Figure 1. Tree-branch combinations with the same standard error of the mean egg masses per 1 000 g (transformed $\log_e$ [(count + 1) per kg] as 20-tree, 2-branch samples).

10-in. (25-cm) sample branch ——————————
18-in. (46-cm) sample branch —— — —— — —
longitudinal half sample branch ------------------

The 10-in. (25-cm) branch tips provide good sample branch sizes, as they yield comparable results at all crown levels. However, they are subject to zero counts at low population levels and to severe defoliation, which is usually worse at the ends of branches. An 18-in. (46-cm) branch sample from either of the upper two crown levels is probably better; it is representative of at least the upper two-thirds of the crown. The longitudinal half branch is generally to be avoided, as it usually requires climbing or felling trees; the line-throwing gun branch sampler (Collis and Harris, Can. J. Forest Res. 3:149-154, 1973) is not efficient in clipping off branches at their bases. Also, as Carolin and Coulter (1972) point out, the greatest effort in such sampling is examining foliage, which is greatest on whole or half branches.

Similar factors affect the choice of crown level. Lower-crown samples can be the largest and most time-consuming units to examine, compounding the disadvantages of the half branch. Samples from the upper crown or midcrown can be utilized if the line-gun sampler is used. A midcrown sample is suggested because it yields numbers intermediate between those from upper and lower crown levels and is usually practical to sample, being reachable by pole pruners in the case of small trees, or by the line-gun sampler.

The number of sample trees and branches examined is usually limited by available time and manpower. The sample combination used is a survey manager's decision, depending upon the mechanics of sampling and the men and equipment available. With the line-gun and sampler method of retrieving branches from the upper crown, it is efficient to take more branches from fewer trees. The data show that a sample with reliability comparable to that of past years' samples, two 18-in. (46-cm) branches from each of 20 trees at a sample point, could be reduced to around 15 trees if three branches per tree were taken, or to 10 trees if five were taken (Fig. 1).

In this study, only data from 1 year were examined, when populations were high and still increasing. More confidence in the design would be achieved by testing new data at different times in the development of an infestation.

SILVICULTURE

Root Forms in Habitats with Heavy Shrub Competition.—Most mature forests in the central and northern interior of British Columbia are composed of white spruce (*Picea glauca* [Moench] Voss) and alpine fir (*Abies lasiocarpa* [Hook.] Nutt.) in varying proportions. The forest inventory of British Columbia shows that this complex covers 52 000 km² (13 million acres), or 7.5% of the total of 710 000 km² (175 million acres) of productive forest land.

On dry sites, the origin of the white spruce-alpine fir forests can be traced to fires and subsequent lodgepole pine or aspen cover under which spruce and fir regenerated. On wet sites, the uneven-aged, understocked character of the forest and absence of charcoal in the soil suggest that these forests have approached the final (climax) stage of their succession. A dense layer of shrubs is usually present and regeneration of spruce and infilling of open spaces is practically nonexistent.

Root system morphology of white spruce and its relationship with soil texture and soil moisture in northern Alberta were described by Wagg (Can. Dep. For. Rural Dev. Publ. 1195, 1967). This note has been written because, on wet sites, in stands with heavy shrub competition, up to 40% of the root system forms of white spruce did not fall into the described categories.

The data were obtained from 1962 to 1973, during studies of root growth and its influence on survival of spruce seedlings in the Crooked River area of the Prince George Forest District of British Columbia. About 300 root systems of juvenile spruce, almost equally distributed on dry, moist, and wet sites, were hydraulically excavated, and root systems of about 60 mature, wind-thrown trees were plotted after the soil was cleaned from the roots. The ages of a few of the largest primary
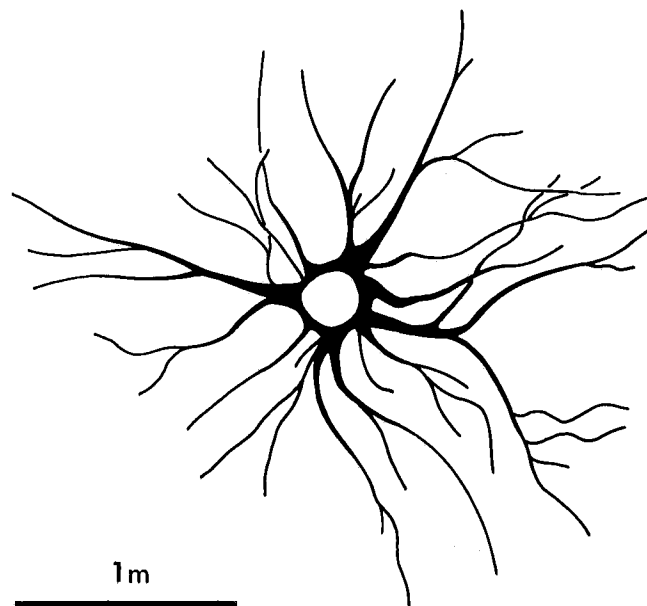

1 m

Figure 1. Root pattern on dry sites with no shrub competition. The tree originated on mineral soil. The root system forms a simple shallow disk. The roots are straight and well branched and radiate in all directions. Grafting is rare.
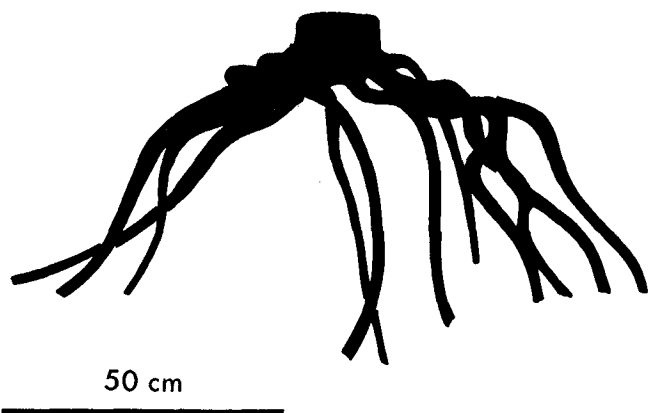
27

50 cm

Figure 2.   Root pattern on wet sites, an open-grown stand with heavy shrub competition. The tree is growing on a rock. Long, poorly branched roots form a simple buttressed root system. Grafting is very common.
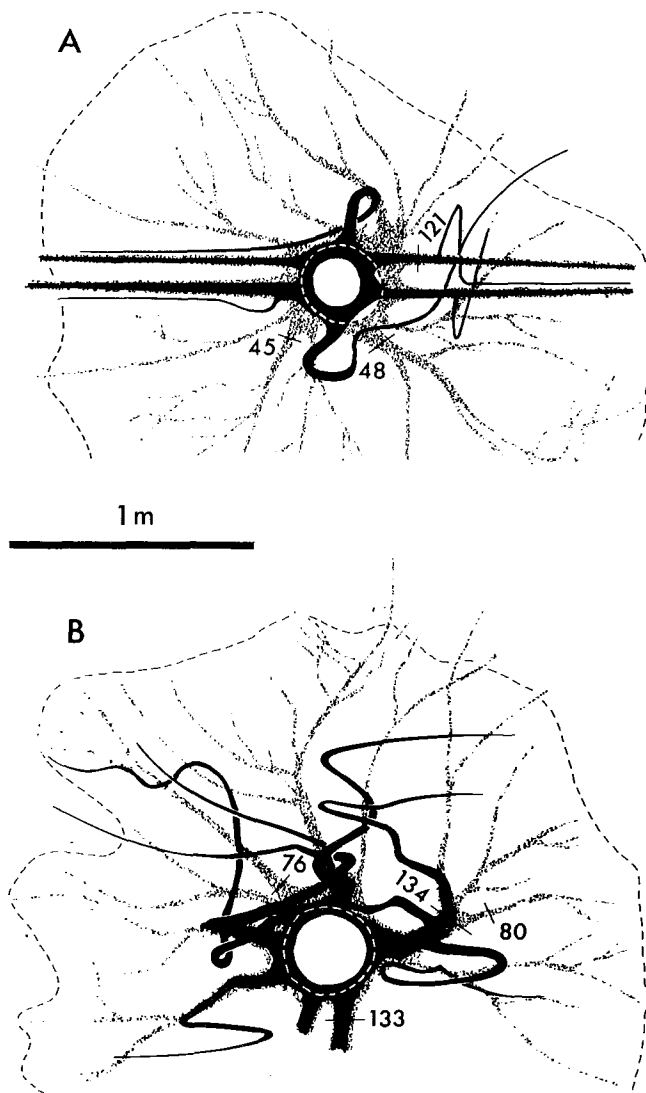

A

1 m

B

Figure 3.   Root pattern on wet sites, an open-grown stand with

heavy shrub competition. Tree A originated on a log, tree B on a stump. With progressing decay, the weight of the trees compressed the original root systems (black roots). A distinct layer of new roots (gray) developed immediately below the original roots in the soil. Grafting is frequent. (The numbers are ages of the roots.)
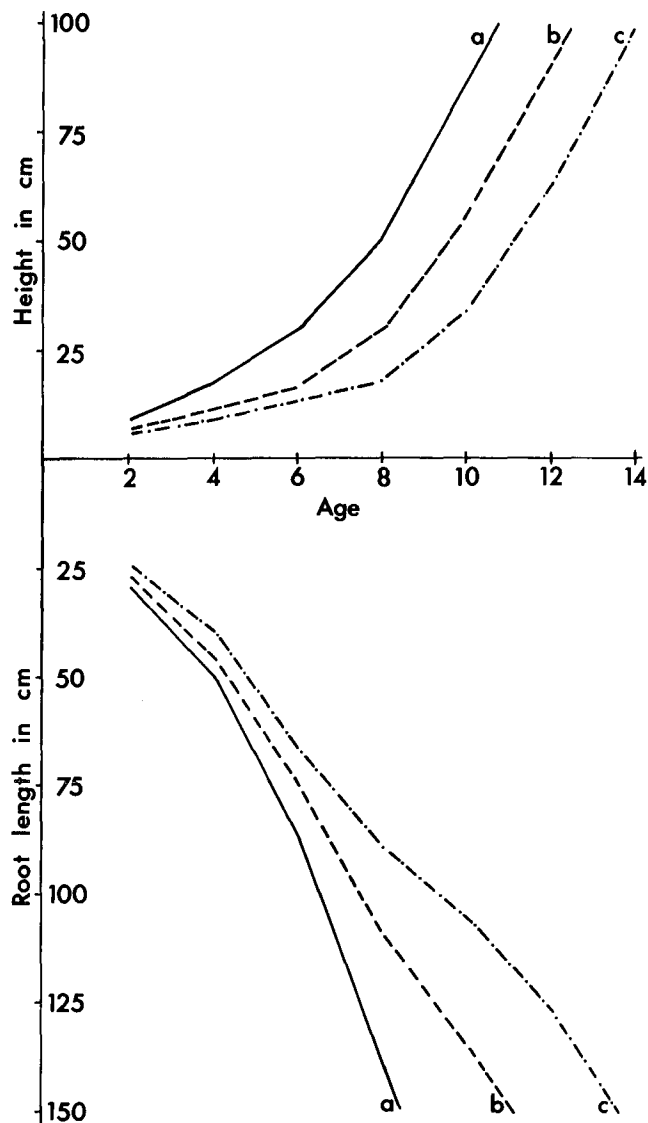

Figure 4.   Height and length of longest laterals. Alluvial site, over-mature spruce stand, wind-damaged 1931, logged 1952, seeded 1954. (a) Unrestricted root systems on mineral soil under light shrub competition. (b) Stilt root systems on decaying logs and stumps and overturned old root systems. (c) Buttress root systems on moss-covered rocks. Regeneration failed under heavy shrub competition.

and secondary roots were estimated from ring counts.

A typical root system of white spruce in dry habitats on sandy or loamy soils consisted of three to six large, almost straight, lateral roots extending radially in different directions (Fig. 1). A small taproot was often present. Unless the soil was shallow over bedrock or hardpan, restriction of the root system was not evident and grafting of roots was

not common. Most large roots were confined to the upper 20 cm of the soil, but small roots usually penetrated to a depth of 80 cm or more. All lateral roots originated at the same level, and the root system typically attained a shallow, wide-spreading form.

In addition to root forms described by Wagg, in wet habitats subject to heavy shrub competition, many root systems had irregular and contorted forms and usually showed complex forking and grafting. They can be classed into two groups, depending on their origin:

1) buttress root systems of seedlings that originated on a rock;
2) stilt root systems of seedlings that originated on decaying wood.

Buttress root system forms were restricted to special habitats, such as lower parts of steep slopes and along the creeks, where boulders occurred. Their shapes were given by the shapes of the supporting rocks (Fig. 2). Because the soil was lacking, the roots developed just below the layer of moss. The lack of soil apparently promoted the formation of long, thin roots, which embraced the boulder (Fig. 2). Root contacts were frequent and grafting was common. Buttress roots, when exposed and subjected to bending, were often thick, but the weight of the tree was carried by the rock. The critical period for tree establishment depended on the size of the rock, and was rarely longer than 8 years. By this time the roots reached into the mineral soil below the boulder.

Stilt root system forms were frequent on Alluvial and Oplopanax sites, where selection by shrub competition played a significant role in tree regeneration. They developed where the tree originated on a decomposing stump, log, or overturned root system of an old tree. The form of the root system also resembled the shape of the original mound. If the decomposition of the mound progressed slowly and the roots thickened, they supported the tree somewhat above the ground level after the mound had disintegrated. If the decomposition progressed rapidly, the weight of the tree distorted the thin, long roots and they attained twisted, knotty shapes (Fig. 3, A and B). New roots, developed from or immediately below these twisted roots, produced a dense root system. As the roots increased in size, they grafted at many points of contact and formed a platelike mass. Usually the largest twisted root was a direct continuation of the stem and was probably of taproot origin.

Frequency of buttress forms of root systems in wet habitats in which boulders occur and frequency of stilt root systems, especially in distorted form, on wet Alluvial and Oplopanax sites, indicated that shrub competition, through elimination of seedlings from shaded mineral soil, favored regeneration on elevated surfaces where light conditions were better and smothering of seedling by leaves was less frequent. Trees, especially in young stands, often grew in rows on decaying logs. It is also probable that the platelike mass of roots fused together provides better stability on wet soils than a simple root system composed of individual roots.

While survival was usually good on the elevated surfaces, the height growth was initially slow. However, it improved rapidly as soon as roots penetrated into the mineral soil (Fig. 4).—S. Eis, Pacific Forest Research Centre, Victoria, B.C.

Photoperiodic Induction of Free Growth in Juvenile White Spruce and Black Spruce.—Recent studies have identified two modes of growth in many northern coniferous species (Jablanczy, Bi-mon. Res. Notes 27:10, 1971; Pollard and Logan, Can. J. Forest Res. 4:308-311, 1974). In mature conifers, potential shoot growth is predetermined by the number of needle priomordia laid down in the developing bud. Juvenile conifers have the possibility of a second mode of growth, which has been termed "free growth," in which priomordia initiated during bud burst are expanded as needles in the current year rather than accumulated within the developing bud. This note examines the influence of photoperiod on the fate of primordia initiated during bud flush and describes some morphological differences between needles originating in the two modes of growth.

White spruce (*Picea glauca* [Moench] Voss) and black spruce (*Picea mariana* [Mill.] B.S.P.) seedlings were grown from seed in 300 ml styrofoam cups (three seedlings per cup). The seed source was Swastika, Ont. (48° 10'N, 80° 10'W). Seedlings were grown for 11 weeks in the Petawawa system for growth acceleration (Logan and Pollard, Can. For. Serv. Inf. Rep. PS-X-62, 1976) and then transferred to a short photoperiod (8 h) for 10 weeks to induce bud formation. After 8 weeks of chilling in darkness at 5°C to break dormancy, the seedlings were divided into seven groups of 20 seedlings each, each group having the same average height. Five groups were placed in a 16-h photoperiod for 2, 4, 6, 8, and 10 weeks respectively and then moved to an 8-h photoperiod until dormancy was induced. A control group was flushed in an 8-h photoperiod, assumed to inhibit free growth. To confirm this assumption, primordia were counted in the buds of one group and compared with the number of needles flushed in the control group. Throughout the experiment, seedlings received a nutrient feed four times daily, and day/night temperature was maintained at 20/15°C. Height was measured weekly from bud burst until growth ceased. Needles were then counted and numbers in excess of those flushed in the 8-h control group were considered to have been formed in free growth.

After bud burst, shoots of all seedlings grew until the sixth week, when treatment differences emerged. A sharp decline in growth, indicating the onset of dormancy, was apparent after 6 weeks in three of the groups: the 8-h control seedlings, and seedlings that had spent only 2 or 4 weeks in the long (16-h) photoperiod (Figs. 1 and 2). Seedlings spending longer periods in the 16-h photoperiod continued to grow
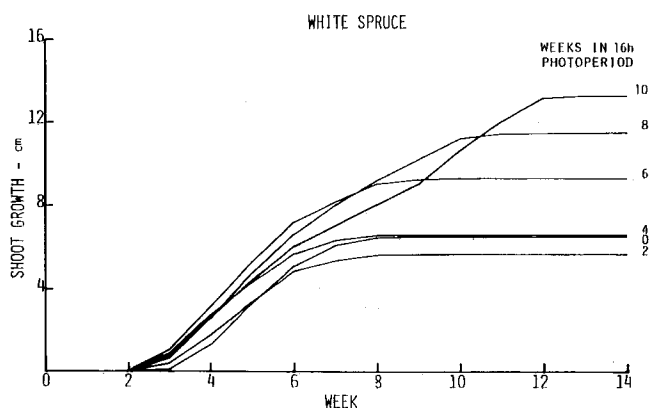
Figure 1.   Weekly shoot growth of white spruce seedlings flushed for 0-10 weeks in a 16-h photoperiod and then transferred to a 8-h photoperiod.
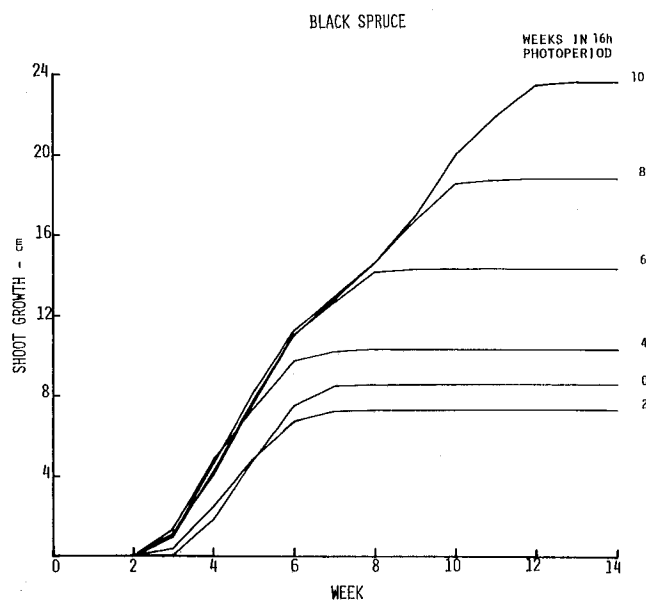
Figure 2.   Weekly shoot growth of black spruce seedlings flushed for 0-10 weeks in a 16-h photoperiod and then transferred to an 8-h photoperiod.