

GROWTH OF TREE SEEDLINGS AS AFFECTED BY LIGHT INTENSITY

**I. White Birch, Yellow Birch, Sugar Maple
and Silver Maple**

by
K. T. LOGAN

Sommaire et conclusions en français

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ABSTRACT

White birch, yellow birch, sugar maple and silver maple were grown for 5 years in 13, 25, 45 and 100 per cent of full light. Height, leaf dimensions, and oven-dry weight of roots, shoots and foliage are presented, and differences in species behaviour as related to light intensity are discussed.

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Growth of Tree Seedlings as Affected by Light Intensity

I. White Birch, Yellow Birch, Sugar Maple and Silver Maple

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K. T. Logan¹

INTRODUCTION

Of all the environmental factors influencing the survival and growth of tree seedlings, light is the one most readily altered and controlled by the forester. Although silvicultural operations may alter other factors such as temperature and soil moisture, these are generally less amenable to control. Furthermore, light is a major factor controlling seedling growth, and thus knowledge of how our native tree species respond to quantity of light is of great interest to the practising forester.

The many experiments reported in the literature have been undertaken in different regions under dissimilar experimental conditions and this fact makes it difficult to draw valid comparisons between species. Even more important, the method of measuring light usually varied with each experiment and thus the quantities reported are not always comparable.

To overcome some of these difficulties, a project was initiated in 1957 at the Petawawa Forest Experiment Station to observe simultaneously under common growing conditions the growth of 23 native tree species at four levels of light. There were two objectives to this project: to determine the range of light conditions within which each species attained its maximum height growth, and to describe differences between species growing under known light intensities.

The experiment included 19 species in the first year: balsam fir, eastern white cedar, larch, jack pine, red pine, white pine, black spruce, white spruce, black ash, basswood, white birch, yellow birch, white elm, mountain maple, red maple, silver maple, striped maple, sugar maple, and red oak.² Three more species, white ash, eastern hemlock and lodgepole pine, were added in the second year together with some additional black ash and basswood seedlings, and one more species, beech, was started in 1961. Some of these species have no commercial value but are often troublesome competitors for merchantable species.

Because it is difficult to follow trends and comparisons simultaneously for a large number of species, the results will be presented in a series of reports dealing with smaller groups. Species have been grouped with their common associates wherever possible, but compromises were necessary for fast growing species that had to be removed from their natural group because they were outgrowing the shelters. This report, the first in the series, describes the growth of white and yellow birch, and sugar and silver maple grown for 5 years in four intensities of light.

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²Scientific names are listed in the Appendix.

METHODS

Seedlings were grown exposed to the sun, and in three shelters made of lath and Fiberglas screen passing 13, 25 and 45 per cent of full daylight respectively (see Figure 1). Seed of local origin was used and the seedlings grown in pots of uniform well mixed sandy loam to facilitate root studies. To prevent their roots becoming pot bound, the seedlings were moved into progressively larger pots during the experiment and were eventually transplanted into the ground. Comparisons were made periodically of seedlings growing in pots and in the ground but no apparent differences in growth were noted. To control insect damage, seedlings were sprayed as required with nicotine sulphate or malathion.

In each light treatment, two rows were assigned at random to each species. At the beginning of the study, there were 20 seedlings to a row for most species, but as seedlings were removed for root studies this was reduced to 10 seedlings per species in only one row by the end of the experiment.

Physical limitations involved in handling such a large number of seedlings precluded the possibility of replicating the light treatments. However this weakness was offset by the uniformity of environmental conditions within each light treatment, and hence the results are considered valid for the particular soil, local climate, and seed source.

Quantity of light in the shelters was measured from dawn to dusk on clear sunny days with integrating spherical illuminometers (Logan, 1955) that have a spectral sensitivity similar to the human eye. The degree of variation both within and between shelters was checked annually. Measurements were also made in 1960

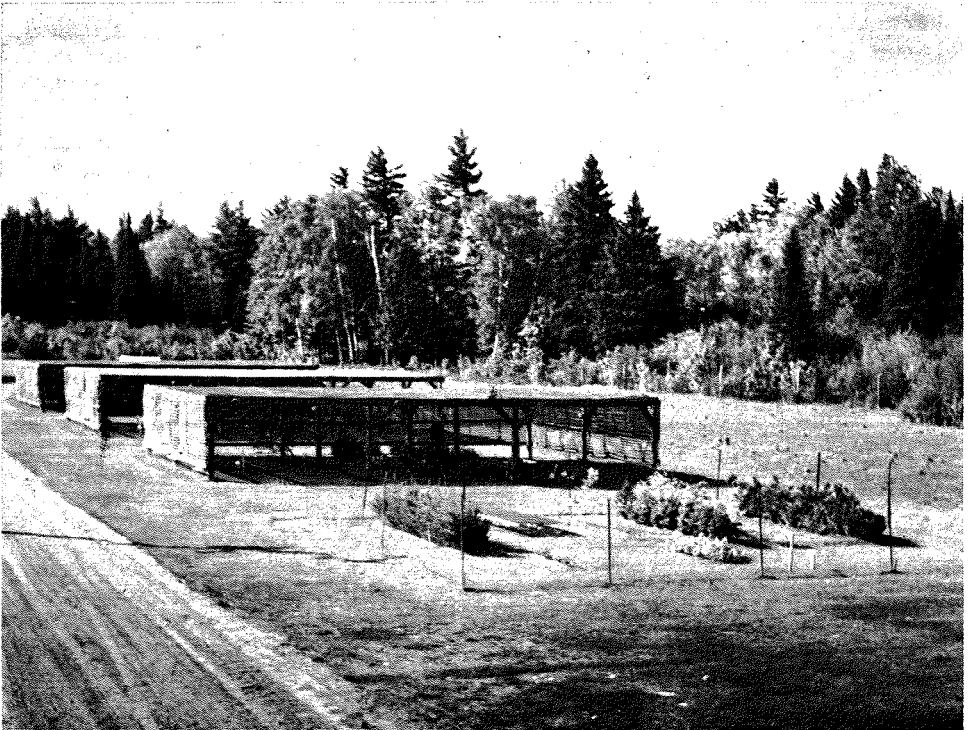


Figure 1. View of the experimental area showing the four light treatments.

and 1961 with a Bellani pyranometer (Courvoisier and Wierzejewski, 1954) which integrates total solar radiation received on a spherical surface. Air temperature and evaporation were measured daily from June 1 to September 15 with Six's type minimum-maximum thermometers and Piché evaporimeters, set 12 inches above ground.

The intention was to have light the main variable controlling growth. To eliminate gross differences in soil moisture between treatments, it was necessary to add water periodically, particularly to seedlings in full light and 45 per cent light. Frequency of watering varied with the weather, and was determined by inspection of the soil ball in the pots.

One drawback of the experimental method deserves comment. As they grew, the seedlings inevitably altered the light environment. Thus the amount of light available at the base of the crown decreased each year, and the quantities of light described in each treatment were available to the tops of the crowns only. However, this is also the measure most frequently used to describe the light climate of a seedling in the forest. Obviously the light climate of the entire crown would be a more meaningful figure, but it is also an exceedingly complex one to obtain (Heinicke, 1963).

The light environment was also modified by the differential growth of species. The faster growing species eventually cast some shade on the slower growing ones. Although some species suffered a temporary reduction in light, the faster growing species were removed from the experiment before they provided any prolonged intensive shade. Nevertheless, whether due to mutual shading or shade from a neighbouring species, it is likely that the average light per crown decreased for all species during the experiment.

At the end of each growing season, the following measurements were taken: height, leader length, diameter at the mid-point of the leader, current year's branch growth, and length and breadth of a typical leaf (length only of needles). Leader length, leader diameter and branch data were not sufficiently informative to be included in this report. Representative samples of seedlings were removed after 3 years and oven-dry weights of tops and roots determined. The four species being reported in this paper were taken from the experiment after 5 years, when some seedlings had reached the top of the shelters (8 feet). Seedlings were severed at the root collar and oven-dry weights of foliage and wood determined. No attempt was made to recover their roots as this would have seriously disturbed the species remaining in the experiment. Significant differences between means were calculated by 't' tests and in this report 'significant' refers to the 95 per cent level or better.

RESULTS

Environment

The light measurements recorded with spherical illuminometers from dawn to dusk on sunny days are summarized in Table 1. These are mean values expressed as a per cent of light received in an open area. The instruments were 18 inches above ground from 1957 to 1960, and 36 to 60 inches above ground in 1961. The number of measurements in each treatment is shown in brackets. On the basis of the measurements recorded from 1957 to 1959, before the seedlings were large enough to modify their environment, the quantity of light admitted by the shelters is referred to in this report as 13, 25 and 45 per cent. Variation within a shelter was negligible. The individual values recorded in the south half of the shelters, where most of the seedlings were located, ranged from 11-13 per cent, 22-25 per cent and 42-44 per cent respectively. The effect of the taller seedlings in cutting off some side light from the instruments became apparent in 1960. In 1961 the illuminometers were raised 36 to 60 inches above ground to avoid the direct shade of seedlings but side light was still reduced.

TABLE 1: QUANTITY OF LIGHT IN EACH SHELTER, EXPRESSED AS A PERCENTAGE OF FULL LIGHT*— NUMBER OF MEASUREMENTS SHOWN IN BRACKETS.

Year	Shelter		
	L 2	L 3	L 4
1957	44 (2)	25 (3)	13 (6)
1958	42 (6)	24 (6)	14 (6)
1959	44 (6)	24 (6)	13 (6)
1960	38 (5)	22 (6)	11 (3)
1961	37 (3)	19 (3)	10 (3)

*Based on readings from sunrise to sunset on clear, sunny days.

Between June 1 and September 15 of 1960 and 1961, a Bellani pyranometer was placed 60 inches above ground for one-week periods in each shelter. The means of five one-week periods in each shelter, expressed as a percentage of radiation received on a Bellani in an open area, are shown in Table 2. These values are almost identical with those recorded by the illuminometers in 1960 and 1961. Apparently the per cent illumination received in a shelter on sunny days also defines the per cent radiation received during the growing season. This suggests that any differences in light quality beneath the shelters are of a minor nature.

TABLE 2: SOLAR RADIATION IN EACH SHELTER — MEAN OF FIVE WEEKLY VALUES, EXPRESSED AS A PERCENTAGE OF RADIATION IN AN OPEN AREA.

Year	Shelter		
	L 2	L 3	L 4
1960	37	19	10
1961	38	19	11

Means of daily minimum and maximum air temperature are recorded for each treatment in Table 3. Maximum temperatures in the open show that 1958 was the coolest year and 1959 the warmest. The mean minimum air temperature was usually 1°F. warmer in the shelters than in the open. Maximum temperatures in 13 per cent light averaged 5° to 6°F. cooler than in full light, although on a few select days the differential reached 9°F. Mean maximum temperatures in the other shelters generally differed from full light by less than 5°F.

TABLE 3: MEANS OF DAILY MINIMUM AND MAXIMUM AIR TEMPERATURES (°F.) BY TREATMENTS, JUNE 1 — SEPTEMBER 15.

Year	13%		25%		45%		100%	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1957*	52	75	51	76	51	77	51	80
1958	48	71	48	72	48	74	47	76
1959	55	78	55	79	54	81	54	84
1960	50	74	50	76	50	78	49	80
1961	53	75	53	77	53	78	52	80

*June 21 — September 5.

The average daily evaporation from a Piché atmometer was similar in 13 and 25 per cent light (see Table 4) and averaged about 20 per cent less than in full light. In 45 per cent light, evaporation averaged about 10 per cent less than in the open area.

TABLE 4: MEANS OF DAILY EVAPORATION (CC.) FROM
PICHÉ ATMOMETERS, JUNE 1 — SEPTEMBER 15.

Year	13%	25%	45%	100%
1957*	3.0	3.1	3.5	3.7
1958	2.8	2.9	3.2	3.6
1959	3.0	3.0	3.4	4.0
1960	2.4	2.5	2.8	3.0
1961	2.3	2.4	2.5	2.7

*June 21 — September 5.

Rainfall and hours of sunshine between June 1 and September 15 are shown in Table 5. The long term averages for this period are 11.1 inches and 860 hours of sunshine. The year 1960 was drier and sunnier than normal.

TABLE 5: RAINFALL AND HOURS OF SUNSHINE FOR THE PERIOD
JUNE 1 — SEPTEMBER 15.

Year	Inches of rain	Hours of sunshine
1957	10.7	800
1958	12.3	859
1959	9.9	887
1960	9.7	952
1961	12.3	759

The pH of 40 soil samples taken from all treatments averaged 5.6 and all samples were within ± 0.3 pH units of the mean. Because variations in pH were small and not systematic, nutrient status of the soil was assumed to be relatively uniform. Soil moisture differences were held to a minimum as described above.

To sum up the environmental data, differences in factors other than light were relatively small and not at critical levels. Therefore, it was assumed that in this experiment quantity of light was the major variable affecting growth.

Seedlings

Height growth of the four species during the experiment is clearly shown for each light treatment in Figure 2. Trends in treatment effects have persisted since the end of the third year of growth (1959). Sugar maple differed from the other species in that for 3 years it has grown better in all shade treatments than in full light. Silver maple has shown a definite preference for 45 per cent light.

The average heights of seedlings at age 5 years were analyzed and significant differences between means determined by 't' tests (Table 6). None of the species attained maximum height in full light. White birch and silver maple were signi-

TABLE 6: AVERAGE HEIGHT (IN INCHES) OF SEEDLINGS GROWN
IN FOUR LEVELS OF LIGHT FOR 5 YEARS

Species	13%	25%	45%	100%
White birch	<u>71</u>	<u>80</u> ²	89 ³	60 ⁴
Yellow birch	<u>60</u> ¹	<u>77</u> ²	<u>84</u> ³	<u>59</u> ⁴
Sugar maple	<u>44</u>	<u>48</u>	<u>47</u>	30
Silver maple	<u>59</u> ¹	<u>57</u>	72	<u>55</u> ⁴

NOTE: Common underlining indicates treatments in which a species showed no significant differences in height; common numerals denote the species in each column that did not differ significantly in average height. Means are based on 10 seedlings per treatment.

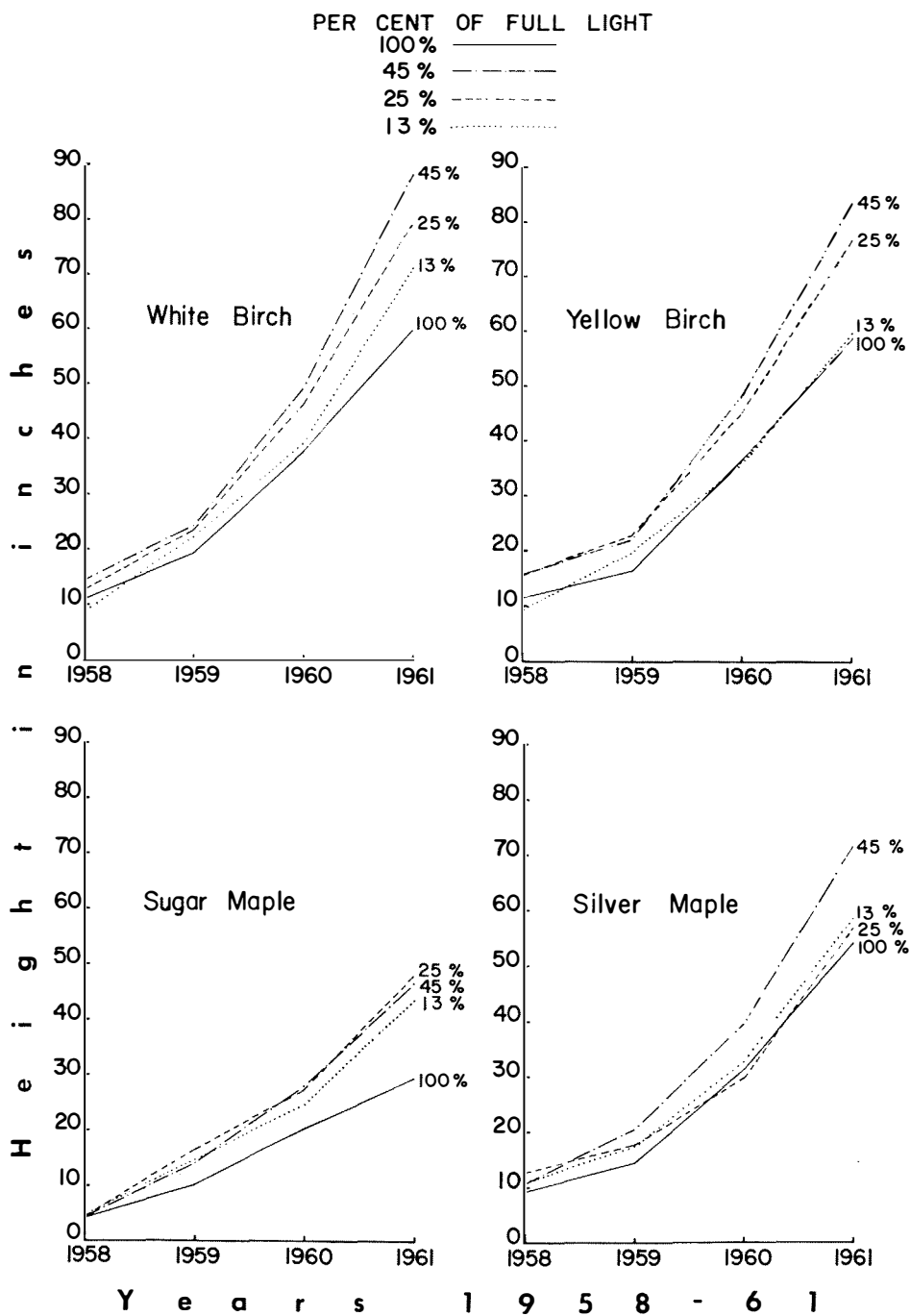


Figure 2. Average height of four species growing in 13, 25, 45 and 100 per cent of full light, 1958-1961.

ificantly taller in 45 per cent light than in any other treatment. Yellow birch reached maximum height in 25 and 45 per cent light, whereas the tallest sugar maple occurred over a range from 13 to 45 per cent light. In each treatment, white birch was the tallest species but only in 13 per cent light was it significantly taller than all other species. On the other hand, sugar maple was the shortest species in all treatments.

Leaf dimensions of all species increased with decreasing light (Table 7). The order of increasing size of leaf was: yellow birch < white birch < sugar maple < silver maple.

TABLE 7: AVERAGE LEAF DIMENSIONS* (IN INCHES) OF SEEDLINGS GROWN IN FOUR LEVELS OF LIGHT FOR 5 YEARS.

Species	13%		25%		45%		100%	
	L	W**	L	W	L	W	L	W
White birch. . . .	5.0	3.4	4.7	3.3	4.3	3.3	3.5	2.6
Yellow birch. . . .	4.7	2.7	4.5	2.6	4.4	2.6	3.4	2.0
Sugar maple. . . .	5.1	5.7	5.0	5.7	4.8	5.6	3.3	3.6
Silver maple. . . .	5.6	6.6	5.3	5.8	5.1	5.3	4.0	4.8

*Means based on a typical leaf from 10 seedlings of each species in each treatment.
**L = length and W = width.

Shoot weights of white birch, yellow birch, and silver maple were greatest in 45 per cent light and in full light (Table 8). Shoot weight of sugar maple did not vary significantly with treatment until light dropped to 13 per cent and was lowest for all species in each treatment.

TABLE 8: OVEN-DRY SHOOT WEIGHT (IN GRAMS) OF SEEDLINGS GROWN IN FOUR LEVELS OF LIGHT FOR 5 YEARS.

Species	13%	25%	45%	100%
White birch.	90.7 ¹	156.7 ²	318.5	243.8 ⁴
Yellow birch.	88.1 ¹	154.8 ²	237.6 ³	236.2 ⁴
Sugar maple.	34.2	44.2	54.5	50.7
Silver maple.	56.4	76.6	171.2 ³	235.0 ⁴

NOTE: Lines connect treatments in which a species showed no significant differences in weight; common numerals denote the species in each column that did not differ significantly in weight. Each value is a mean for 10 seedlings.

Weight of foliage dropped significantly with each decrease in light except for white and yellow birch in full light and 45 per cent light, and yellow birch and sugar maple in 45 and 25 per cent light (Table 9). Sugar maple leaf mass weighed less than that of the other species in each treatment.

TABLE 9: OVEN-DRY WEIGHT OF FOLIAGE (IN GRAMS) FROM 5-YEAR-OLD SEEDLINGS GROWN IN FOUR LEVELS OF LIGHT.

Species	13%	25%	45%	100%
White birch.	39.9 ¹	54.9 ²	97.2 ⁴	96.6 ⁴
Yellow birch.	36.5 ¹	51.1 ^{2,3}	72.3 ⁵	95.0 ⁴
Sugar maple.	18.5	27.5	34.0	50.4
Silver maple.	32.7 ¹	43.3 ³	77.7 ^{4,5}	154.6

NOTE: Lines connect treatments in which a species showed no significant differences in weight of foliage; common numerals denote the species in each column that did not differ significantly in weight of foliage. Values are means of 10 seedlings each.

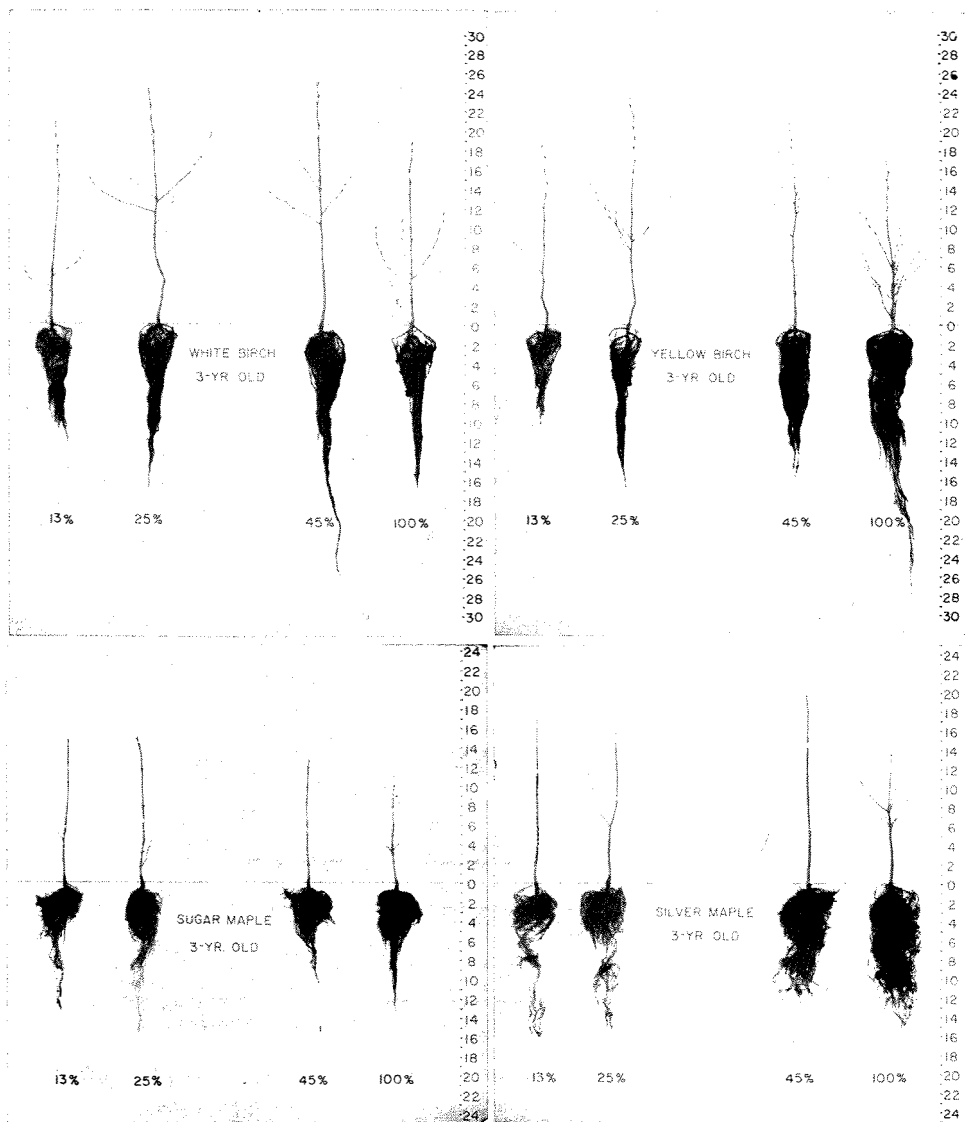


Figure 3. Representative seedlings from each light treatment, age 3 years.

Root weights of 3-year-old seedlings growing in the lowest light treatment were strikingly smaller than in full light for all species except sugar maple (Table 10 and Figure 3). Root weights of sugar maple grown in shade did not differ significantly from those grown in full light. In full light, white and yellow birch roots weighed more than those of sugar maple, but in 13 per cent light they weighed considerably less than sugar maple roots.

TABLE 10: OVEN-DRY ROOT WEIGHT (IN GRAMS) OF SEEDLINGS GROWN IN FOUR LEVELS OF LIGHT FOR 3 YEARS.

Species	13%	25%	45%	100%
White birch	3.5 ¹	6.4 ^{3,4}	11.8 ⁶	13.7
Yellow birch	3.2 ¹	6.3 ³	9.4 ^{4,7}	10.9
Sugar maple	6.8 ²	8.0 ^{4,5}	8.8 ⁷	7.8
Silver maple	6.6 ²	8.5 ⁵	17.0	17.8

NOTE: Lines connect treatments in which a species showed no significant differences in weight; common numerals denote the species in each column that did not differ significantly in weight. Values are means of 10 seedlings each, except for sugar maple where 5 seedlings were used. The only two sugar maple treatments to differ significantly were 13 and 45 per cent light.

DISCUSSION

Because of similarities in response to reductions in light, white birch, yellow birch and silver maple are first discussed as a group, and sugar maple is then contrasted with them. Finally sugar maple and yellow birch are compared in greater detail with reference to their growth beneath a forest canopy. In this discussion it is assumed that the trends established for root weights of 3-year-old seedlings continued into the fifth year of growth.

When light was reduced to 45 per cent, shoot and root weight of the three species did not change significantly, but the seedlings were significantly taller than in full light. The tendency was for the number of branches to decline (see Figure 3) and growth to be concentrated on the stem. Leaves of all species increased in size when light was reduced to 45 per cent. Silver maple foliage weighed only half as much as in full light but this did not affect growth. The reduced weight could be partially explained by differences in leaf density; any reduction in number of leaves apparently reduced the amount of mutual shading rather than the effective surface area.

With further reductions in light, shoot and root weight dropped significantly below the levels attained in 45 per cent light. Average height also declined, though not as drastically as seedling weight. Leaves continued to increase in size and decrease in weight with decreasing light.

Sugar maple differed from the other three species in its response to light. It was the smallest species in all treatments, both by height and weight of stem, and its growth was much less affected by reducing light. Maximum height growth extended over a broad range from 45 per cent light down to 13 per cent. Unlike the other species, there were no significant differences in shoot or root weight when light was reduced from full light to 25 per cent light. Root weight of sugar maple seedlings growing in 13 per cent light was little different from that of seedlings in full light, whereas roots of the other species weighed only one-third as much in low light as in full light. Sugar maple leaves were larger than the birches but smaller than silver maple leaves, and they weighed less in each treatment than those of the other species.

It is appropriate to compare in greater detail the effect of light on the growth of sugar maple and yellow birch. These two species are associated throughout much of their natural range in eastern Canada. Yellow birch is more valuable (Anon, 1962) but it is not generally so easy to regenerate. Both Linteau (1948) and Jarvis (1957) have emphasized the importance of seedbed preparation and adequate light in regenerating yellow birch in tolerant hardwood stands. Godman and Krefting (1960), working in Upper Michigan, have also pointed out the need for adequate light for satisfactory growth of yellow birch seedlings. The results of the present experiment suggest an explanation for differences in growth and survival of yellow birch and sugar maple under varying light intensities.

In this experiment height and weight of the above ground parts of 5-year-old yellow birch were significantly greater than sugar maple, even in low levels of light, whereas in the forest yellow birch seedlings grow more slowly than sugar maple in dense shade (Jarvis, 1956). This apparent anomaly is attributed to differences in root growth of the two species in low light. Yellow birch roots were greatly diminished by reducing light and in 13 per cent light weighed only half as much as sugar maple roots. A relatively small root system was not a critical factor in the experiment where root competition was not intense. However, sugar maple with its root system only slightly reduced by shade, is clearly better prepared to meet the intense root competition present in a tolerant hardwood forest.

Several suggestions are offered in explanation of superior sugar maple root growth in low light. Obviously sugar maple must allocate more photosynthate to the roots than does yellow birch. This may be simply a question of translocation, or it may also be related to the metabolic efficiency of the two species: in spite of a smaller crown, more photosynthate may be manufactured by sugar maple and be translocated to the roots.

Another possibility is that morphological differences between the species may result in a differential absorption of radiant energy. On sugar maple each pair of opposite buds (and hence each leaf and branch pair) is oriented on the main stem at a 90° angle from the previous pair; also the leaves are thrust out from the stem by their longer petioles. These two morphological characteristics may combine to lessen the degree of mutual shading on a sugar maple seedling and provide a more efficient orientation of leaves for the absorption of energy.

The results of this study suggest that differences in growth of yellow birch and sugar maple beneath a dense forest may stem from differences in their root development. Further studies are required to elucidate the reasons for superior sugar maple root growth in low light.

SUMMARY AND CONCLUSIONS

White birch, yellow birch, sugar maple and silver maple were grown for 5 years in 13, 25, 45 and 100 per cent of full light. Oven-dry root weights at age 3 years and height, shoot weight, leaf dimensions and weight of foliage of 5-year-old seedlings are presented. The most important findings of the effect of light on growth of these species were:

1. Silver maple exhibited a marked preference for 45 per cent light. In fact seedlings in full light, having twice the weight of leaves and exposed to double the intensity of light, were shorter and not significantly heavier than seedlings in 45 per cent light. Although differences in leaf weight could be partially explained by differences in leaf density, it is concluded that seedlings in full light utilized energy less efficiently than those in 45 per cent.
2. Height growth of white birch was also superior in 45 per cent light to any other treatment, and weights of root, shoot and foliage were comparable in this treatment to values in full light.
3. The tallest yellow birch seedlings were growing in 25 and 45 per cent light. Since the heaviest seedlings were in 45 and 100 per cent light, the optimum level for this species is probably closer to 45 than to 25 per cent light. This compares with field data from Godman and Krefling (1960) who reported the best stem, leaf and root development and the greatest amount of seasonal height growth on yellow birch seedlings in 50 per cent light.
4. Unlike the other species, sugar maple was adaptable to a wide range of light treatments. Maximum height occurred over a range from 13 to 45 per cent of full light, and reductions in light had much less effect on its root and shoot weight.

5. In comparison with sugar maple, yellow birch seedlings were taller and shoots were heavier, even in the lowest light treatment. However, in 25 and 13 per cent light yellow birch roots were significantly smaller than those of sugar maple. The inability of yellow birch to compete with sugar maple in the dense shade of the forest is attributed to its inferior root growth in low light. Further studies are required to determine whether these results are due to differences in photosynthetic efficiency or in the distribution of the products of photosynthesis. Differences in leaf morphology may also be involved.

SOMMAIRE ET CONCLUSIONS

Pendant 5 ans, l'auteur a étudié des bouleaux blancs, des bouleaux jaunes, des érables à sucre et des érables argentés qui croissaient exposés à 13, 25, 45 et 100 p. 100 d'intensité lumineuse. Le poids des racines d'arbres de 3 ans, séchées à l'étuve, la hauteur, le poids des tiges, les dimensions des feuilles et le poids du feuillage d'arbres de 5 ans sont donnés dans cette publication. D'après l'étude, les constatations les plus notables sur l'influence de la lumière par rapport à la croissance des essences susmentionnées sont les suivantes:

1. L'érable argenté croît mieux par une intensité lumineuse de 45 p. 100. En effet, des semis qui croissaient en pleine lumière étaient plus courts et à peine plus lourds que les semis exposés à la lumière d'une intensité de 45 p. 100, bien que le poids de leur feuillage et l'intensité lumineuse fussent doubles. Même si la différence de poids du feuillage peut dépendre de la différence de densité du feuillage, l'auteur a conclu que les semis poussant en pleine lumière n'utilisent pas l'énergie solaire aussi efficacement que ceux qui poussent en lumière à 45 p. 100 d'intensité.
2. Le bouleau blanc croît de même mieux en hauteur à 45 p. 100 d'intensité lumineuse qu'à toute autre intensité; le poids des racines, de la tige et du feuillage était à peu près le même qu'en pleine lumière.
3. Les semis de bouleau jaune les plus hauts se trouvaient exposés à 25 et 45 p. 100 d'intensité lumineuse. Les poids les plus élevés ayant été constatés chez les semis exposés à 45 p. 100 de lumière, il est probable que le pourcentage le plus favorable à la croissance de cette essence est plus proche de 45 p. 100 que de 25 p. 100. Cette conclusion se rapproche de celle de Godman et Krefting qui ont signalé en 1960 que le gain en poids de la tige, du feuillage et des racines, et la croissance moyenne en hauteur des semis de bouleau jaune étaient supérieurs lorsque l'intensité de la lumière était de 50 p. 100.
4. Différent en cela des autres essences, l'érable à sucre se complait dans des intensités de lumière variées. Les gains en hauteur les plus notables ont été constatés dans des intensités variant de 13 à 45 p. 100 de la pleine lumière, et la réduction de l'intensité de lumière influait sur le poids des racines et de la tige dans une moindre mesure.
5. En comparaison des semis d'érable à sucre, les semis de bouleau jaune étaient plus hauts et leur tige plus lourde même en lumière de moindre intensité. Toutefois, chez les semis de bouleau jaune exposés à 25 et 13 p. 100 de lumière, les racines étaient beaucoup moins développées que celles des semis d'érable à sucre. L'inaptitude du bouleau jaune à concurrencer l'érable à sucre dans l'ombre opaque de la forêt dense est attribuée à une plus faible croissance de ses racines en lumière peu intense. Il y aurait lieu d'étudier la chose de plus près afin de déterminer si les résultats constatés proviennent des différences d'efficacité de la photosynthèse ou de la répartition inégale des produits de la photosynthèse. Peut-être les différences du caractère morphologique des feuilles interviennent-elles aussi.

APPENDIX

Common and Botanical Names of Plants Mentioned in Text

<i>Common Names</i>	<i>Latin Names</i>
Ash, black.....	<i>Fraxinus nigra</i> Marsh.
Ash, white.....	<i>Fraxinus americana</i> L.
Basswood.....	<i>Tilia americana</i> L.
Beech.....	<i>Fagus grandifolia</i> Ehrh.
Birch, white.....	<i>Betula papyrifera</i> Marsh.
Birch, yellow.....	<i>Betula alleghaniensis</i> Britt.
Cedar, eastern white.....	<i>Thuja occidentalis</i> L.
Elm, white.....	<i>Ulmus americana</i> L.
Fir, balsam.....	<i>Abies balsamea</i> (L.) Mill.
Hemlock, eastern.....	<i>Tsuga canadensis</i> (L.) Carr.
Larch.....	<i>Larix laricina</i> (Du Roi) K. Koch
Maple, mountain.....	<i>Acer spicatum</i> Lam.
Maple, red.....	<i>Acer rubrum</i> L.
Maple, silver.....	<i>Acer saccharinum</i> L.
Maple, striped.....	<i>Acer pensylvanicum</i> L.
Maple, sugar.....	<i>Acer saccharum</i> Marsh.
Oak, red.....	<i>Quercus rubra</i> L.
Pine, jack.....	<i>Pinus banksiana</i> Lamb.
Pine, lodgepole.....	<i>Pinus contorta</i> Dougl. var. <i>latifolia</i> Engelm.
Pine, red.....	<i>Pinus resinosa</i> Ait.
Pine, white.....	<i>Pinus strobus</i> L.
Spruce, black.....	<i>Picea mariana</i> (Mill.) BSP.
Spruce, white.....	<i>Picea glauca</i> (Moench) Voss

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