The cells can be separated individually to arrange trees in any field planting design. Prior to planting, the rooting medium was drenched with the fungicide, Quintozene, to eliminate soil fungi.

Two workers were able to cut and plant approximately 300 cuttings per hour while labelling and documenting their work at the same time. The number of cuttings that each seedling yielded varied between 10 and 88, but they averaged 42 per clone (Table 1).

The rooting environment. When the leach tube trays were filled with cuttings, a fine fog nozzle was used to mist the cuttings. Following misting the trays of cuttings were immediately placed on benches in rooting tents. The rooting tents were constructed on rolling benches inside the greenhouses. These tents consisted of a sheet of clear polyethylene supported by a metal hoop and nylon cords. One layer of white Terelyne shade cloth (55% shading) was placed over the polyethylene to provide shade during rooting.

The rooting tents maintained very high humidity surrounding the cuttings. Aluminum water piping and nozzles were installed above and below the rooting tents. These water lines were controlled by timers which provided approximately

[2] Registered Trade Name of Ray Leach Cone-Tainer Nursery.

60 seconds of mist every 30 minutes. This arrangement was successful in maintaining the high relative humidities required for rooting without getting excessive amounts of water onto the rooting medium. The sheets of polyethylene trapped the moisture sprayed from under the benches. The mist sprayed from above the rooting tent dampened the shade cloth. This moisture mostly evaporated but some of it eventually dripped to the floor and thus contributed to increased relative humidity in the greenhouse. We attempted to maintain the humidity in the rooting tents at approximately 85 to 90%, although many times it was above or below these values. Misting from above the rooting tents with cold water also enabled us to control the temperature inside the rooting tents.

Tending the cuttings. The cuttings required 8 weeks of very close tending during which time, temperature, moisture, relative humidity, light, and disease conditions were closely regulated in the rooting tents. A 24-hour photoperiod was maintained; it consisted of natural sunlight during daylight hours supplemented by fluorescent lamps at 500 lux intensity at night. Temperature was maintained at a minimum of 20°C and temperatures up to 30°C were tolerated as long as the relative humidity was also high. When the temperature was excessive, the polyethylene sheet was lifted for a few minutes to remove the hot air. Light misting of the cuttings by hand with a fog nozzle was done up to 3 times daily depending on weather conditions. The objective was to place water droplets only on the foliage. Heavy misting was avoided because it leads to saturation of the growing medium, reducing aeration and increasing the likelihood of disease. The main disease problem in rooting black spruce cuttings is attack by *Botrytis* spp. To prevent this fungicides were applied once a week for 8 weeks. Benlate and Rovral were applied individually in alternative weeks.

Terelyne shade cloth was used in rooting black spruce cuttings. We have noticed that under excessive light such cuttings do not root well, and the same is true for low light conditions (6). There must be sufficient light to sustain some photosynthesis, otherwise the carbohydrate supply will diminish to the point where cuttings will not have the capacity to root. On any given day, we attempted to maintain a minimum of 3,000 lux and a maximum of 13,000 lux, at the brightest time of the day in our rooting tents. This could mean removing the shade cloth from the north side of the rooting tents, or using lighter shade cloth, when the intensity was too low. Also, portions of the greenhouses, where the light intensity was consistently below the minimum level, were not used for rooting black spruce cuttings. When the light intensity at the

brightest time of day was higher than 13,000 lux, shading was increased over the cuttings.

Rooting the cuttings. Weekly sampling of the cuttings showed that most of the rooting occurred in the 5, 6, and 7th week. By the tenth week, 97% of the 35,700 cuttings had rooted. At this time, the cuttings underwent a 2-week conditioning period to allow them to adjust to greenhouse conditions. During this time, misting was slowly withdrawn, ventilation periods were increased, exposure to sunlight was increased, and normal fertilization was resumed. This was done progressively so that by the end of the 2-week conditioning period, the polyethylene and shadecloth were entirely removed from the rooting tents (Figure 2).

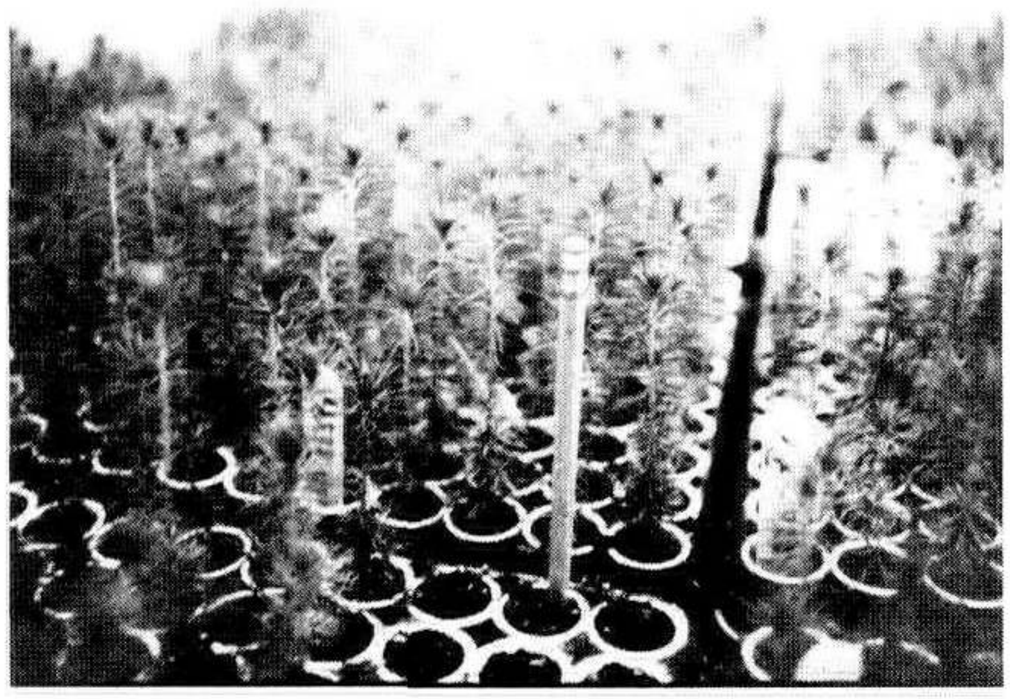

Figure 2. The first cuttings taken from black spruce seedling ortets 12 weeks after planting.

The second cutting. After the first cuttings were taken in March, 1982, the seedling ortets were returned to pre-cutting growing conditions in the greenhouse, i.e. 24-hour photoperiod and regular fertilization, as described previously. They were repotted in June into standard round 150 mm pots to ensure that they would continue growing freely until August. A second set of cuttings was taken in August from both the seedling ortets and the first cuttings to produce the 140 cuttings per clone. A total of 119,000 cuttings were planted in August, 1982. By mid-October approximately 90% of them had rooted. These will be grown over-winter in our greenhouses and will be ready for outplanting in progeny tests in the spring of 1983.

Plantation surveys of black spruce cuttings planted in 1979 and 1980, in comparison tests with seedlings, have shown that cuttings survive and grow as well as seedlings.

Future production at Orono. It appears that the next cycle of black spruce cuttings for progeny testing will be carried out by taking only one set of cuttings to achieve the 140 ramet/clone objective. We have improved our growing techniques and feel that black spruce can be grown from seed to a height

of 60 cm and a root collar diameter of 10.0 mm in 7 months. Black spruce seedlings of this size will normally yield approximately 140 cuttings each.

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THE ROOTING STIMULUS IN PINE CUTTINGS

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Abstract. Occurrence, distribution, and function of the "endogenous root-forming stimulus" (ERS) were examined in jack pine (*Pinus banksiana* Lamb.) seedling cuttings via surgical treatment and application of indole-3-butyric acid (IBA). Removal of terminals or needles markedly reduced rooting, indicating that both terminals and needles contained substantial amounts of ERS and that ERS was rather generally distributed in the cuttings. However, terminals contained much more ERS per unit dry weight, compared to needles. ERS consisted of an auxin and non-auxin component. Applied IBA did not replace the effects of terminals on rooting and, therefore, was largely ineffective when non-auxin ERS was limiting. Auxin ERS was initially required for the development of callus in which primordia initiated. Subsequently, auxin and non-auxin ERS were required for primordium development. However, limiting the supply of non-auxin ERS was primarily responsible for reduced rooting after terminals were removed.

About 100 years ago the idea arose that chemical factors in the aerial portion of plants controlled the formation of roots (26). Subsequently, it was learned that auxin, indole-3-acetic acid (IAA), and one or more non-auxin chemicals accumulated