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# bi-monthly research notes

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*Photoperiodic Induction on Free Growth in Juvenile White  
Spruce and Black Spruce*

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## ENTOMOLOGY

**Egg-sampling for Western Spruce Budworm on Douglas-fir.**— Western spruce budworm, *Choristoneura occidentalis* Freeman, is a major pest of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) in some British Columbia forests. Infestations occur periodically, and successive years of heavy defoliation will weaken and even kill the trees. Thus reliable sampling surveys are important to measure and record annual population fluctuations.

Limited resources dictate that simple, inexpensive sampling methods be developed. The egg stage of the budworm is a good one to sample because 1) it precedes the destructive period of the budworm (older larvae) by up to 9 months, giving ample time for the planning of future survey and control operations, 2) egg masses are deposited on needles, which are relatively easy to collect and examine in a quantitative manner, and 3) this stage is a stable one, enabling handling over many weeks without significant change.

Methods already investigated for sampling spruce budworm eggs involve a choice of branches, or parts of branches, from different locations within the crown. McKnight (USDA Forest Serv. Res. Note RM-122, 1968) found that the density of egg masses per 100 in.<sup>2</sup> (645 cm.<sup>2</sup>) of foliage on a midcrown, 24-in. (61cm) branch-tip sample gave an estimate similar to that found with conventional half-branch samples. Carolin and Coulter (USDA Forest Serv. Res. Pap. PNW-149, 1972) developed a technique using the latter but did not test the reliability of smaller branch sizes.

In the current study, smaller part-branches collected from three crown levels were compared with half-branch samples to determine if the former could be used to reduce both collection and examination costs for the purpose of comparing year-to-year population levels. Samples were collected from Gingerbread Creek in the Lillooet River valley, about 24 km northwest of Pemberton, where populations of western spruce budworm had risen to outbreak levels. In October 1970, 20 trees averaging 20 cm dbh and 17 m in height were selected in each of four defoliation categories — from a stand of 60-year-old Douglas-fir on a southwest aspect at elevation 760 m.

These categories were as follows: nil or trace (some defoliation may be detectable on new foliage); light (noticeable defoliation, but only on new growth; no significant top defoliation); medium (upper quarter of crown partially defoliated); moderately heavy (upper quarter to half of crown 50% or more defoliated, obvious defoliation over remainder of tree; trees defoliated to point where there was virtually no foliage on entire tree were excluded from sample).

Two whole branches were taken from each of the upper, middle, and lower crown levels; hatched-egg masses, subsampled so as to record separately those from the 10-in. (25-cm) and 18-in. (46-cm) apical portions and a longitudinal half of each branch, were removed and counted by two successive examiners. The numbers of masses per 1,000 in.<sup>2</sup> (6 452 cm<sup>2</sup>) and per kg (fresh weight) of foliage were determined; foliage area was calculated by assuming the branch tips and half branches to be triangular, and multiplying the length by half the width at the widest point. Only branches with little or no defoliation were selected, or the measurement was made after discarding heavily defoliated tip portions. Fresh foliage weight included all parts of the sample branch-tips but omitted the primary branch axis of the longitudinal half branches.

The data were compared by analysis of variance, repeated measures design (Winer, Statistical principals in experimental design, McGraw-Hill, New York, 1971). Since the populations were asymmetrically distributed and showed heterogeneity of variance, the data were transformed. A logarithmic transformation,  $\log_e [(count + 1) \text{ per } 1,000 \text{ in.}^2 \text{ or per kg}]$ , stabilized the variance better than a square root transformation.

The results indicated no differences in numbers of egg masses per 1,000 in.<sup>2</sup> or per kg among the four defoliation classes used; therefore, defoliation level was not considered further in the analysis. There were significant between-tree, between-crown-level and between-sample-branch size differences in transformed egg mass counts (Table 1). Comparison by the Newman-Keuls test of the transformed means averaged across defoliation classes (Table 1) (Miller, Simultaneous statistical inference, McGraw-Hill, New York, 1966) showed no significant differences in the numbers of egg masses per unit of sample within different crown levels using the 10-in. (25-cm) sample size. The other two sample-branch sizes also yielded results similar to each other, except that the 18-in. (46-cm) samples from the lower crown contained significantly fewer eggs than mid- and uppercrown samples, and longitudinal half-branch samples (area basis only) had significantly larger numbers at midcrown than at the other two levels.

The results from different sample-branch sizes within each crown level were compared, and they showed that all three sample branches differed significantly from one another at the lower and middle crown levels but, at the upper crown level, only the 10-in. (25-cm) sample size differed from the others.

The foregoing suggests that no single type of sample alone could provide an absolute estimate of total populations on the tree. For year-to-year-trend comparisons, such an estimate is not necessary, but the same type of sample must be taken each year. A sample somewhat representative of the whole population is an asset, and it is important to minimize sampling effort without sacrificing reliability.

TABLE 1

Log-transformed mean numbers of western spruce budworm egg masses per 1 000 g and 1,000 in.<sup>2</sup> (6 452 cm<sup>2</sup>) of Douglas-fir foliage, Pemberton, 1970 (data transformed  $\log_e [(count + 1) \text{ per } 1,000 \text{ in.}^2 \text{ and per } 1 \text{ kg}]$  comparing sample-branch sizes and crown levels by the Newman-Keuls Test). (Two means within each row or column followed by the same letter are not significantly different at the .05 level.)

Crown level	Branch size					
	Per 1 000 g of foliage			Per 1,000 in. <sup>2</sup> of foliage		
	Longitudinal ½ branch	18" branch tip	10" branch tip	Longitudinal ½ branch	18" branch tip	10" branch tip
Upper	2.027 <sup>od</sup>	1.585 <sup>bd</sup>	-0.059 <sup>a</sup>	0.758 <sup>cd</sup>	0.395 <sup>bd</sup>	-1.458 <sup>a</sup>
Middle	2.731 <sup>c</sup>	1.646 <sup>b</sup>	-0.395 <sup>a</sup>	1.406	0.454 <sup>b</sup>	-1.786 <sup>a</sup>
Lower	2.095 <sup>c</sup>	0.590	-0.227 <sup>a</sup>	0.468 <sup>c</sup>	-0.924	-1.903 <sup>a</sup>

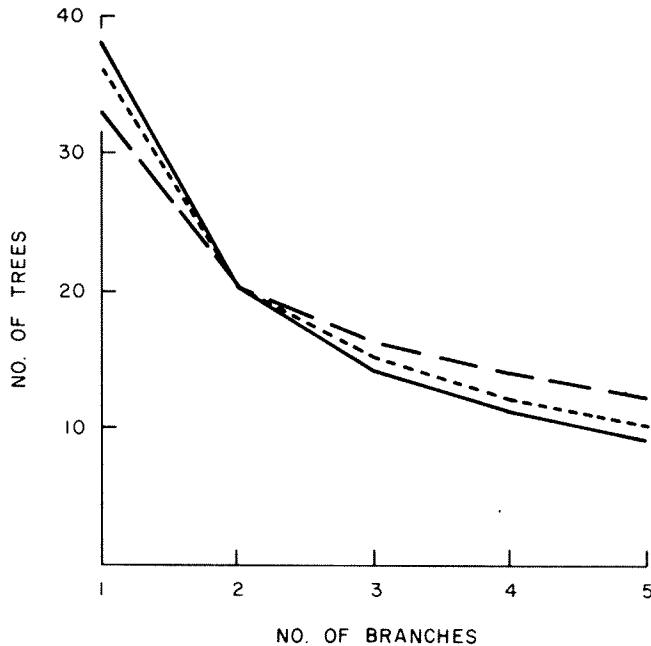


Figure 1. Tree-branch combinations with the same standard error of the mean egg masses per 1 000 g (transformed  $\log_e[(\text{count} + 1) \text{ per kg}]$  as 20-tree, 2-branch samples).

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.

Dr. R.R. Davidson, of the University of Victoria Mathematics Department, and D.W. Whitney, formerly of the Pacific Forest Research Centre Biometrics Unit, provided statistical advice and services; the former scientist's work was under a statistical consultation contract with the Centre.—J.W.E. Harris, Pacific Forest Research Centre, Victoria, B.C.

## 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 km<sup>2</sup> (13 million acres), or 7.5% of the total of 710 000 km<sup>2</sup> (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

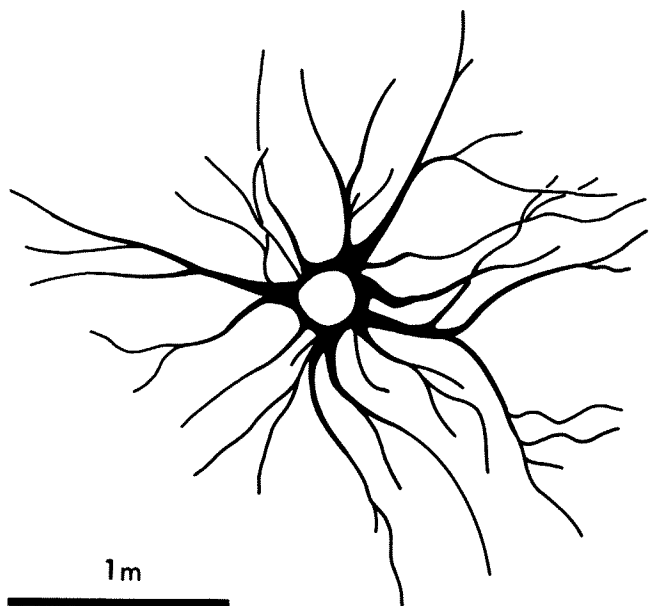


Figure 1. Root pattern on dry sites with no shrub competition. The tree originated on mineral soil. The root system forms a simple shallow disk. The roots are straight and well branched and radiate in all directions. Grafting is rare.

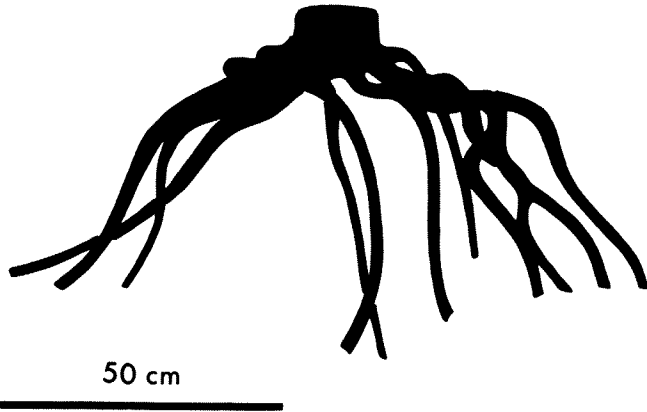


Figure 2. Root pattern on wet sites, an open-grown stand with heavy shrub competition. The tree is growing on a rock. Long, poorly branched roots form a simple buttressed root system. Grafting is very common.

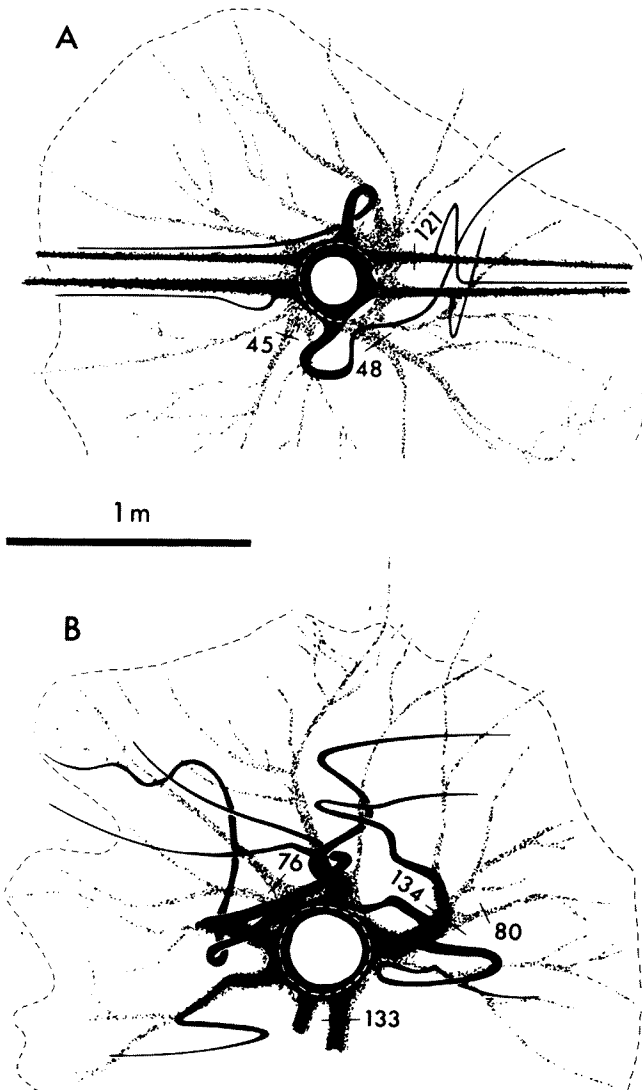


Figure 3. Root pattern on wet sites, an open-grown stand with

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.)

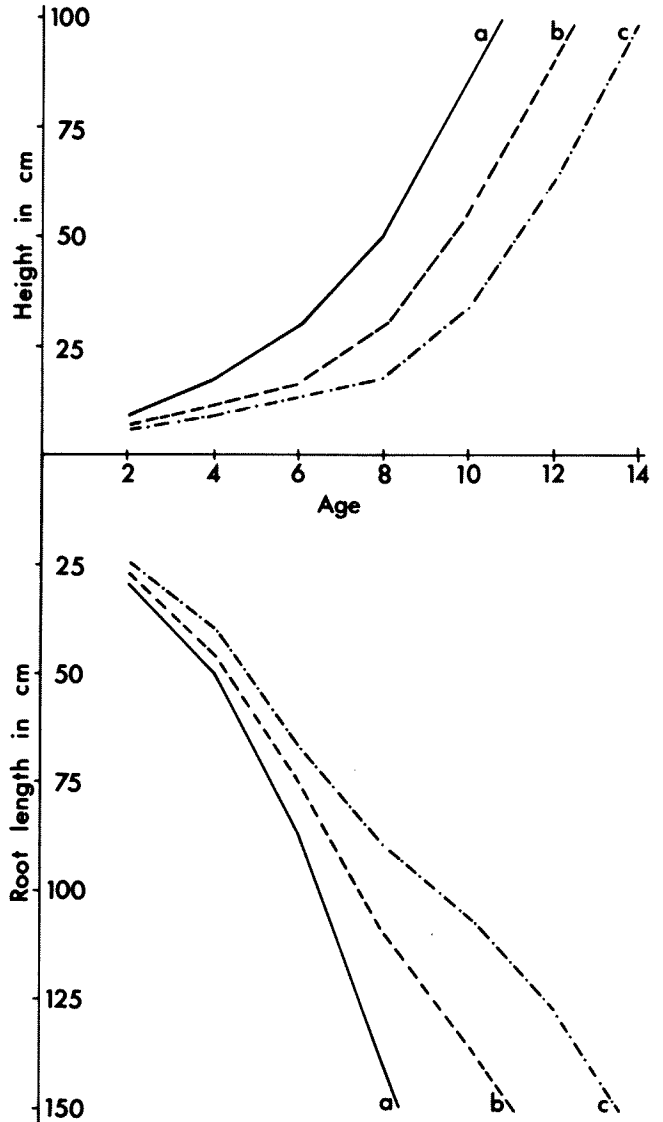


Figure 4. Height and length of longest laterals. Alluvial site, over-mature spruce stand, wind-damaged 1931, logged 1952, seeded 1954. (a) Unrestricted root systems on mineral soil under light shrub competition. (b) Stilt root systems on decaying logs and stumps and overturned old root systems. (c) Buttress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

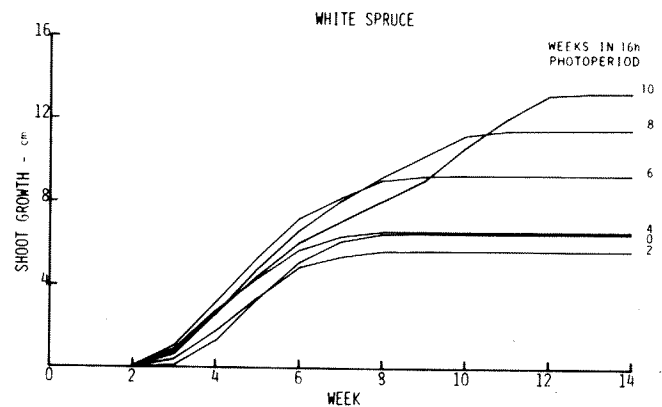


Figure 1. Weekly shoot growth of white spruce seedlings flushed for 0-10 weeks in a 16-h photoperiod and then transferred to a 8-h photoperiod.

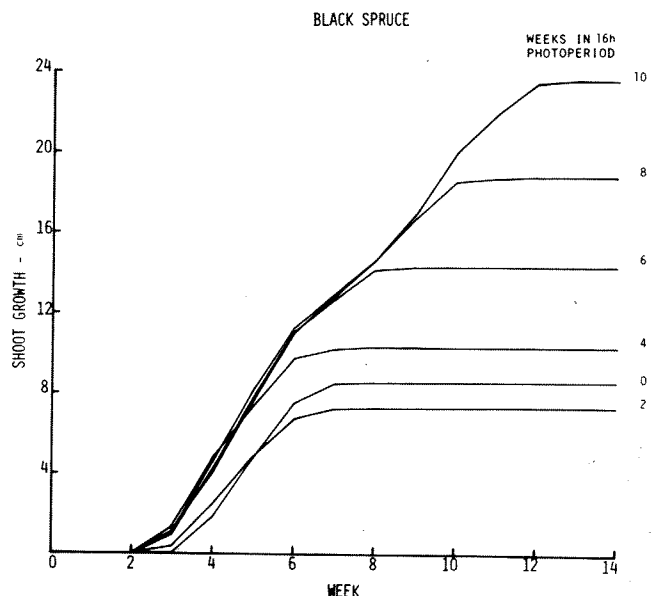


Figure 2. Weekly shoot growth of black spruce seedlings flushed for 0-10 weeks in a 16-h photoperiod and then transferred to an 8-h photoperiod.

beyond the sixth week. Rate of growth of black spruce during this period was twice that of white spruce.

Needle counts revealed those treatments in which free growth had occurred. First, the number of needles on the white and black spruce control seedlings (240 and 326 respectively) flushed in an 8-h photoperiod did not differ significantly from the number of primordia counted in terminal buds at the start of the experiment (236 and 303 respectively). Thus the predetermined embryonic shoot was flushed out in 6 weeks in an 8-h photoperiod without any free growth (Figs. 1 and 2). Similarly, seedlings flushed for 2 or 4 weeks in a long photoperiod did not differ in needle number from the controls (Table 1), indicating that these treatments did not induce free growth. But seedlings that were flushed for 6 to 10 weeks in a 16-h photoperiod did accumulate significant increases in needle complement. It would appear that a minimum period of 6 weeks in a 16-h photoperiod was required for the induction of free growth in white and black spruce seedlings.

TABLE 1

Number of needles\* on shoots of white spruce and black spruce seedlings flushed for 0-10 weeks in a 16-h photoperiod and then transferred to an 8-h photoperiod

Number of weeks in 16-h photoperiod	White spruce	Black spruce
0 (Controls)	240a	326a
2	242a	334a
4	255a	354a
6	293b	423b
8	339c	505c
10	385d	570d

\*Numbers associated by common letters are not significantly different (Duncan's Multiple Range Test,  $p = 0.05$ ).

These results shed some light on the fate of bud-scale primordia when free growth is induced. Pollard (Can. J. Forest Res. 3:589-593, 1973) has shown that primordia initiation in white spruce begins at bud burst; without free growth, these early primordia develop into bud scales. Furthermore, if these early primordia are permitted to develop for 20 days in a short photoperiod, they cannot then be induced to flush out as needles even when returned to a long photoperiod (Pollard and Logan, Proc. 14th Meet. Can. Tree Improv. Assoc., Part 1:137-141, 1975). In this experiment, the early primordia, which formed at bud burst in a long photoperiod, seem to have the option of developing into either bud scales or needles. The option is controlled by photoperiod, not at the time of initiation but several weeks later. The crucial period was between the fourth and sixth weeks of treatment (2 to 4 weeks after bud burst). Given a short photoperiod at this time, dormancy is induced and these initial primordia appear after the sixth week as bud scales on the developing bud; given a long photoperiod, free growth is induced and they are flushed out as free-growth needles.

The changeover from predetermined to free growth could usually be identified on the shoot. Free-growth needles were stouter and longer than predetermined needles and broader at their base as though they were incipient bud scales. In addition, the stem unit length (distance between two successive needles) increased significantly, from 0.31 mm in predetermined growth to 0.39 mm in free growth for white spruce, and from 0.37 mm to 0.48 mm for black spruce. The onset of free growth was also marked by the presence of several lateral shoots.

Shoot growth was reduced during the first 2 weeks of free growth, which coincided with the time of flushing the initial bud-scale primordia, but then returned to a rate of growth approximating that in the predetermined growth phase (Figs. 1 and 2).

Free growth is a juvenile character which is lost when the seedling reaches 5-10 years of age. But during those years, it may confer a considerable advantage on seedling growth. For example, in this experiment seedlings doubled their annual height increment after only 4 weeks of free growth.

The assistance of Dr. D.F.W. Pollard and W. Kean with primordia and needle counts is gratefully acknowledged.—K.T. Logan, Petawawa Forest Experiment Station, Chalk River, Ont.

## ERRATA

In *Some Parasites and Insect Predators of the Blackheaded Budworm in Newfoundland*, which appeared on pages 11 and 12 (vol. 33, no. 2), the following corrections are in order:

1. <sup>2</sup>J.R. Barrow should read <sup>2</sup>J.R. Barron.
2. *Apanteles* sp. nr. *popularis* group<sup>1</sup> should read *Apanteles* n. sp.
3. *Copidosoma deceptor* Miller<sup>5</sup> should read *Copidosoma deceptor* Miller<sup>5</sup> and it is in Encyrtidae, not in Braconidae.
4. *Glypta fumiferana* (Viereck)<sup>2</sup> should read *Glypta fumiferanae* (Viereck)<sup>2</sup>.
5. *Itopectis vesca* Townes<sup>2</sup> should read *Itopectis vesca* Townes<sup>2</sup>.
6. *Propisilomma columbianum* (Ashmead)<sup>4</sup> is in Diapriidae, not in Ichneumonidae.

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