MANAGEMENT OF TREE GROWTH AND
RESEARCH PLANTATIONS

Donald A. Fraser[1]

ABSTRACT.--Reports vegetative growth and reproductive responses in white and black spruce resulting from: control of soil moisture by means of overhead sprinklers, photoperiod by means of incandescent lamps, and thermoperiod by means of heated plastic shelters. Increased lateral branch and diameter growth resulted in white spruce from irrigation(a). Continuous light (b), increased apical growth but no diameter. Raised temperature (c) forced early bud growth as well as early apical growth cessation. (b) plus (c) caused early bud growth and late apical growth cessation. (a) as well as (b) plus (c) resulted in early, more abundant male and female conelet production in white spruce. Root-pruning had an immediate, additional stimulatory effect, but subsequently reduced vigor had deletorious effects on conelet production. The responses in black spruce were similar. Photoperiod and gibberellic acid responses in growth chambers are briefly mentioned.

Understanding the basic ecology, physiology, and genetics of forest trees is essential for manipulating and interpreting the physical and biological factors of the environment. Moisture, nutrients, photoperiod, thermoperiod, and growth-influencing substances are physical factors that may be manipulated. Biological elements include the beneficial presence of nitrogen-fixing organisms in the soil, and the deleterious effect of insects and pathogens.

We conducted experiments to determine what effect these factors had on tree growth and on production of reproductive buds. The experimental work was conducted in special outdoor testing areas and in growth chambers. Although other species were also investigated, chief emphasis was on white (Picea glauca (Moench) Voss) and black spruce (P. mariana (Mill.) BSP.).

[1] Department of Geography, Concordia University, Montreal, Quebec, Canada.

## FIELD EXPERIMENTS

### Methods

In 1956 the Corry Lake Tree Physiology Area was established in Chalk River, Ontario, on a 3-acre site of loamy sand with adequate fertilization. It was designed for progressive plantings of white and black spruce and selected hardwood species for managing environmental factors. Special emphasis was placed on the following factors that might accelerate the production of flower primordia and consequent seed production in commercial plantations.

(1) Soil moisture was regulated with overhead irrigation sprinklers drawing untreated water from Corry Lake. During early stages of plantation establishment, white clover was sown around the young saplings to improve the soil and to limit competition from weeds present in the original field.

(2) Photoperiod was extended with incandescent lamps (Fraser 1966).

(3) Thermoperiod was altered with heated plastic enclosures that extended the frost-free period.

The control was the cleared 6-acre Loon Lake Physiology Area on a loam sand represented by moisture regimes from dry to wet (Fraser 1954). This control area was planted concurrently with the Corry Lake Physiology Area, so that growth under a natural environment could be compared with growth of trees treated to accelerate vegetative and reproductive growth.

Apical as well as diameter growth of leaders and lateral branches were measured periodically from March 21 to August 29, 1969 on 9-year-old white spruce. In addition, the development of reproductive buds was tallied annually for 9 years in four plantations of white spruce and one of black spruce, established in 1956 with 3-year-old seedlings of local provenances as follows:

1. White spruce under natural environment.
2. White spruce under natural light, but irrigated and fertilized.
3. White spruce under continuous light, irrigated, and fertilized.
4. Same as "3" but root-pruned twice in a circle 18 inches from the trunk to an 8-inch depth, when the saplings were 7 and 8 years old.
5. Black spruce under the same conditions as "3" and "4".

## RESULTS AND CONCLUSIONS

### Vegetative Growth Response

Soil Moisture--Apical and diameter growth of white spruce control trees were greatest on the dry site (fig. 1). However, greater lateral branch and diameter growth were found on the irrigated area where adequate moisture and nutrients were provided throughout the season. The influence of the natural range of moisture on radial growth of mature trees was reported earlier (Fraser 1956).

Photoperiod--Continuous light increased apical growth, yet more important was the longer period over which the apical extension took place, for this represented a longer time available for the formation of reproductive buds (fig. 1).

Thermoperiod--Raised temperatures altered the time of the period of apical growth, but did not affect diameter growth (fig. 1). When temperatures were raised in mid-April, when frost is still frequent under natural conditions, growth began in April rather than in late May. Therefore, temperature controls the time growth begins in the spring (Fraser 1972). However, growth also stopped earlier in the warmer environment.

The combination of continuous light and raised temperature caused apical growth to begin earlier and stop later (fig. 1). The first time the saplings were exposed to such an extended photoperiod a 30 percent increase in leader growth was obtained. This response gradually diminished when the extended photoperiod was continued over a period of years on the same saplings. Therefore, lengthened photoperiod will accelerate growth of nursery material but the next use should be when accelerated production of reproductive buds is desirable.

### Reproductive Growth Response

The white spruce control trees developed reproductive buds when 13 years old: 8 percent male and 11 percent female buds which was less than one male and two females per plantation tree (fig. 2). A peak of 32 percent of the saplings produced male and 19 percent female buds with an average of 15 male and 9 female buds the next year. No reproductive buds were formed the following year.

When white spruce was grown under natural light, irrigated, and fertilized, reproductive buds were produced earlier and in larger quantities. Reproductive buds were first developed when these trees were 10 years old--5 percent of the trees produced male and 8 percent female buds; both male and female buds averaged one per tree. When the saplings were 14 years old, 40 percent of the trees produced male and 33 percent female buds

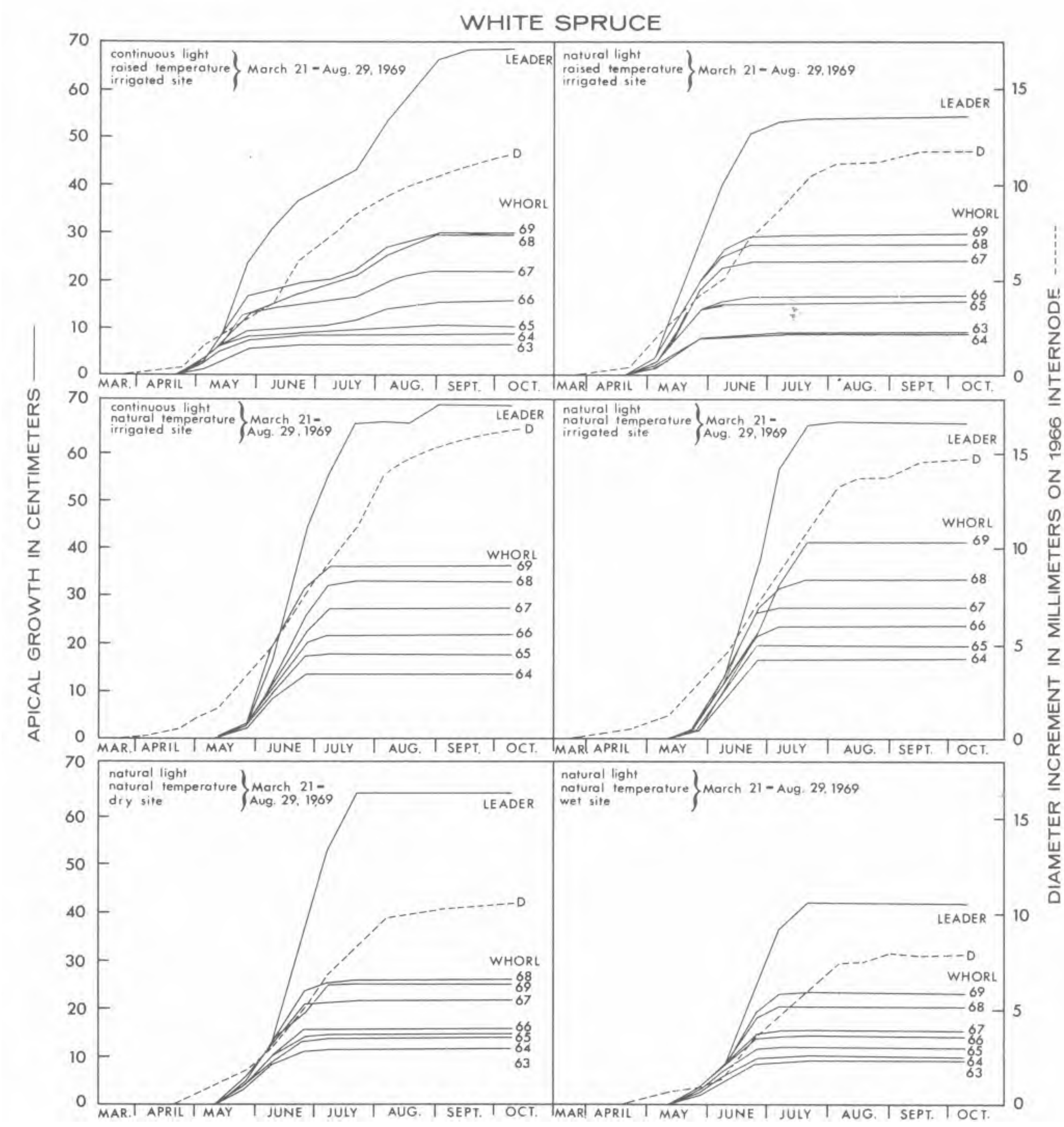



Figure 1.--Average leader (four trees per sample), lateral shoots (four branches per whorl), and diameter growth of 9-year-old white spruce grown under various combinations of photoperiod, thermoperiod, and soil moisture.

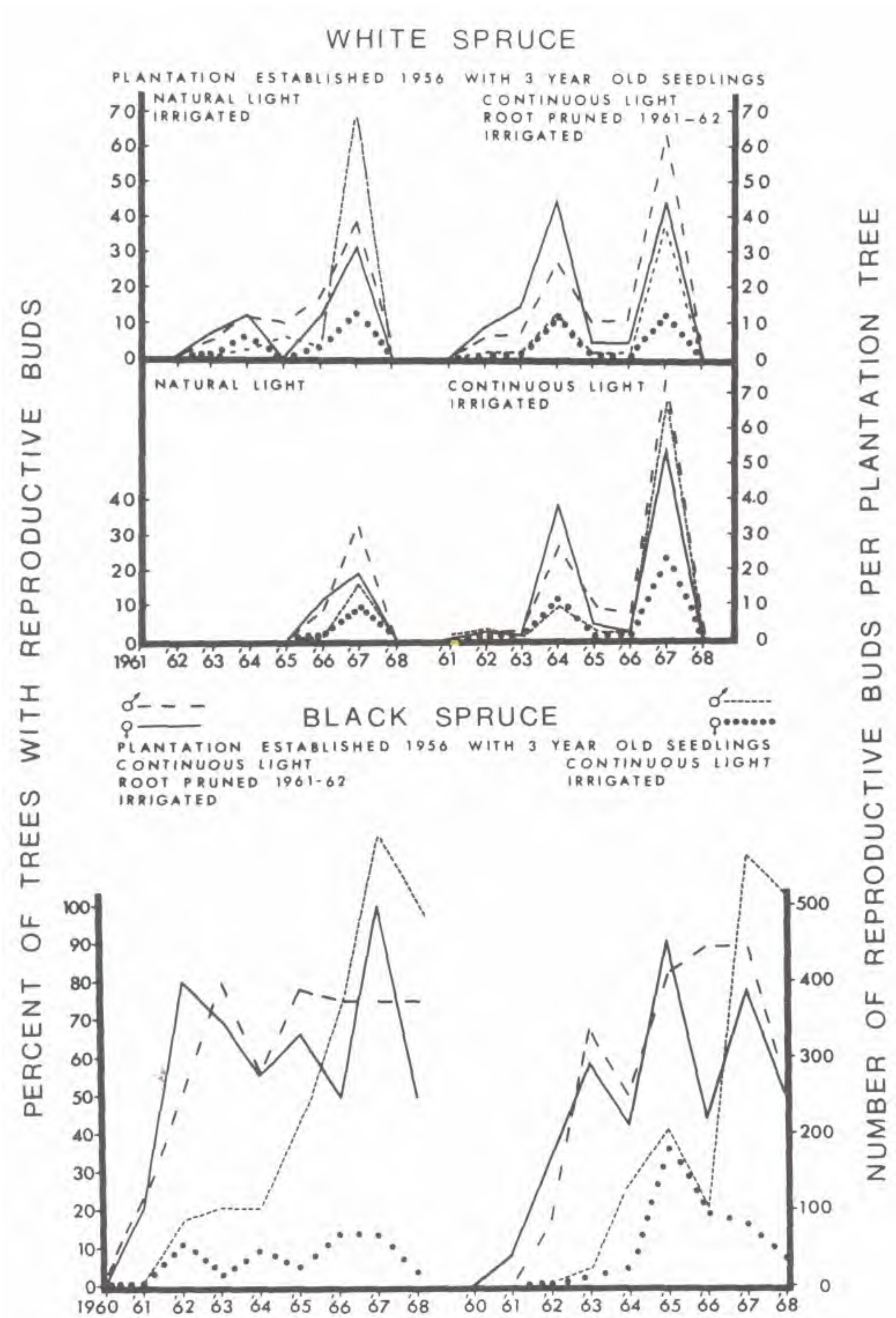



Figure 2.--White and black spruce trees with reproductive buds and reproductive buds per tree during the 1961-1968 period.

with an average of 70 male and 13 female buds per tree, compared with the 32 percent and 19 percent peak in the control trees.

White spruce saplings under continuous light in an irrigated and fertilized soil also produced reproductive buds earlier than those grown in a natural environment; 26 percent produced male and 40 percent female buds with an average of 10 male and 13 female buds per tree at an age of 11 years. In 1967 when all plantations had trees producing reproductive buds, this continuous light plantation had male buds on 74 percent of the trees and females on 53 percent with an average of 67 male and 23 female buds per tree.

Root-pruned trees produced reproductive buds more abundantly at a slightly earlier age--30 percent male and 45 percent female buds from an 11-year-old sapling, but 3 years later only 55 percent male and 45 percent female buds were produced compared with the 74 percent male and 53 percent female buds in the unpruned continuous light saplings.

Black spruce was also studied in the irrigated and fertilized Corry Lake Physiology Area plantation under continuous light in a preliminary experiment (fig. 2). Reproductive buds appeared when the saplings were 7 years old. Two years later, 80 percent of the root-pruned saplings were producing male buds under continuous light compared with 65 percent of the unpruned saplings; 100 percent of the root-pruned saplings produced female buds at an age of 14 years. Yet, this gave an average of only 50 female buds per tree, while the unpruned trees, although they were not developing uniformly, had a maximum of 200 female buds per tree 2 years earlier, when 90 percent of them produced female buds. Thus, root-pruned black spruce saplings produced more reproductive buds in the first year after root-pruning, but the number decreased later when the effect of reduced tree vigor due to root-pruning became evident.

It would appear that genetical response might be favored by the supply of nutrients alone, as attested in the white spruce by reproductive bud production at the earliest data. However, the two peaks in reproductive bud development indicate an overall effect of light, especially on the production of female buds. Both black and white spruce responded to root-pruning by immediate production of reproductive buds, but these trees did not remain as productive over several years as did the undisturbed trees. The method might, therefore, be suitable when only one year of high reproductive bud development is required.

## GROWTH CHAMBER EXPERIMENTS

Borthwick *et al*. (1956) established that alternations of the light and dark period in combinations other than that of two uninterrupted periods within 24 hours will often stimulate additional growth. Thus, three different light-dark combinations were selected: (1) 12 hrs light and

Figure 3.--White spruce seedlings sprayed weekly with 100 ppm $GA_3$ and grown for 8 months under three different photoperiods as indicated under each seedling.

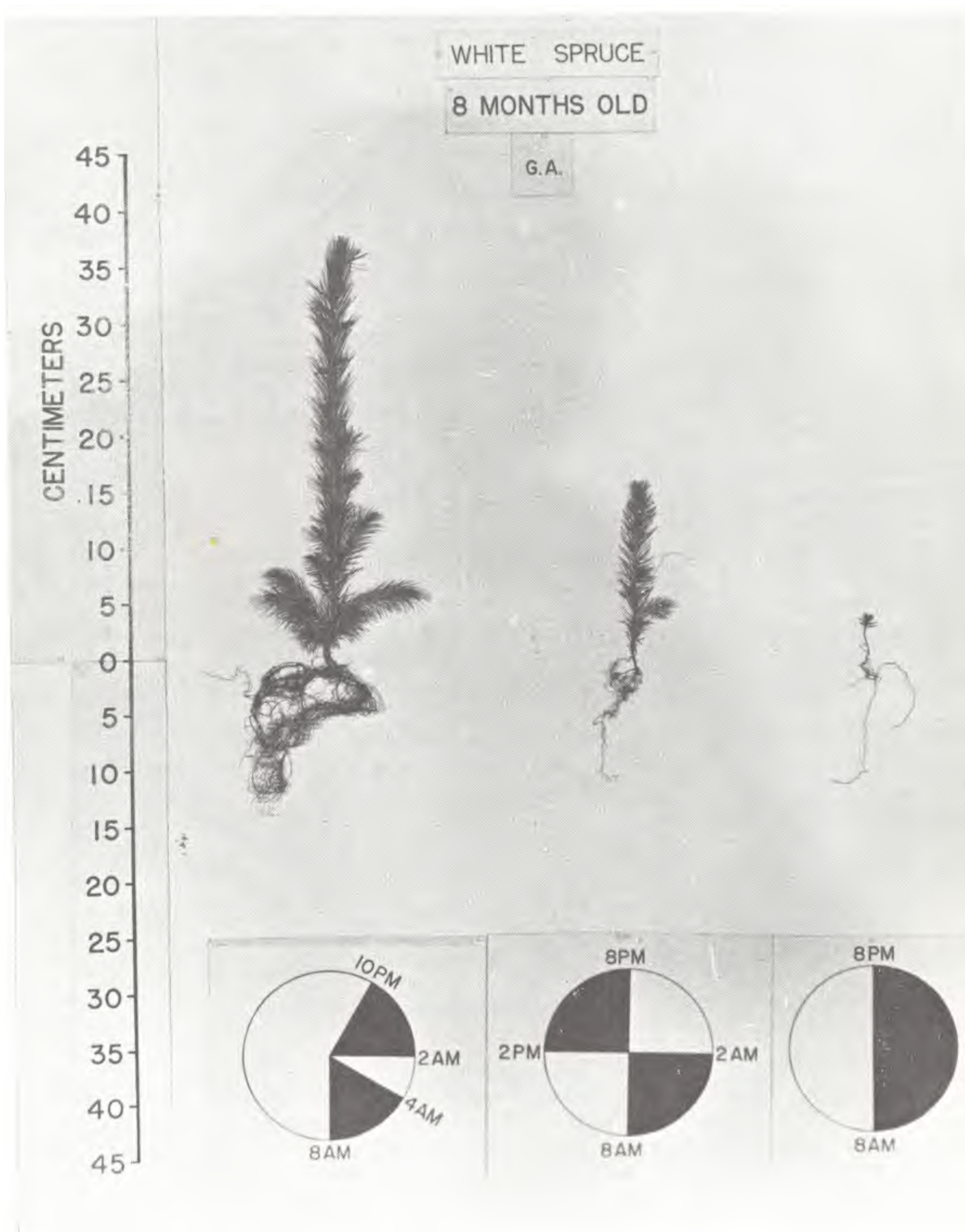
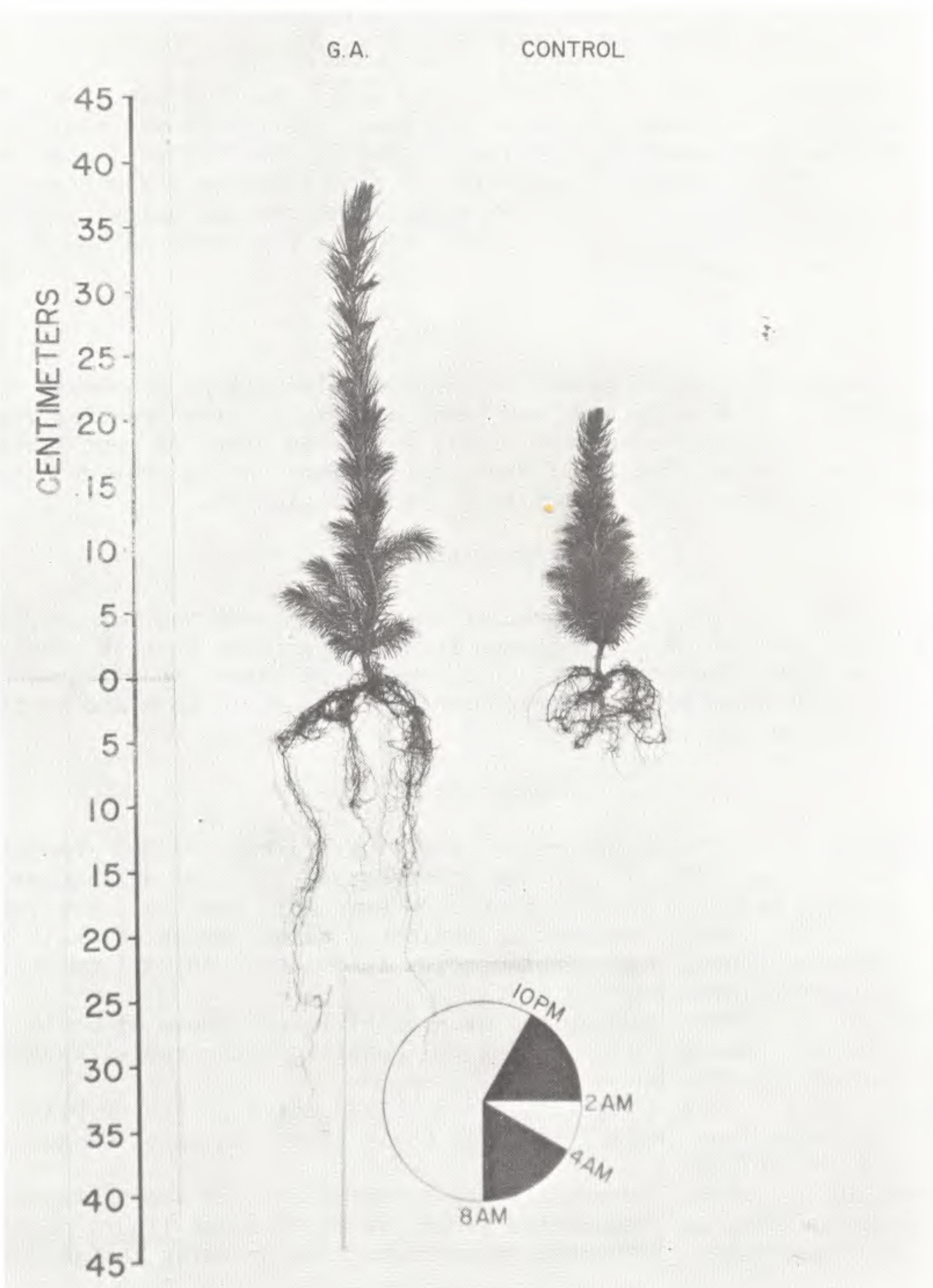


Figure 4.--White spruce seedlings sprayed weekly with 100 ppm $GA_3$ and grown for 8 months under the photoperiod as indicated below. Control seedling shown on the right grown under the same conditions but without gibberellic acid treatment.



12 hrs dark; (2) 6 hrs light and 6 hrs dark alternating; and (3) 14 hrs light, 4 hrs dark, 2 hrs light, and 4 hrs dark. The effect of the dark and light combinations on the growth of spruce seedlings follows that for herbaceous plants. The 6 hrs light and 6 hrs dark periods produced more growth than the 12 hrs light and 12 hrs dark periods. Greater growth was obtained with the 14 hr light period followed by 4 hrs dark, 2 hrs light, and 4 hrs dark (fig. 3).

Gibberellic acid ($GA_3$) was applied weekly as a foliar spray after germination at a concentration of 100 ppm. Its effect was additive to that of the lengthened photoperiod in that it accelerated leader growth (fig. 4). This response is opposite to that reported for white-cedar (*Thuja occidentalis* L.) where $GA_3$ application reduced apical growth and started flower primordia development within a few weeks of the first application (Fraser 1970).

## SUMMARY

Management of tree growth in research plantations decreases the time required for seed production and hence assists in tree breeding experiments. Production of larger seedlings within a shorter time, if root systems are not reduced at the expense of shoot elongation, should provide material better suited for plant competition when out-planted.

## ACKNOWLEDGMENTS

I wish to express my appreciation to members of the former Tree Physiology Section of the Petawawa Forest Experiment Station, Chalk River, Ontario, who assisted in the conduct of these experiments. Dr. E. E. Gaertner provided help both with the field work and in the compilation of results.

## LITERATURE CITED

Borthwick, H. A., S. B. Hendricks, and M. W. Parker. 1956. Photoperiodism. p.479-517. In Radiation Biology III. A. Hollaender (Ed.). Visible and Near Visible Light. McGraw-Hill Book Co., New York.

Fraser, D. A. 1954. Ecological studies of forest trees at Chalk River, Ontario, Canada. I. Tree species in relation to soil moisture sites. Ecology 35:406-414.

Fraser, D. A. 1956. Ecological studies of forest trees at Chalk River, Ontario, Canada. II. Ecological conditions and radial increment. Ecology 37:777-789.

Fraser, D. A. 1966. Vegetative and reproductive growth of black spruce (*Picea mariana* (Mill.) BSP.) at Chalk River, Ontario, Canada. Can.J. Bot. 44:567-580.

Fraser, D. A. 1970. Interaction of gibberellic acid and photoperiod on reproductive and vegetative growth of white cedar (*Thuja occidentalis* L.) seedlings. 12th Meet. Comm. For. Tree Breeding in Can. Proc.

Part 2: p.15-20.
Fraser, D. A. 1972. Tree responses to seasonal changes in light and temperature. Int. Geogr. 1:306-308.