bi-monthly research notes

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BOTANY

Estimating Annual Height Growth by the Internode Method.—The best way to estimate an annual height increment in a tree is to measure the appropriate internode. In practice an internode is defined by the distance between two subsequent branch whorls (Romberger, U.S. Dep. Agric., For. Serv. Tech. Bull. 1293, 1963; Stiell, Can. Dep. For. Tech. Note 122, 1962); but when the positions of terminal and lateral buds are examined, it becomes apparent that annual shoot growth does not end at the center of a branch whorl (Fig. 1 and Table 1). When the true annual height increment of young trees or seedlings is desired, the accuracy of the measurable variables is critical. To make an accurate measurement one must have complete knowledge of the morphology of the nodal region and the technique of the measurement.

This study was undertaken to determine if the method of estimating annual height growth or volume growth by measuring internodes to branch whorls is acceptable for young trees and seedlings. The distinguishable zonation in the pith (Fig. 1), delineating the growth from year to year, is due to the collenchyma

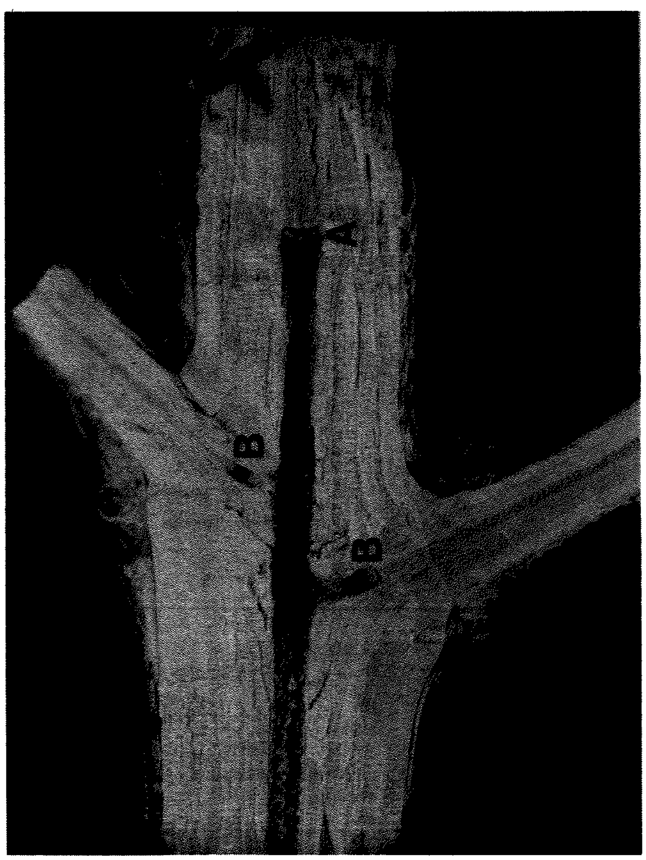

Figure 1. A longitudinal-radial section of a 23-year-old Douglas-fir 14 ft (4.3 m) in height showing the true ends of the segments in stem (A) and branches (B).

TABLE 1
Distance between the end positions of annual-growth segments and the centers of the corresponding branch whorls

Species	Number of observations	Average distance mm	Average distance inches	Coefficient of variation %	Crown class
Lodgepole pine	88	11.72	0.46	59.2	Codominant
White spruce	26	10.31	0.41	74.8	Intermediate and dominant
Douglas-fir	39	11.87	0.47	68.8	Intermediate

plate that develops at the base of the buds. This plate extends across the pith of the stem and into the cortex (Romberger, U.S. Dep. Agric., For. Serv. Tech. Bull. 1293, 1963). Wagg (Can. Dep. For. Rural Dev., For. Branch, Dep. Publ. 1192, 1967) also noted a distinct year-by-year demarcation of pith growth in white spruce stems and branches. Early and late pith could be separated on the basis of color and cell structure, with special reference to lumen diameter and wall thickness, in much the same manner as springwood and summerwood. The ratio of early pith to late pith varied from 3:1 to 6:1, depending on species and growing conditions. Pith laid down early in the growing season was up to three times greater in diameter than that laid down at or near the end of the season. The pith diameter generally increased with increasing length of annual growth segments and increasing tree heights. This phenomenon clearly indicates the presence of compressive stresses exerted by the growing cambial force on the previously formed cell structure.

Two trees from each of three coniferous species, namely, lodgepole pine, white spruce and Douglas-fir, were investigated. After careful splitting of boles, the piths were examined along their entire lengths. The piths in all trees were readily separated into annual-growth segments (Fig. 1). Since the collenchyma plates are not always visible to the naked eye, the separation of internodes by the collenchyma-plate concept did not seem practical. However, when the continuous pith body in the split stems was exposed to drying, the adjacent annual pith segments retracted through shrinkage. The separation gaps that resulted had clearly defined the correct end positions of the annual-growth segments, i.e. the true length of the internodes. Further, it was observed that the separation gaps never occurred in the center of branch whorls but always at some distance above it. This clearly supports the view that the branch whorls are not the true end-boundary indicators of any true internode. The distances between the centers of branch whorls and the true ends of the annual-growth segments with their variations are shown in Table 1. The variation could perhaps be attributed to the degree of the annual effect of the environment. Besides, the variation suggests that the distance between the centers of branch whorls and their true ends cannot be compensated by a simple constant term in a stem-analysis model or volume model.

From the well-known concept of height-diameter relations for volume estimate, it might be assumed that a similar relation may be found between the true lengths of internodes and the corresponding thickness of annual radial-growth increments for annual volume-growth estimate. From the latter relation the estimation of annual volume increment of young trees and stands could be accomplished indirectly with a high degree of accuracy.—E.F. Wass, Forest Research Laboratory, Victoria, B.C., and T. Szabo, Eastern Forest Products Laboratory, Ottawa, Ont.

Temporary Stimulation of Photosynthetic Rate by a Short Photoperiod.—During the course of an experiment on the effect of temperature and photoperiod on induction of dormancy in two provenances of jack pine [*Pinus divaricata* = *banksiana* Lamb.], the photosynthetic rate of seedlings was observed to increase temporarily in response to a short photoperiod. No reference could be found to this phenomenon, which is described here because of its relevance to photoperiodic experiments in controlled environments. Jack pine seedlings from Petawawa, Ont. (46°N 77°W) and Lac La Ronge, Sask. (55°N 105°W) were grown in a growth room at 22°C and 16 hr photoperiod. The growing medium was turface which was watered automatically with a nutrient solution four times daily (Pollard, Can. Forest. Serv. Inf. Rep. PS-X-28, 1971). After 9 weeks in the long photoperiod, seedlings were divided into three groups and placed in a short photoperiod (8 hr) in three growth cabinets at 15°, 20° and 25°C respectively. Seven seedlings were selected at random for photosynthetic measurements in the long photoperiod and after 2, 4 and 7 weeks in the short photoperiod. During the last 2 weeks in the long photoperiod, the photosynthetic rate of both provenances remained steady at 18 mg CO_2/g needle/hr. After 2 weeks in the short photoperiod photosynthetic rates had increased significantly (Fisher's t test, $p = 0.02$), but subsequently declined to rates below those obtained in the long photoperiod (Table 1). The response was similar for both provenances and all temperatures. No diurnal fluctuations in photosynthesis could be detected in either photoperiod.

TABLE 1

Photosynthetic rate (mgCO_2/g needle/hr) of jack pine seedlings from Petawawa and Lac La Ronge in a long photoperiod and after 2, 4 and 7 weeks in a short photoperiod at 15°, 20° and 25°C.

Weeks in short photoperiod	Petawawa, Ont.			Lac La Ronge, Sask.		
	15°	20°	25°	15°	20°	25°
0		18[a]			18[a]	
2	22	24	25	22	24	24
4	18	20	21	19	21	21
7	11	17	17	10	15	14

[a] Seedlings in a long photoperiod at 22°C.

The "source-sink" hypothesis that actively growing sinks for photosynthates influence rate of photosynthesis (Sweet and Wareing, Nature 210:77-79, 1966) suggests an explanation for this phenomenon. The actively growing "sinks" may be maintained for the first 2 weeks in the short photoperiod. In this connection, Kawase (Amer. Soc. Hort. Sci. 78:532-544, 1961) found no change in growth rate of yellow birch [*Betula alleghaniensis* Britt.] until their third week in a short photoperiod. If the photosynthetic rate were to remain unchanged in the 8 hr photoperiod, seedlings would produce only half as much photosynthate as in the 16 hr photoperiod. The subsequent increase in photosynthetic rate is in response to the continuing demands of the actively growing "sinks". However, short photoperiods upset the balance of growth regulators and induce dormancy (Phillips and Wareing, Naturwiss. 13:317, 1958). As growth slows down, demand for photosynthate slackens and the photosynthetic rate declines.—K.T. Logan, Petawawa Forest Experiment Station, Chalk River, Ont.

ENTOMOLOGY

Biological Control of the European Spruce Sawfly in Newfoundland.—The European spruce sawfly [*Diprion hercyniae* (Htg.)] was first recorded in Canada in 1930 on the Gaspe Peninsula, Quebec. By 1940, it had spread throughout New Brunswick and severely defoliated many stands of black and white spruce (Bird and Elgee, Can. Entomol. 89:371-378, 1957). In the same year it was discovered in the Humber Valley in western Newfoundland and had spread to the Baie Verte and northern peninsulas by 1948 and into central and eastern areas by 1959. Survey records, obtained from beating infested trees indicate that population levels increased from an average of 20 larvae per sample to 90 larvae per sample between the years 1943 and 1951 and between 1958 and 1970 (Fig. 1). During these periods defoliation was severe in some stands but tree mortality was negligable.

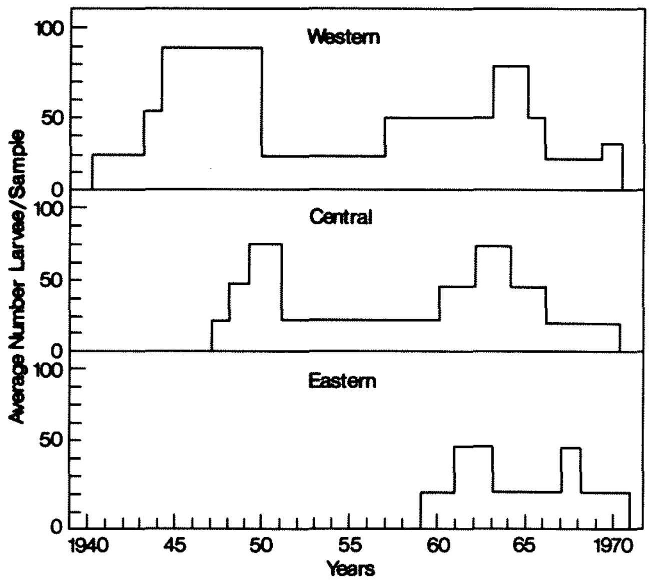

Figure 1. Outbreaks of the European spruce sawfly in Newfoundland.

Damage is caused by the larvae feeding on the needles of host trees, primarily the spruces. White spruce is the preferred host but both red and black spruce may be severely defoliated. Several years of severe defoliation can cause tree mortality and more than 10 million cords (36 million cubic meters) of spruce were killed in the 1930's in Quebec (Reeks and Barter, For. Chron. 27:140-156, 1951).

The extensive areas of defoliation and the history of tree mortality in Quebec, prompted Newfoundland Forestry Officials to introduce the nucleopolyhedrosis virus [*Borrelinavirus hercyniae*] a key factor in the reduction of sawfly numbers in New Brunswick (Neilson and Morris, Can. Entomol. 96:773-784, 1964). The virus was obtained from the Maritime Forest Research Centre, Fredericton, N.B., and applied as a liquid suspension to sawfly-infested white spruce trees in the Humber Valley in 1943 and 1944. It established readily but appeared to disperse slowly; in 1948 the virus was applied again to infested trees on the Baie Verte Peninsula. It was also introduced into new infestations on the Northern Peninsula by releasing virus-infested larvae collected in the Humber Valley area. The virus dispersed rapidly and was apparently the primary factor contributing to the collapse of infestations early in the 1950's (Fig. 1). In the late 1950's sawfly numbers increased again, averaging 90 larvae per tree in central, and 25 per tree in western Newfoundland; even higher numbers have been recorded since 1960. These recent periods of high population have lasted only 1 or 2 years as opposed to the 5-8 year period recorded for the initial outbreak. The virus was assumed to be the principal factor in shortening the outbreak period but the introduction of invertebrate parasites and the masked shrew have doubtlessly improved the biological control complex of this sawfly.

Insect parasites of the European spruce sawfly were introduced from Europe between the years 1943 and 1949. These included species of Hymenoptera; *Dalbominus fuscipennis* (Zett.), *Exenterus amictorius* (Panz.) and *E. confusus* Kerr; and a Diptera, *Drino bohemica* Mesn. released in infested stands in western

Newfoundland (McGugan and Coppel, Tech. Commun. Commonw. Inst. Biol. Cont. No. 2 pp 35-127, 1962). The *Exenterus* spp. and *Drino* sp. had been shown by Neilson and Morris (*loc. cit.*), to be important in regulating sawfly populations in the Maritime provinces. In Newfoundland, none of the hymenopterous species and only one specimen of the diptera, *D. bohemica*, have been recovered. However, the records mean little as the presence of virus in the sawfly populations has made it difficult to rear larvae to determine parasitism. More sophisticated rearing techniques are presently being tested in an attempt to provide an evaluation of the role of parasites in the control of *D. hercyniae*.

The masked shrew [*Sorex cinereus cinereus* Kerr] is probably another factor in controlling the European spruce in Newfoundland. It was introduced in 1958, to improve the biological control complex of a number of forest insects, and has since spread throughout the Island. Studies have shown that the shrew is a good predator of the larch sawfly in Newfoundland (Warren, G.L., Proceedings, Tall Timbers Conference on Ecological Animal Control by Habitat Management. 2:185-202, 1970) and the European spruce sawfly in New Brunswick (Morris. Can. Entomol. 74:197-202, 1942). Studies by Bider (Info. Rpt. N-X-78, Nfld. Forest Res. Centre, 1972) have also shown that in Newfoundland the shrews preferred habitat is closed coniferous stands such as the black spruce stands attacked by the European spruce sawfly. Results of surveys show that shrew populations levels on the Island are higher than those in adjacent mainland forests. Due to the high population levels of the shrew, their preference for black spruce stands, and their efficiency as predators of sawflies, it is assumed that this shrew is a valuable addition to the biological control complex of the European spruce sawfly on the Island.—R.C. Clark, L.J. Clarke and K.E. Pardy, Newfoundland Forest Research Centre, St. John's Nfld.

First Successful Total Laboratory Development of Eggs of the European Pine Sawfly [*Neodiprion sertifer* (Geoff.)].— Laboratory studies essential to the development of new methods for controlling *Neodiprion sertifer* (Geoff.) and other *Neodiprion* species that overwinter naturally in the egg stage as partially developed embryos have been seriously hampered by the inability to rear the insects through a complete life cycle totally divorced from exposure to natural conditions. We have experienced no difficulty in obtaining mating and oviposition when using cut pine branchlets [*Pinus sylvestris* L. and *P. resinosa* Ait.] held 12-15 inches (30.5-38.1 cm) under banks of two to eight 40-watt Sylvania Gro-lux fluorescent lamps with either a 13- or 17-hour photophase in a room at 20°C and 70% RH. Once the eggs are laid, embryogenesis progresses rapidly at 20°C but stops after about 10 to 15 days and is not resumed unless the embryos are exposed to low temperature. We have not been able to prevent the arrest in embryogenesis by using various photoperiod regimes or by manipulating needle moisture content and/or chemical applications; and we conclude that there is a true embryonic diapause in *N. sertifer*. There is no question that water uptake from the host plant is vital to embryological development, but our data do not support Breny's hypothesis (Breny, Mem. Acad. R. Belg. Cl. Sci. 30, 88 p., 1957) that a water deficit initiates and maintains the developmental arrest.

In the past, experimental rearings involving embryological development have necessitated the use of small potted trees so that the egg clusters could be exposed to natural overwintering conditions after prediapause development in the laboratory. This procedure is not satisfactory because of the risk of loss of material and also because the handling of potted trees is cumbersome. Recently we have obtained larval eclosion from eggs laid in the laboratory in needles on cut pine branchlets by exposing the shoots containing the partially developed embryos to regulated temperatures below 20°C. First results indicate that the embryonic diapause is effectively fulfilled in about 2 months' exposure to 10°C; considerably longer is required at 15°C (17-hour photophase at both temperatures). These results agree with our findings that under natural conditions the embryonic diapause is fulfilled in the late fall with exposure to only moderately cool temperatures. Not only is the embryonic diapause fulfilled at 10°C, but embryological development also takes place and we recorded larval hatch from two egg clusters at 10°C after 137 days from oviposition. At 20°C, postdiapause embryological development required 1.5 to 2 weeks.

Larvae hatching from the laboratory laid eggs developed normally and spun cocoons after 3 to 4 weeks at 20°C and 17 hr photophase. Incubation of the cocoons at 20°C in darkness resulted in adult emergence after about 8 weeks, indicating the presence of a prepupal diapause as was anticipated from exposing the feeding larvae to a long photophase. Thus we would expect that the laboratory treatment of eggs will not interfere with the avoidance of the prepupal diapause by exposing developing larvae to short photophases, and the period of time spent in the cocoon may be reduced to about 5 weeks at 20°C.

Our current success is partially because our methods of treating cut pine branches enable us to keep them healthy in the laboratory for periods up to 3 to 4 months at 20°C. The branchlets are given a simplified version of the sterilization procedure published by Moore and Clark (J. Econ. Entomol 61(4): 1030-1031, 1968) to reduce the growth of microorganisms on the cut stems which otherwise clogs the water conducting tissues and leads to early death of the shoot. The provision of suitable lighting is also important in maintaining healthy cut branchlets.

To our knowledge this is the first record of laboratory rearing of *N. sertifer* through the entire egg period. With improvements in culture methods that we can envisage, continuous laboratory rearing of several generation a year will be possible; and this will greatly enhance certain avenues of research. A continuous culture method may also lead to easier production of biological control agents such as the nuclear polyhedrosis virus. Detailed accounts of our field and laboratory experiments on embryonic development will be published elsewhere.—D.R. Wallace and C.R. Sullivan, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

Erratum

Vol. 28. No. 5, page 31, col. 2. In equations (3), (4), (5), (6) and (7) for ft^e read ft^2.

FOREST PRODUCTS

Degradation of Arabinose in Wood Attacked by Thermophilic Fungi.—Thermophilic fungi occur abundantly in outside stored pulpwood chips (Smith and Ofosu-Asiedu, Can. J. Forest Res. 2:16-26, 1972), where they contribute significantly to the processes of thermogenesis and chip degradation. In the laboratory, several of these fungi have been shown to cause wood weight loss when grown under suitable cultural conditions (Ofosu-Asiedu and Smith, Mycologia, two papers in press). Considering these wood weight losses, Bergman and Nilsson (Res. Notes R60, Dep. Forest Prod., Roy. Coll. Forest., Stockholm, 1968) noted that a number of soft-rot fungi isolated from birch chips, including some thermophilic species, did not cause lignin losses and therefore seemed to be degrading the carbohydrate content of the wood. Several thermophilic fungi produce cellulolytic enzymes and therefore the potential to degrade cellulose (Fergus, Mycologia 61:120-129, 1969; Tansey, Arch. Mikrobiol. 77:1-11, 1971), although the evidence for certain fungi is still conflicting. Chang and Hudson (Trans. Brit. Mycol. Soc. 50(4):649-666, 1967) found that both cellulose and hemicelluloses were quite susceptible to microbial attack during the self heating of straw and, in 60 days of composting, about 71% of the cellulose was removed. Since relatively little information is available on the specific chemical activities of thermophilic fungi on wood, studies of this problem were initiated with thermophilic fungi previously isolated from a spruce-pine wood chip pile and with ponderosa pine [*Pinus ponderosa* Laws.] sapwood as a substrate.

The methods used for culturing these fungi and placing them in contact with test wood blocks were those described by Ofosu-Asiedu and Smith (Mycologia, in press). The fungi tested were *Allescheria terrestis* Apinis, *Talaromyces emersonii* Stolk and *Sporotrichum thermophile* Apinis. After incubation periods of 2, 6 and 12 weeks in contact with the fungi, the six matched wood blocks for each time period were ground to pass through a 60-mesh sieve and a random 1 g sample of this ground wood was taken for lignin and carbohydrate analyses.

Klason lignin contents were determined by the Tappi Standard T130S-54 and were not corrected for acid-soluble lignin. Constituent monosaccharides were determined by gas-chromatographic analyses of the reduced acetylated sugar residues recovered from the Klason lignin filtrate with inositol added as an internal standard (Sawardeker *et al.*, Anal. Chem. 37(12): 1602-1604, 1965). The column was packed with 3% ECNSS-M on Gas Chrom Q and peak areas were measured with an electronic integrator. Results are given in Table 1.

TABLE 1
Lignin and arabinose contents of ponderosa pine sapwood before and after degradation by some thermophilic fungi[a]

Fungi	Incubation time (weeks)	Lignin (% o.d. wood)	Arabinose (% o.d. wood)
Control	2	24.7	1.5
	12	25.1	1.6
Allescheria terrestris	2	25.2	1.5
	6	25.2	0.0
	12	26.3	0.0
Talaromyces emersonii	2	25.5	0.8
	6	25.1	0.2
	12	25.8	0.1
Sporotrichum thermophile	2	25.5	0.4
	6	26.1	0.2
	12	25.7	0.2

[a] Percentages are based on degraded wood as the original wood weights were not available. Previous tests showed that these three fungi would give no more than about 4% dry-weight loss over the longest incubation period.

The results for arabinose indicate a decrease of this sugar residue with increasing time of attack by all of the fungi. No trend could be established for glucose, mannose and xylose, but these were within the experimental variation of the method. The decrease in arabinose, but stability of the other three sugar residues and lignin, was observed by Hunt (Bi-mon. Res. Notes 27:3-4, 1971) in white spruce [*Picea glauca* (Moench) Voss] and lodgepole pine [*Pinus contorta* Dougl. var. *latifolia* Engelm.] pulpwood chips recovered after 24 months of storage from the upper, highly heated region of a chip pile. As very large numbers of several species of thermophilic fungi were isolated from this same region of a chip pile (Smith and Ofosu-Asiedu, Can. J. Forest Res., *op. cit.*), it seems probable that thermophilic fungi were responsible for the observed losses of arabinose.

The authors acknowledge the assistance of Dr. K. Hunt, Western Forest Products Laboratory, in this project.—Roger S. Smith, Western Forest Products Laboratory, Vancouver, B.C., and A. Ofosu-Asiedu, Forest Products Research Institute, Univ. P.O. Box 63, Kumasi, Ghana.

SILVICULTURE

Containerized Seedlings: Relation between Container Size and Production Period.—The principal biological advantage of container planting is that seedlings can be planted with an undisturbed and undamaged root system; their chances for survival and successful establishment are thus increased. This, associated with the possibility of large gains in planting productivity, has promoted interest in the use of containerized seedlings as an alternative regeneration technique. In practice, considerations of bulk and weight limit the container size that can be conveniently and economically employed for large-scale reforestation. As a result, most containers used operationally have been characterized by small soil volumes. In Ontario, for example, a 9/16-inch-diameter x 3-inch-long (14 x 76 mm) plastic tube has been standard since 1966, some 90 million having been planted to 1971 (Reese, Can. Forest. Serv., Inform. Rep. DPC-X-2, 1971). A ¾-inch (19 mm) variant of the same tube has been used in Alberta.

For economic reasons, a rapid growth rate during the short nursery phase is important: the quicker a seedling can be grown to plantable size, the cheaper is the product and the more efficient the use of greenhouse and nursery facilities. It has been shown, however, that tubes of the foregoing dimensions may severely restrict seedling growth during rearing, leading to a significant loss of growth potential after 12–15 weeks from sowing (Endean, Can. Forest. Serv., unpublished data; Scarratt, Tree Planters' Notes, *in press*). For white spruce [*Picea glauca* (Moench) Voss] and jack pine [*Pinus banksiana* Lamb. (= *P. divaricata* (Ait.) Dumont)], increasing tube diameter to 1¼ inches (32 mm) resulted in a marked improvement in growth over 12 weeks (Scarratt, *ibid.*), allowing a seedling of given size to be raised in a shorter period. Since there was a possibility of early growth restriction in tubes of this size also, a study was undertaken in 1971 to determine the effect of container size (diameter) on growth progression rates in the same two species. Four sizes of 3-inch-long plastic tube were compared, namely, those of 9/16–, ¾–, 1¼– and 2-inch (14, 19, 32, 51 mm) diameters.

The study was conducted in a fiber-glass greenhouse, with air temperatures maintained between 21°C and 29°C throughout the experiment. Seedlings were grown in a locally collected, well-decomposed peaty muck (pH = 5.1), supplemented with potassium sulphate and finely ground 20% superphosphate (70 and 1,000 g/m^3 respectively). To promote a more uniform germination rate, the white spruce seed was soaked in tap water at 3°C for 48 hr before sowing. From the 28th day after sowing, the seedlings were fertilized at 2-week intervals with a nutrient solution (RX-15), applied individually by pipettor to ensure equal application rates to each seedling.

The four sizes of container were arranged on a bench in a randomized block design with three replicates, each consisting of a tray of 100 (10 x 10) closely packed seedlings. At 2-week intervals from the 8th to the 18th week from sowing, five seedlings were taken at random from the central 36 (6 x 6) seedlings in each replicate for measurement. The seedlings removed were replaced by fillers of equivalent age and size, marked to avoid removal at subsequent sampling dates.

There was a marked response to container diameter in both species, resulting in diverging patterns of growth (Figs. 1, 2). At the relatively low nutrient levels employed, growth rates were somewhat less than those obtained in earlier studies (Scarratt, *ibid.*), and significant differences in seedling size between tubes began to appear only after the 12th week from sowing. In many instances, differences were visible much earlier, and it was clear that the 9/16– and ¾-inch-diameter tubes had an adverse influence

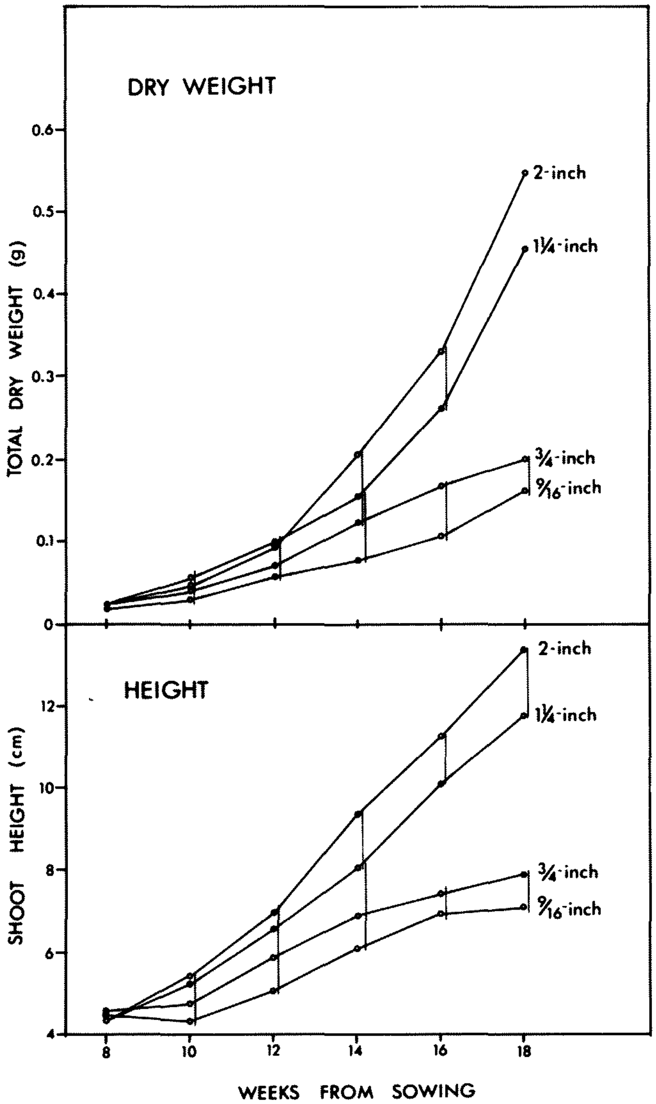

Figure 1. Growth of white spruce seedlings in four sizes (diameters) of plastic tube. Means not bracketed by the same vertical line are significantly different at the p .05 level. (n = 15)

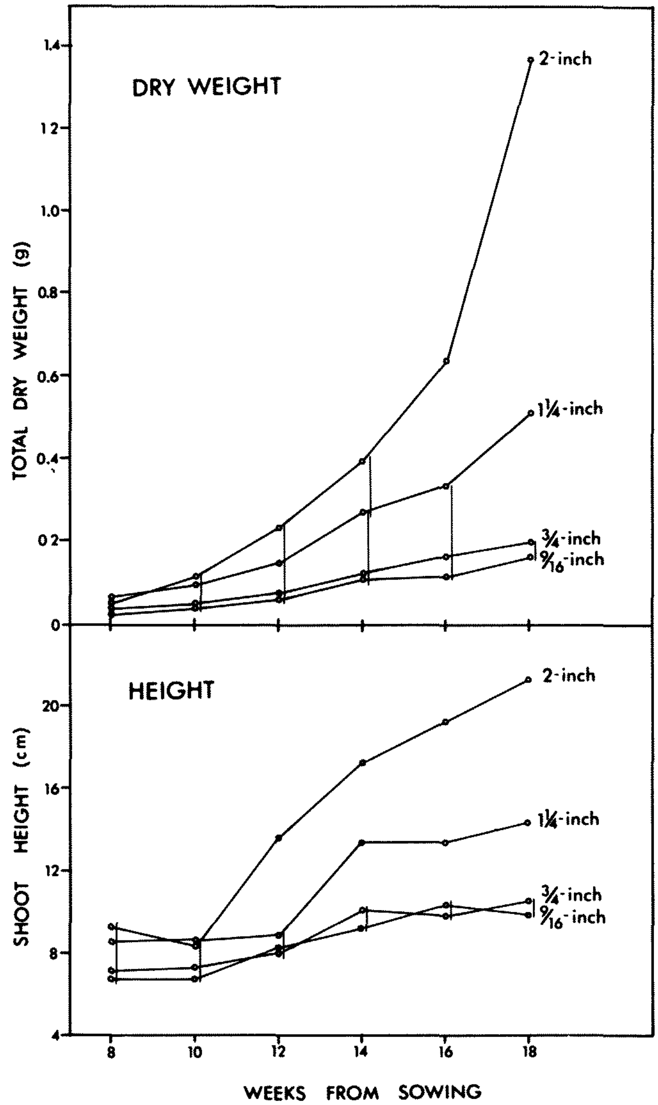

Figure 2. Growth of jack pine seedlings in four sizes (diameters) of plastic tube. Means not bracketed by the same vertical line are significantly different at the p .05 level. (n = 15)

on growth rates from an early age. The data suggest that growth restrictions originated between the 8th and the 10th week after sowing in white spruce and well before the 8th week in jack pine.

The data presented here are for shoot height and total dry weight only; very similar responses were observed for root-collar diameter, side-shoot numbers and dry weights of shoot and root. In general, growth rates were substantially greater in the 1¼- and 2-inch-diameter tubes, and the differential in size between seedlings grown in these and the smaller tubes became progressively larger as the production period was increased. For example, between the 8th and the 18th week, the dry weight increase of white spruce grown in 1¼- and 2-inch-diameter tubes was 3.0 and 3.7 times greater, respectively, than the increase in 9/16-inch tubes. Fourteen weeks after sowing, the average dry weight of white spruce seedlings in 9/16-inch-diameter tubes amounted to only 50% of that for seedlings grown in 1¼-inch tubes and 37% of that for seedlings grown in 2-inch tubes; at 18 weeks the figures were 36% and 30% respectively. Jack pine suffered an even greater loss of growth potential in the 9/16-inch tube (figures comparable with those given for white spruce were 38% and 26% respectively, at 14 weeks; 32% and 12% at 18 weeks). Increasing tube diameter to ¾ inch gave no significant benefit in terms of growth rate or gross seedling size in either species. It is not possible to say from these results whether the observed restriction of growth in the 1¼-inch tube was solely an effect of limited rooting volume or whether lack of aerial growing space was a contributory factor. Certainly, seedlings grown in the 2-inch-diameter tube tended to have more side shoots and their increase in size may be partly due to their enhanced photosynthetic capability.

These data demonstrate severe growth restriction of seedlings grown in 9/16- and ¾-inch-diameter tubes and the considerable loss of growth potential over the course of a normal production period. Owing to the early onset of growth restriction in these tubes, the adoption of a container of larger diameter would achieve faster growth and shorten the production periods. However, while biological considerations might favor the use of 2-inch diameter containers, economic constraints, such as available greenhouse and nursery space, increased costs of transportation and handling, etc., are likely to limit the size of container used operationally. Consequently, for the production of white spruce and jack pine container planting stock with a shoot length of 4–5 inches (10–12 cm), the best compromise would be a container of approximately 1¼-inch diameter.—J.B. Scarratt, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

The Effects of Site Preparation on Summer Soil Temperatures in Spruce-Fir Cutovers in the British Columbia Interior.— Few studies have mentioned the potentially beneficial effects of site preparation on soil temperature regimes. However, indirect evidence suggests that, in northerly or high elevation areas where soil temperatures are relatively low and moisutre is usually adequate, increases in soil temperature may be beneficial to forest regeneration. For example, Babalola *et al.* (Plant Physiol. 43: 515–521, 1968) found that net photosynthesis of *Pinus radiata* seedlings increased with soil temperature up to 26.7°C. Bowen (Aust. J. Soil Res. 8: 31–42, 1970) also observed beneficial effects to *P. radiata* seedlings from increasing soil temperature. He reported that total root length of 3-week-old seedlings was doubled and phosphate uptake was considerably increased by raising the soil tsmperature from 15 to 25°C. Chalupa and Fraser (Can. J. Bot. 46: 65–69, 1968) found that white spruce seedlings produced a finer, more fibrous root system and a lower shoot-root ratio at higher soil temperature than at lower ones, although total seedling weight was inversely correlated to soil temperature. The present study examines the effects of site preparation on summer soil temperatures within the rooting zone of planted seedlings.

The study was carried out in white spruce [*Picea glauca* (Moench) Voss]/alpine fir [*Abies lasiocarpa* (Hook) Nutt.] cutovers in the Montane Transition Section (Rowe, Can. Dept. North. Affairs and Nat'l. Res., For., Br., Bull. 123, 1959) 40 miles (1.6 kilometers) northeast of Prince George, British Columbia at Lat. 54°10'. Plots were established on each of three typical sites characterized by differences in soil texture: fine sand, silt loam and clay loam.

Three treatments were applied to the study sites: scalping (brush and duff removed), clearing (brush removed, duff left intact) and control (brush and duff left intact). Heavy slash was manually removed from all plots. Scalping was done by a bulldozer with an angled blade, and clearing was accomplished with a brush cutter, followed by herbicide treatment.

Three temperature sensors (germanium diodes) were installed at a depth of 5 cm (2 inches) in each treatment plot on each of the three study sites. Sensors were located at points judged to be representative of the plot. Since duff thickness was generally less than 5 cm on all sites, all sensors were located in mineral soil, regardless of surface treatment. Temperatures were monitored at additional depths on the silt loam sites where sensors were also installed at depths of 2 cm (.86 inch) (in the humus layer), 11 and 23 cm (4.9 and 10.0 inches). Temperature readings were taken with a meter at approximately weekly intervals from 6 July to 23 September. Readings were taken between 1400 and 1600 hr and, on one occasion (29 July), every 2 hr for a 24-hr period. The diurnal trend indicated that the readings taken at 5 cm between 1400 and 1600 hr closely approximated daily temperature maxima for that depth. Comparisons among means were tested for significance by Tukey's HSD procedure.

Soil temperature on all sites, regardless of treatment, increased rapidly through the first half of July, remained fairly constant to mid-August, then decreased for the duration of the study period. On the silt loam site, the daily maximum temperature at 5 cm on the control plot remained at about 17°C from 20 July to 10 August (Fig. 1). An almost identical seasonal trend and mid-summer temperature plateau was recorded on the control plot on the clay loam site. The control plot on the drier and less brushy sand site reached a mid-summer plateau of about 20°C at the 5 cm depth.

Brush removal (clearing) resulted in a 1- to 2-deg increase for most of the study period at the 5 cm depth on the silt loam site (Fig. 1). This difference, although consistent, is not statistically significant (5% level). The same treatment led to temperature increases of as much as 4 deg on the clay loam site (critical difference at the 5% level = 2.97 deg), while the removal of the sparse brush on the sand site had virtually no effect on soil temperature at the 5 cm depth.

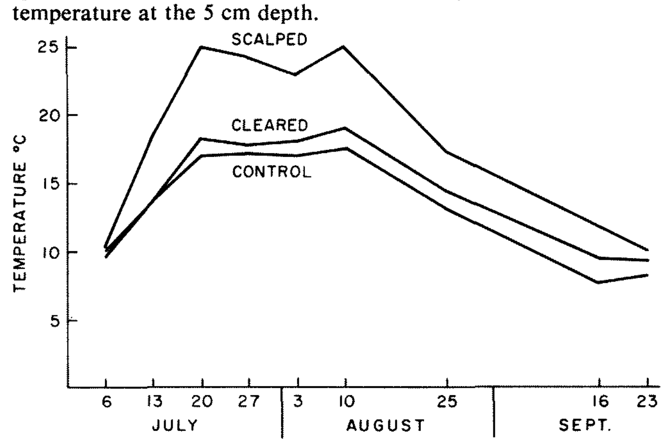

Figure 1. Seasonal march of maximum soil temperature at the 5 cm depth on the silt loam site.

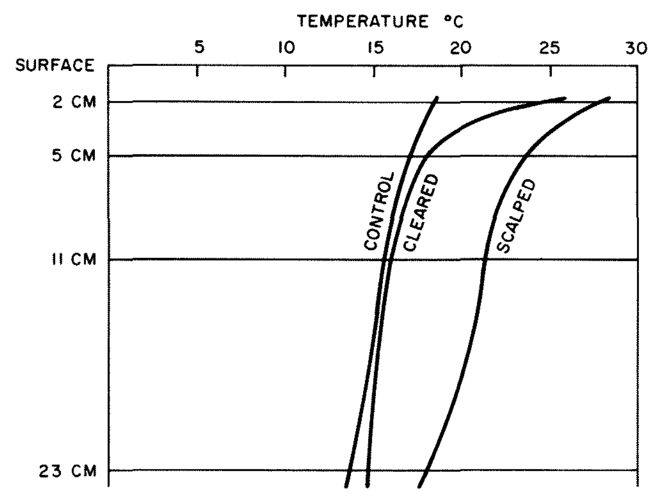

Figure 2. Profile of the average maximum soil temperature from 30 July to 10 August on the silt loam site.

A marked increase in daily maximum temperature at 5 cm was noted on all scalped plots. The 5 cm maximum temperature for the mid-summer period was raised about 5 deg on the sand site and 6–8 deg on the silt loam (Fig. 1) and clay loam sites, bringing all plots to a plateau of 24–25°C. These temperature increases were statistically significant in all cases.

Data obtained over a 24-hr period on the silt loam site indicate, at least for the 5 cm depth, that temperature increases brought about by scalping prevail throughout the diurnal cycle.

The maximum temperature on the scalped plot was 7 deg over that on the control plot, and the minimum on the scalped plot remained 2 deg above that on the control plot.

Temperatures obtained between 1400 and 1600 hrs on the four sampling dates from 20 July to 10 August on the silt loam site were averaged for each depth. These data are presented in Fig. 2 which shows that the soil temperature increase effected by site preparation, particularly by scalping, was manifested at least as deep as 23 cm on this site.

Results of this study show that increased soil temperatures within the rooting zone for forest regeneration follow mechanical site preparation and persist at least through the subsequent summer. The fact that, under conditions of the study, more of the increase is due to duff removal than brush removal, suggests that the increased summer soil temperatures will prevail for several seasons. Work done elsewhere on the effect of soil temperature on seedling physiology and development suggests the temperature changes observed in this study are biologically significant—R.C. Dobbs and R.G. McMinn, Pacific Forest Research Centre, Victoria, B.C.

Height Growth of White Spruce Transplanted from BC/CFS Styroblocks.—At the Petawawa Forest Experiment Station, seedlings are being raised in BC/CFS Styroblocks (Matthews, Dep. Environ. Inf. Rep. BC-X-58, 1971) in conditions which provide accelerated rates of growth. The system is used to provide experimental stock for tree improvement research (Pollard and Teich, Bi-Mon. Res. Notes 28:19-20, 1972). In this program, seedlings are often transplanted from Styroblock plug moulds to plastic pots or nursery beds. In the research reported here, it was found that seedlings could be kept in Styroblocks to ages 3–13 weeks before transplanting without affecting subsequent height growth in the same season. However, height growth declined slightly if the seedlings were kept in the moulds beyond age 13 weeks.

White spruce [*Picea glauca* (Moench) Voss] seed of local origin was sown in the BC/CFS Styroblock 2 (40 cc per cavity, 2.7 cm spacing — 2.44 cubic inches, 1.1 inches). At weekly intervals (seedling age 3–15 weeks) 20 seedlings were transplanted to 300 ml plastic pots. A 3:1 mixture of peat and vermiculite was used in both Styroblocks and pots. The seedlings were grown in a greenhouse (16 hr photoperiod, 20–30°C) and were watered four times daily by an automatic nutrient feed system (Pollard, Can. Forest. Serv. Inf. Rep. PS-X-28, 1971). Height of all seedlings was measured weekly until they were 18 weeks old, at which time most of the seedlings had set terminal buds.

Table 1 shows the mean height for every second week of transplanting and measuring. Under these conditions, the seedlings may be transplanted between ages 3–13 weeks with no appreciable effect on subsequent height growth. Even those seedlings which were removed from the Styroblock in their first 6 weeks – before their root systems had formed a compact plug in the mould – were unaffected by transplanting. When 13 weeks old, shoots and roots of seedlings in the Styroblocks were very crowded and their branch and leader growth declined. Poor form and reduced growth of seedlings transplanted after this time are apparent (Fig. 1). Seedlings could probably be held in Styroblocks for longer periods in environments which do not provide accelerated rates of growth.

TABLE 1

Mean height (cm) of seedlings transplanted at ages 3-15 weeks. Standard deviation at 18 weeks = $< \pm 3.5$ cm.

Age when measured (weeks)	Age when transplanted (weeks)						
	3	5	7	9	11	13	15
3	2						
5	2	2					
7	3	4	4				
9	4	5	5	5			
11	7	7	7	6	8		
13	10	10	10	10	11	11	
15	14	14	15	14	14	14	13
17	17	17	18	18	18	17	15
18	18	18	19	19	19	18	16

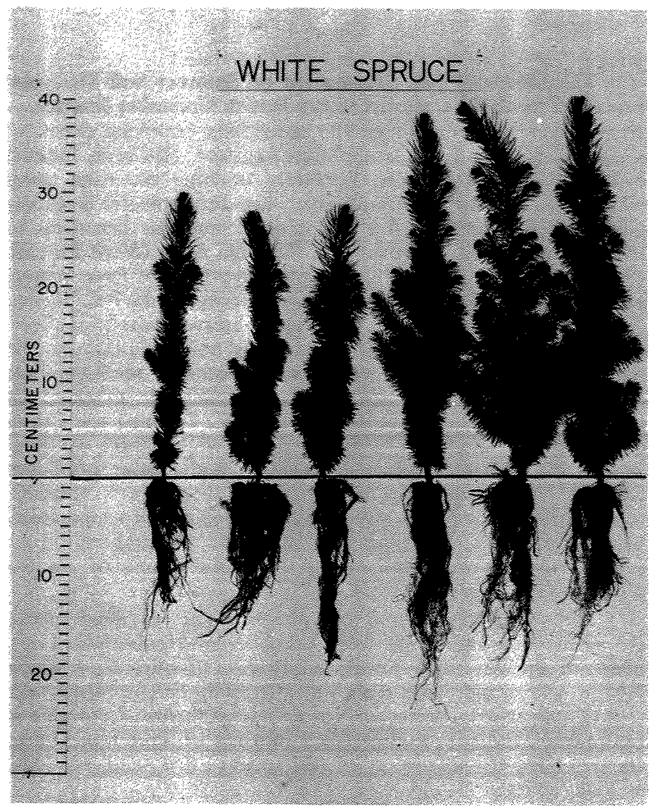

Figure 1. Seedlings transplanted at age 15 weeks (left) and age 9 weeks (right) showing poor branch development on former. Age when photographed: 22 weeks.

The wide latitude of age at which seedlings may be transplanted provides flexibility in designing experiments and constitutes a further advantage to this system of growing research stock. Although this system is used at Petawawa on a research scale, the results may have a broader interest to those growing seedlings in Styroblocks for reforestation purposes.—K.T. Logan, Petawawa Forest Experiment Station, Chalk River, Ont.

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