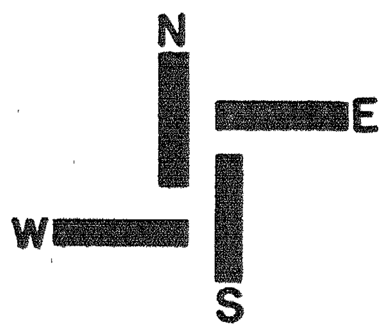
Germination & Growth of PAPER BIRCH & YELLOW BIRCH in Simulated Strip Cuttings

by David A. Marquis



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TO ENCOURAGE REGENERATION

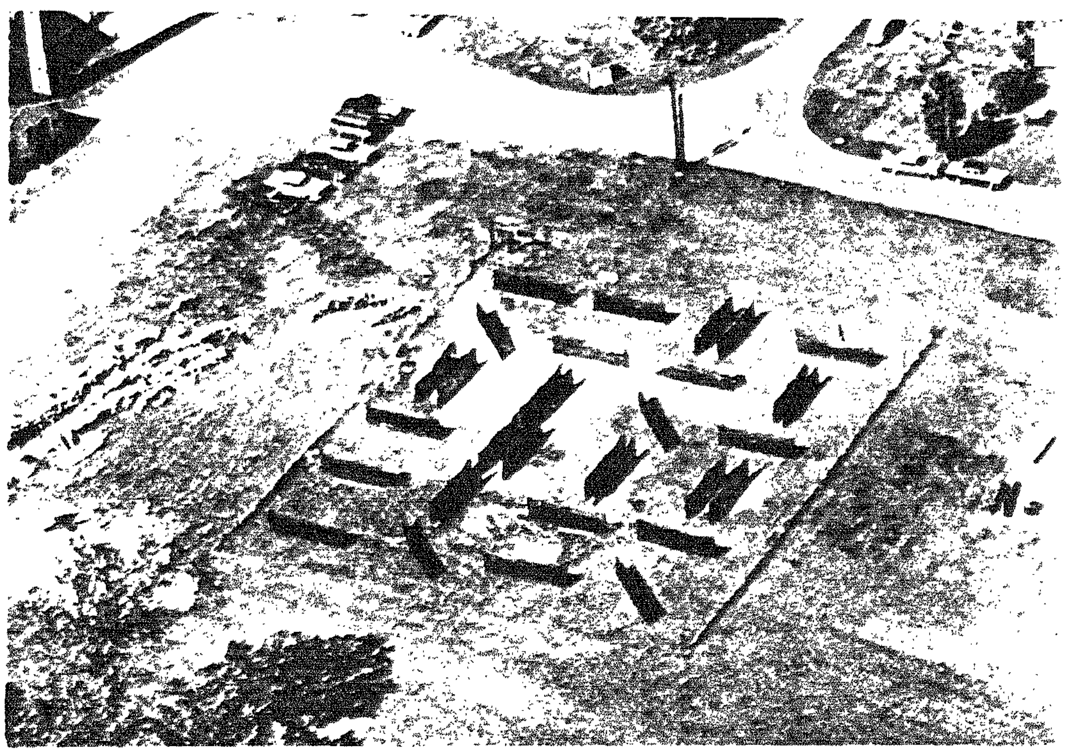
SEED germination and seedling establishment of paper birch (*Betula papyrifera* Marsh.) and yellow birch (*Betula alleghaniensis* Britton) are most satisfactory where there is abundant soil moisture and freedom from excessively high soil temperature. In a cutover forest, these conditions occur most frequently in areas shaded from direct sunlight and on scarified seedbeds that contain exposed mineral soil (*1, 4*). Attempts to encourage birch regeneration, then, could logically take two forms: use of cutting methods that provide the optimum degree of shade, and/or seedbed preparation. The study reported here deals with the first possibility.

STUDY METHODS

Clearcuttings can provide a variety of sunlight exposures depending on the size, shape, and orientation of the openings. Narrow strip cuttings appear to offer the best possibilities for practical use (5). With this in mind, a study was designed, first, to test the effect of six different types of strip clearcuttings on the germination, survival, and growth of paper birch and yellow birch; and, second, to obtain detailed records on the light, soil moisture, and soil temperature regimes in these cuttings.

Because of the large variations introduced in field studies by differences in site, soil, animal damage, etc., the experiment was not set up in actual strip cuttings. Instead, the light conditions of various strip cuttings were simulated with shade screens and the entire study was conducted in a ½-acre fenced plot where many miscellaneous factors such as animal damage could be eliminated, other factors such as soil type could be standardized, and still other factors such as soil moisture could be altered as an experimental treatment.

Figure 1. — Aerial view of the study layout, at Bartlett, New Hampshire.



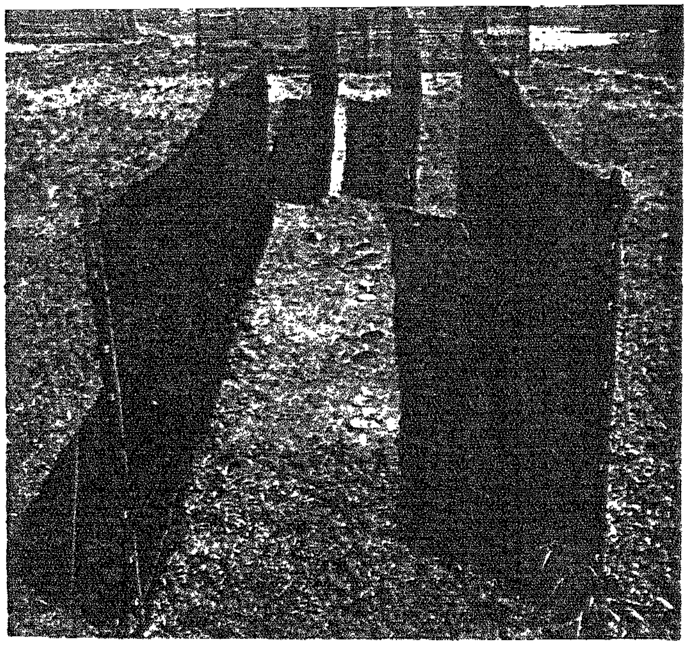


Figure 2. — Close view of two north-south oriented screens. Treatment (b) in foreground, treatment (c) in middle background; and several east-west screens in far background.

The experimental design was a split-plot that contained four blocks, six main plots, and four subplots. Three annual replications were made. The main plots were used for six light-exposure treatments in which open shade, such as that found along the borders of strip cuttings, was created artificially with saran cloth screens. Screens blocking 50 and 80 percent of the light were selected for this study. The 80-percent shade cloth closely simulated the average border shade of strips measured on the Bartlett Experimental Forest in New Hampshire. The screens were 6 feet tall and 20 feet long. A 6-inch gap between the bottom of the screen and the ground allowed air movement along the ground.

Unnatural effects frequently associated with shade screens were minimized with this screen arrangement. There was no overhead screen to intercept rainfall or alter air temperature. Wind movement was slightly restricted, but not so much as by other types of screen. The general arrangement of screens is shown in figure 1 and a close view of several screens is shown in figure 2.

The light exposure treatments were:

Treatment	*Shade cloth*	*Light pattern*	*Type of cutting simulated*
(a)	80%[1]	Full sunlight.	Exposed portions of larger patch, strip, or clearcuttings.
(b)	80%	3½ hrs. sunlight at noon; shade morning and afternoon.	North-south oriented strip with width equal to border-tree height.
(c)	80%	2 hrs. sunlight at noon; shade morning and afternoon.	North-south strip with width equal to ½ border-tree height.
(d)	80%	Sunlight early morning and late afternoon; shade during midday.	East-west strip with width equal to ½ border-tree height.
(e)	50%	Same as (d).	Same as (d) but less dense border shade or shade in a shelterwood cut.
(f)	80%	Direct sun in morning; shade afternoon.	Northwest-southeast strip with width equal to ¾ border-tree height.

[1] An east-west screen was used on the north side of the plots in this treatment; it cast no shade on the plots but helped to keep other factors such as wind movement uniform over all treatments.

There were four subplots at each screen: one for each combination of two species — paper birch and yellow birch — and two moisture regimes. Moisture regime A represented natural soil moisture as affected by light exposure, rainfall, and other environmental factors. Moisture regime B was supplemented so that soil moisture was maintained between 80 and 100 percent of field capacity.

Each subplot consisted of two 6-inch diameter porous clay flower pots, buried in the ground so that the top of the pot was just above the ground line. Moisture regime B pots were nested inside 7-inch plastic pots that had side drain holes 2 inches up from the bottom. A 2-inch level of water was maintained in each plastic pot to serve as a reservoir for the soil in the clay pot. This maintained soil moisture near the field capacity at all times on moisture regime B.

Soil in each pot was obtained from the B_2 horizon of a Hermon sandy loam on the Bartlett Experimental Forest. This soil is typical of those on which birch grows naturally. For the experiment, the soil was dried and thoroughly mixed; stones were removed by passing soil through 1/4-inch mesh sieve; then the soil was supplemented with 0.8 g. of 10-10-10 fertilizer and 2.4 g. of lime to every kilogram of soil. Even after these additions, soil nutrient and pH level was low, as evidenced in the following soil analysis performed by the Morgan method (*2*):

pH	*Nitrate nitrogen*	*Ammonia nitrogen*	*Phosphorus*	*Magnesium*	*Potassium*	*Calcium*
5.1	20 ppm (low)	30 ppm (medium)	trace (trace)	1 ppm (very low)	70-90 ppm (low)	520 ppm (very low)

The soil was compacted slightly in the pots to obtain a bulk density of about 1.0.

Birch seed, collected from a single tree of each species and sieved to obtain uniformity of size, was sown at the rate of 200 seeds per pot. As the seeds germinated, they were marked with plastic toothpicks. If a seedling died, its toothpick was removed. Germination and mortality observations were made at weekly intervals. After the main surge of germination was completed, seedlings were thinned to a maximum of nine seedlings per pot to insure that competition did not affect treatment responses. Mortality was therefore a calculated estimate derived from the number of seedlings that died before thinning, the number alive before thinning, and the mortality percentage after thinning.

A duplicate set of two pots was used for height and dry-weight determinations. Seedlings in these pots were started from seed and grown for two months under artificial lights in the laboratory. Each pot that contained two established seedlings was placed under the screens in the study area during the last week of May. Some variation in growth occurred under the artificial lights. Therefore pots were assigned to blocks on the basis of their original height: tallest seedlings in block I, next tallest in block II, and so on. This technique of starting the seedlings early in the laboratory was used because many seedlings that were started from seed in the study area did not make sufficient growth in the first growing season for accurate growth measurements. Dry-weight measurements do not include leaves. A typical subplot is shown in figure 3.

One pot of each subplot in blocks I and IV was selected for soil-temperature measurements. Copper-constantan thermocouples placed at the surface and 1 inch below the surface were used to measure soil temperature, and Coleman fiberglas soil-moisture units were placed on edge in the top 1 inch of soil to measure moisture. Lead wires from all sensing units were run to rotary switches at a central control panel so that all 96 temperature units and 48 moisture units could be read in quick succession. Coleman units were laboratory-calibrated against gravimetric determinations, using the study soil. Field capacity (0.06 atm) and wilting points (15 atm), as determined on a tension table and pressure membrane, were 48 and 9 percent by volume respectively.

Moisture and temperature were recorded three times a week, May through September, with readings at noon and 3 p.m. EST. On an average of 1 day each week, the readings were taken every hour from 9 a.m. to 3 p.m., and on several occasions readings were taken at hourly and half-hourly intervals from sunrise to sunset. Rainfall and air temperatures were recorded daily at the Bartlett Experimental Forest Headquarters, 1/4 mile from the study area.

Light was measured on each plot an average of once a month. Cumulative light over the middle 8 hours (8 a.m. to 4 p.m. EST) was measured with the chemical light meter (*3*). Intensity readings at 10-minute intervals were also taken on each plot on several occasions with a Weston model-756 illumination meter. Light readings were normally taken on bright sunny days, but one overcast day was sampled for comparison.

The entire study was repeated three times during the growing seasons of 1962, 1963, and 1964. Thus, with 4 blocks, 6 light treatments, 4 species-moisture treatments, and 3 years, 288 plots were used in the study.

Differences due to treatment were tested for significance by analysis of variance. The germination and survival data were subjected to the arc-sin transformation before statistical analysis. A probability level of 0.05 was accepted for significance.

During the course of the study, some changes in procedures were

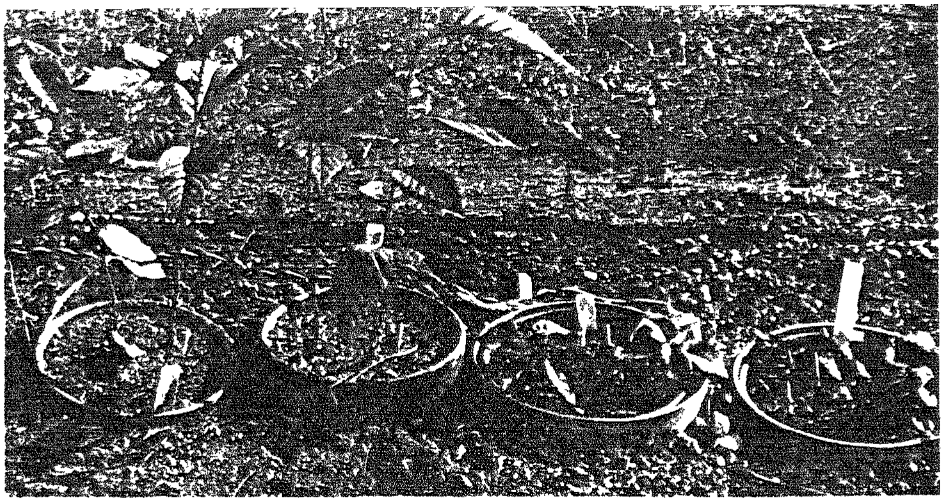


Figure 3. — A subplot of four pots. The two pots on the left contain large yellow birch seedlings used for growth determinations (moisture regime A pots). The two pots on the right contain paper birch seedlings used for germination and mortality, soil moisture, and temperature measurements (moisture regime B). In the actual study each subplot contained only one species and one moisture regime.

made. For the 1962 and 1963 replications, seed was sown in the pots used for germination during October of the previous year so that it would overwinter in the natural conditions. But some loss of seed was suspected from this procedure. Therefore in 1964 seeds were sown in the spring to minimize such losses.

In 1962, growth determinations were made on seedlings started in the study area. However, because many of these 1962 seedlings did not grow enough to be measured accurately, the seedlings used for growth determinations in 1963 and 1964 were started in the laboratory in a separate set of pots, as previously mentioned. The 1962 growth data have been omitted entirely from this report.

A third major change was in light treatment (f), which was added after the 1962 replication. Thus there are no treatment (f) data for 1962. Neutral values were computed for these missing data, using Snedecor's (6) techniques so that the statistical analysis might be run on all 3 years combined. These neutral values minimize the error sums of squares in the analysis and have a minimum effect on the outcome of the test.

THE ENVIRONMENTS STUDIED

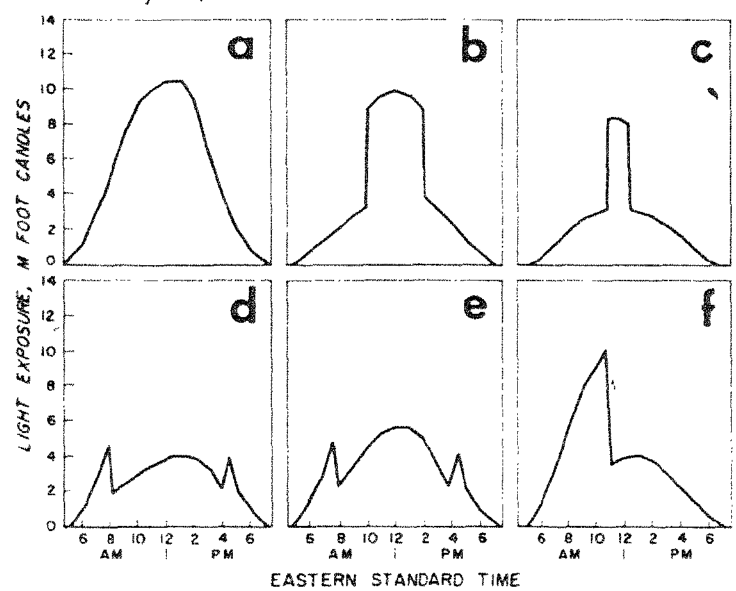
Light Exposure

The actual pattern and intensity of light received under each of the six treatments on a sunny day with intermittent clouds is shown in figure 4. Total or cumulative light received over an entire day is shown as a percentage of full sunlight in the following tabulation. This cumulative light is based on the average of all chemical light readings, and it is adjusted to represent a full 15-hour day.

Light treatment (per cent)					
(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*
100	65	43	48	58	66

The intensity of light received on the overcast day was only about 20 percent of that received on sunny days. On the overcast day, all treatments received about equal light except for treatment

Figure 4. — Light exposure under the various screens on July 28, 1964.



(c), which received 40 percent less than the others because of the closeness of the two parallel screens.

Soil Moisture

Average soil moisture during the 3-year period varied significantly between light treatments and moisture treatments. Most of the variation among light treatments was due to treatment (a) — full sunlight — which had significantly lower moisture than all other treatments combined. Summary of average soil moisture, May to September, for all three growing seasons, is shown in the following tabulation, in percentage by volume.

Moisture regime	*Light treatment*					
	(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*
A	21	30	29	26	26	23
B	45	48	49	48	47	48

Several selected examples of seasonal soil moisture are shown in figures 5 and 6. Figure 5 compares the widely fluctuating natural

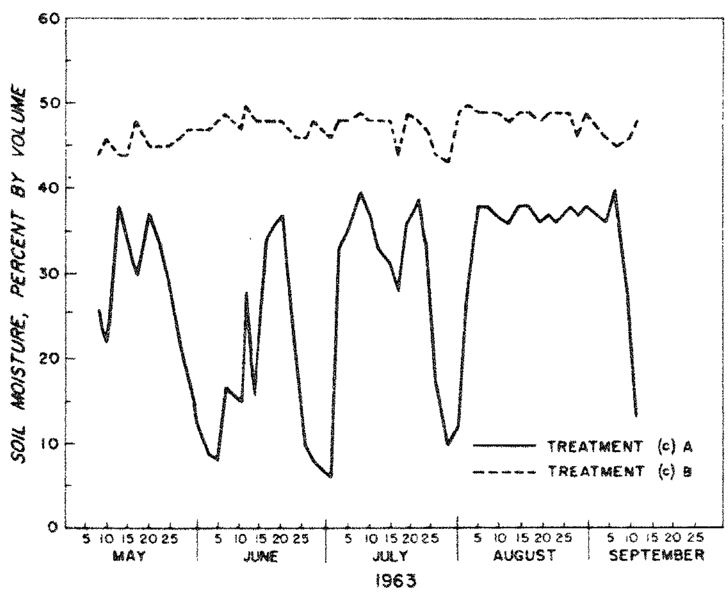
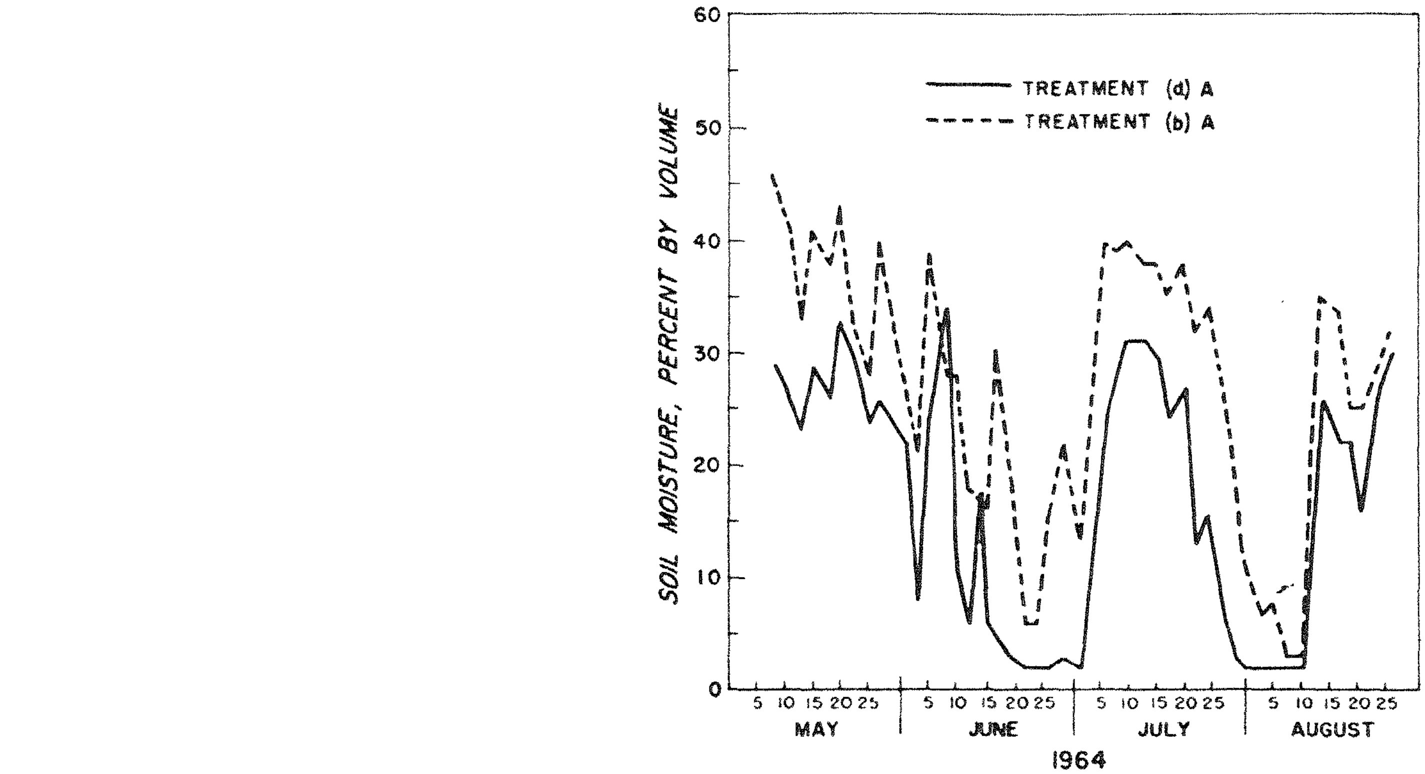


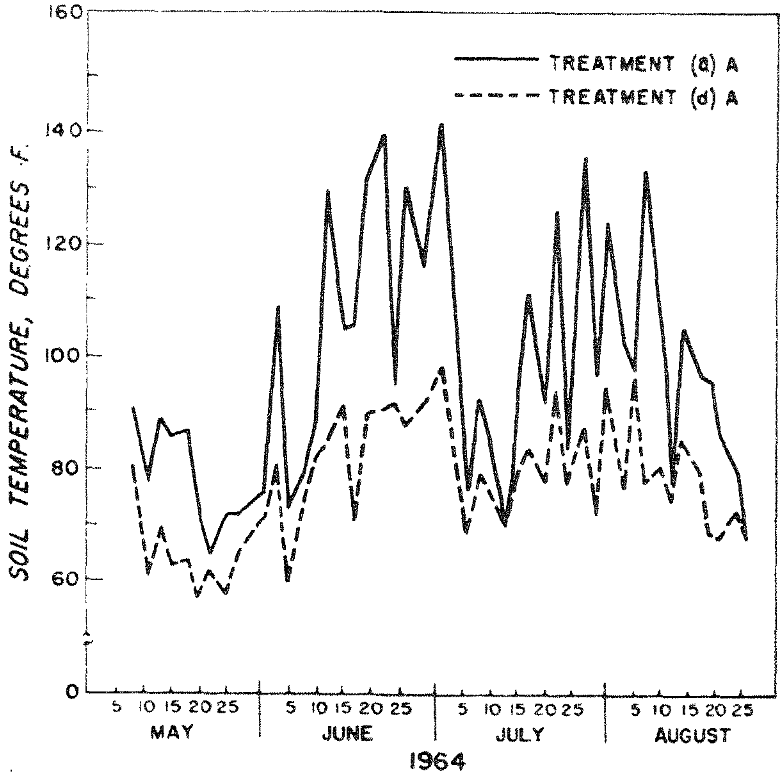
Figure 5. — Soil moisture on narrow north-south treatment (c) during 1963 — moisture regime A compared with moisture regime B.

Figure 6. — Soil moisture on moisture regime A (natural moisture) during 1964. Full sunlight treatment (a) compared with north-south shaded treatment (b).



soil moisture (regime A) on treatment (c) with the higher and relatively stable moisture of regime B on the same treatment. Figure 6 compares seasonal soil moisture on regime A for light treatments (a) and (b). In addition to the fact that moisture content was generally higher on the shaded treatment (b) than on full sunlight treatment (a), it is important to note the differences between the two treatments in regard to the wilting point (9 percent). Treatment (a) fell below the wilting point four times in 1964, for a total of 39 days. Treatment (b) fell below the wilting point only twice, for a total of 13 days. On both occasions when treatment (b) fell below the wilting point, it required 6 or 7 days longer to do so than treatment (a). Thus in a period of long-con-

Figure 7. — Soil temperature on moisture regime A (natural moisture) during 1964. Full sunlight treatment (a) compared with east-west shaded treatment (d).



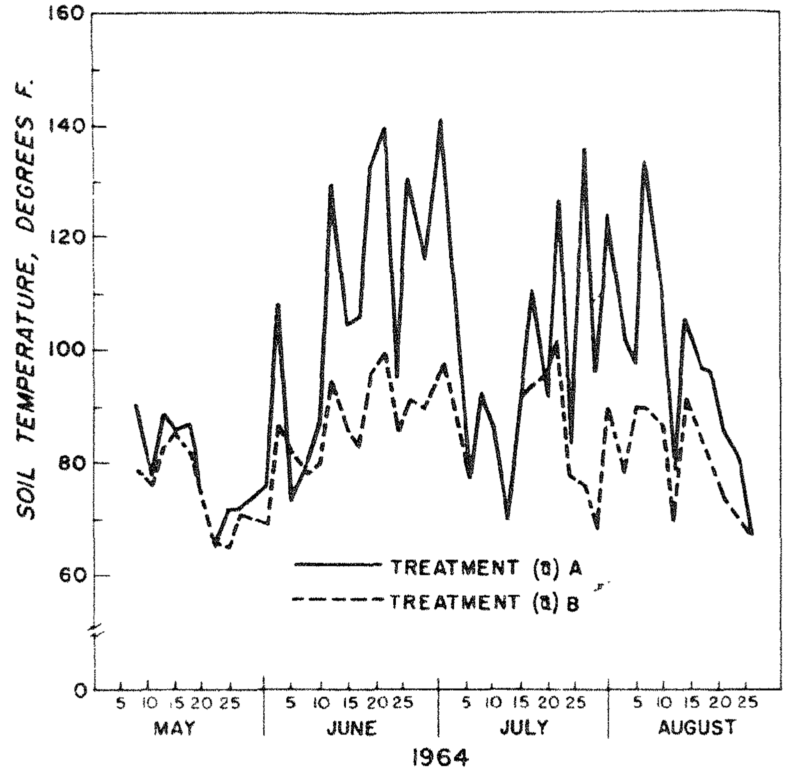
tinued drought the shaded strip offered nearly a week of protection from critically low soil moisture.

Soil Temperature

Average noontime surface soil temperatures, May to September, for all three growing seasons, varied significantly between both light treatments and moisture treatments, as the following tabulation indicates:

Moisture regime	*Light treatment*					
	(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*
A	93°F.	86°F.	81°F.	74°F.	77°F.	76°F.
B	83	81	76	70	74	72

Figure 8. — Soil temperature on full sunlight treatment (a) during 1964. Moisture regime A compared with moisture regime B.



Temperatures were highest in direct sunlight, lowest on plots that received the most shade. The difference in average noontime surface soil temperatures on treatments (a) and (d) was 19°F. Soil temperatures were lower when the soils were moist than when they were dry. In full sunlight, noontime surface soil temperatures averaged 10°F. cooler on regime B than on regime A. However, the magnitude of even these differences is misleading because rainy and overcast days as well as sunny ones were included. On clear days, the differences were much greater. This is evident in a comparison of noontime surface soil temperatures on two light treatments and two moisture regimes respectively (figures 7 and 8). In both cases, differences in excess of 40°F. occurred. Diurnal fluctuations in soil temperature were closely associated with light exposure; highest temperatures occurred during periods of highest light intensity.

SEEDLING RESPONSES

Germination

Germination for all 3 years combined is shown in table 1. Germination differences among species, light treatments, moisture regimes, and the light-moisture interaction were all highly significant. The differences between species resulted from lower viability of yellow birch seed as revealed in laboratory germination tests. This difference was consistent in each of the 3 years of the study, suggesting that yellow birch seed may normally be less viable than paper birch seed. The other germination differences seem to be straightforward responses to the various environments.

Germination was highest on those treatments that received the most shade, had the highest soil moisture, and did not attain high surface soil temperatures. The interaction of moisture and light is particularly revealing. On treatment (a), where plots were hot and dry from exposure to direct sunlight, the addition of water on regime B increased germination 14 times. But on treatment (c), where heavy shade conserved natural moisture, supplemental watering increased germination only 1.7 times.

On the basis of their ability to provide suitable environments for germination (assuming natural moisture), the six simulated strip cuttings might be divided into three groups: Best conditions

Table 1. — Germination in percent of seeds sown

Species	Moisture regime	Light treatment (a)	(b)	(c)	(d)	(e)	(f)	All light treatments
Paper birch	A	2	9	12	9	7	3	7
Yellow birch	A	1	5	10	7	4	3	5
Paper birch	B	20	22	24	18	18	19	20
Yellow birch	B	15	16	14	16	14	16	15
Both species	A	1	7	11	8	6	3	6
Both species	B	18	19	19	17	16	18	18

found in a narrow north-south strip (treatment c); intermediate conditions found in treatments (d), (b), and (e) in that order, representing narrow east-west strips and a wider north-south strip; poorest conditions found in treatments (f) and (a), which represented northwest-southeast strips and larger clearcuttings respectively.

Mortality

Differences in mortality (table 2) due to light treatments and moisture regimes were highly significant; those due to the light-moisture interaction were significant at the 0.05 level. Differences between species were not significant. Mortality, like germination, followed a pattern directly related to the environmental treatments. Mortality was lowest on treatments that received heavy shade and supplemental moisture. The light-moisture interaction on mortality, although significant, was not so dramatic as the light-moisture effect on germination. Supplemented moisture reduced mortality 2 times on treatment (a) as compared with 1.3 times on treatment (c).

On the basis of their ability to provide suitable environments for survival (assuming natural moisture), the six simulated strip cuttings might be divided as follows: least mortality in treatments (c), (d), and (e), medium conditions in (b) and (f), and highest mortality in (a).

In general, then, treatments favorable for germination were also favorable for survival. However, there were some slight shifts in the relative favorability, as evidenced by the groupings above. Al-

Table 2. — Mortality in percent

Species	Moisture regime	Light treatment (a)	(b)	(c)	(d)	(e)	(f)	All light treatments
Paper birch	A	73	60	40	44	51	64	55
Yellow birch	A	79	63	53	49	50	57	58
Paper birch	B	44	36	32	27	38	28	34
Yellow birch	B	33	42	40	23	32	35	34
Both species	A	76	61	47	47	50	60	57
Both species	B	38	39	36	25	35	31	34

though these differences are small and are probably of little practical importance, it is interesting to speculate on the reasons.

The north-south screens received direct sunlight for a short period at noon; soil temperatures rise sharply during this period but the duration of exposure apparently does not permit excessive soil drying. The east-west treatments did not receive direct sun during midday; and soil temperatures remained much lower there, while soil moisture was about the same as the north-south treatments. The north-south screens were relatively more favorable for germination than for survival. The opposite was true on the east-west treatments. It would seem, therefore, that the higher soil temperatures and short sunlight exposure on the north-south treatments favored germination of the seed but resulted in some heat damage to the new seedlings.

Height Growth and Dry Weight

Height growth (difference between seedlings at the time they were placed in study and at the end of growing season) and dry weight (total) data are shown in tables 3 and 4.

Two factors limit interpretations of these growth data. First, there was a great deal of unexplained variation, in spite of efforts to reduce it. Even under uniform laboratory conditions, growth differences of 2 or 3 times occurred. These variations probably obscured some relationships that might otherwise have been revealed. The large variations may be characteristic of first-year seedlings. Such variations would likely be less during later years after the seedlings became better established.

Second, the method of watering on moisture regime B, which worked very well for germination and mortality responses, disrupted the normal root growth on regime B seedlings. The 2-inch layer of saturated soil in the pot effectively limited rooting to the upper 2/3 of the soil volume. In contrast, seedlings on moisture regime A were able to utilize all the soil in the pot and many seedlings even extended roots through the hole in the pot bottom into the surrounding soil. Thus lower growth on moisture regime B is probably due to the watering method and not to higher moisture in the usable soil.

Table 3. — Average height growth/seedling in inches

Species	Moisture regime	Light treatment (a)	(b)	(c)	(d)	(e)	(f)	All light treatments
Paper birch	A	1.00	2.00	1.67	2.19	1.66	1.67	1.70
Yellow birch	A	.77	1.98	1.83	1.57	1.75	84	1.46
Paper birch	B	1.57	1.52	1.40	.89	1.10	1.30	1.30
Yellow birch	B	1.78	1.38	1.55	1.61	1.42	1.14	1.48
Both species	A	88	1.99	1.75	1.88	1.76	1.26	1.58
Both species	B	1.68	1.45	1.48	1.25	1.26	1.22	1.39

Table 4. — Total dry weight in milligrams/seedling

Species	Moisture regime	Light treatment (a)	(b)	(c)	(d)	(e)	(f)	All light treatments
Paper birch	A	640	991	1,022	1,376	954	811	966
Yellow birch	A	648	1,039	1,236	1,050	848	700	920
Paper birch	B	1,236	815	984	489	681	689	816
Yellow birch	B	932	759	800	996	958	676	854
Both species	A	644	1,015	1,129	1,213	901	756	943
Both species	B	1,084	787	892	742	820	682	834

In spite of these limitations, there are significant and meaningful differences between treatments. On moisture regime A, full sunlight treatment (a) had significantly less growth than the other five treatments. On moisture regime B, differences did not attain significance, but the trend was opposite; that is, greatest growth occurred on treatment (a). Thus height growth was limited by lack of soil moisture under full sunlight conditions with natural moisture, but when soil moisture was not limiting, growth was at least equal, and possibly better, under full sunlight than under shade.

Growth did not vary significantly among the five shaded treatments. However, it must be remembered that the variation in total light received was small, ranging only from 43 to 66 percent of full sunlight. The pattern in which this light was received did vary among treatments, but this apparently had little effect on growth.

Root-shoot ratios, based on dry weight, differed significantly on moisture regime B, where soil moisture was similar on all treatments. Paper birch had a significantly higher root-shoot ratio than yellow birch. Paper birch attained significantly greater root-shoot ratios in full sunlight than in any of the shaded treatments. Yellow birch, the more tolerant of the two species, followed the same pattern, but differences in root-shoot ratios between sun and shade did not attain statistical significance.

These differences in root-shoot ratios may be very important in determining the ecological positions of the two species. Under full sunlight, paper birch has larger roots than yellow birth. Once established, it would thus be better able to survive and grow on dry, fully exposed areas than yellow birch. But when shaded, paper birch root growth is significantly reduced, making it less able to compete there than yellow birch, the root growth of which is not so much affected by moderate shade.

On moisture regime A, soil moisture variations apparently obscured differences in root-shoot ratios. The root-shoot ratios for moisture regime B are given in the following tabulation:

Species	*Light treatment*						*All light treatments*
	(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	
Paper birch	9.94	3.00	4.33	3.97	3.50	3.83	4.73
Yellow birch	6.18	3.02	3.06	4.80	2.99	3.04	3.85

CONCLUSIONS

Because shade favored seedling establishment and full sunlight favored seedling growth, a primary objective of this study was to determine which type of strip might be the best compromise; that is, which would provide both enough shade for seedling establishment and enough direct sunlight for adequate growth.

From the results, it would seem that such a compromise is not really necessary. Differences in growth did occur between the shade treatments and full sunlight treatment, but no significant differences were found among the various shade treatments in this study. Therefore a logical choice would be to use strips that give the best germination and survival. This would be either a narrow north-south strip (treatment c) or a narrow east-west strip (treatment d), the width being more important than the orientation.

Narrow strips would certainly seem to be the desirable choice if the strips were cut in a progressive series; that is, if the new strips were cut adjacent to old ones at about 3-year intervals, which would remove the shade after an initial establishment period. If strips were not to be cut progressively, or if the cutting intervals were to be much longer than 3 to 5 years, the heavy shade would probably begin to influence seedling growth. In such cases, wider strips — such as treatment b — would be the safer choice.

■

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