



**PLANTING SITE,
SHADE, & LOCAL
SEED SOURCE:**

**Their effects on the
emergence & survival
of eastern white
pine seedlings**

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RAYMOND E. GRABER received his Bachelor of Science degree in forestry from the University of Washington in 1957. He then worked for 2 years in farm forestry and state forest management before taking graduate studies in forest ecology at Oregon State University. He joined the Northeastern Forest Experiment Station as a research forester in 1961, and he has worked mainly with problems of regeneration of white pine. At present he is associate plant ecologist on the staff of the Station's genetics project at Durham, New Hampshire.

PLANTING SITE, SHADE, & LOCAL SEED SOURCE:

Their effects on the emergence & survival of eastern white pine seedlings

THE PURPOSE of our study was to examine some of the factors that influence seedling emergence and seedling survival of direct-seeded white pine (*Pinus strobus* L.). Our major concern was the response of white pine to a particular set of growing conditions as determined by the planting site and the shade treatment. We were especially interested in the effects of these growing conditions on the seedling emergence pattern, on seedling survival, and on the causes of seedling mortality.

Local seed sources were used because the results of recent studies suggest that certain seed sources may be better adapted than others to the rigorous conditions that often exist during the period of germination and seedling establishment. Irgens-Moller¹ showed that Douglas-fir seed collected on a southern aspect germinated nearly twice as fast as seed collected on the northern aspect of the same hill. Rapid germination would definitely favor survival on hot, dry, south-facing slopes. Zobel (1959), working

¹ Personal correspondence with H. Irgens-Moller, 1960.

in Texas and Louisiana, found that survival of loblolly pine seedlings from seed collected from moist sites was about nil, while seed collected from drier sites only a few miles farther north produced very drought-hardy seedlings.

METHODS AND MATERIALS

Five seed lots were collected within a 30-mile radius in southwestern Maine. Each collection was made from five or more trees. Soil drainage at each location was classified according to the method of Husch and Lyford (1956). Descriptive information about the seed lots and the soil drainage at each location is presented in table 1.

Seed from the air-dried cones was extracted and cleaned by hand. Empty and partially filled seed were removed, by winnowing. The seed was stored in sealed containers at 36°F. for 4 weeks before sowing in early November.

Two old-field planting sites were selected to provide a wide range in natural soil-moisture regimes. One soil was a moist Sutton loam with a relatively high moisture-holding capacity. The soil drainage class was moderately well-drained. The other site

Table 1.—Seed and soil drainage information

Seed source	Seed per pound	Seed viability ¹	Soil drainage class
	<i>No.</i>	<i>Percent</i>	
North Fryeburg	21,300	99.5	Excessively drained
Acton	24,000	99.0	Somewhat excessively drained
Alfred	17,700	98.5	Somewhat excessively drained
Lovell	24,000	87.5	Well-drained
Lebanon	20,900	94.0	Moderately well-drained

¹ Based on laboratory germination test.

was a droughty Windsor loamy sand. This excessively drained soil had a very low moisture-holding capacity.

Although the two planting sites differed in many ways, including differences in fertility, pH, and texture, the main difference was in their relative ability to store moisture near the surface and thus favor or restrict seed germination and initial seedling survival.

In preparation for planting, both sites were plowed and disked. During the growing season, all plots were hand-weeded frequently to control herbaceous competition.

We tested two light-intensity treatments by placing separate covers over each of 24 small seeding locations or units at each site. Light shade — 85 percent of full light — was provided by covers of No. 2 mesh hardware cloth. Heavy shade — 40 percent of full light — was provided by attaching Lumite Saran² shade cloth to the top and sides of hardware cloth covers. These covers also served to exclude small mammals and birds.

The 24 seeding units at each site were arranged in 6 blocks of 4 units each. Two units were given light shade, and two units were given heavy shade. There were five rows per unit, one randomly assigned to each of the seed sources. Rows were spaced 6 inches apart, and each row was sown with 20 seeds at 1-inch intervals. Seeds were pressed into the soil surface and then were covered with 1/3 inch of soil. The sowing was completed in November 1961.

Starting in early May, observations were made twice each week to record seedling emergence and mortality. As each seedling emerged, it was marked with a color-coded toothpick. When mortality occurred, the marker was removed, and the cause of death was recorded. The final observation was made in late October 1962.

For the subsequent statistical analysis of data, the two seeding units under each light intensity in a block were treated as one plot, and the two rows of each seed source in a plot constituted

²Mention of a particular product does not imply endorsement by the Forest Service or the U. S. Department of Agriculture.

a subplot. That is, in each block, the data from two similarly shaded rows of the same seed source were averaged and handled as single observations. The treatments and seed sources were tested for significance at the 5-percent level of probability by analysis of variance for a split-plot experiment nested within two sites.

RESULTS AND DISCUSSION

Total Emergence

Emergence was good: an overall average of 76 percent of the viable seeds produced a seedling. The effect of seed source on seedling emergence was not statistically significant. Differences among the five seed sources were small and could not be logically related to soil drainage at the seed collection sites (table 2).

Planting site, shade intensity, and their interaction — site x shade — significantly affected seedling emergence. The interaction between the planting site and the shade intensity reflects the major influence of soil moisture on germination and seedling emergence (fig. 1).

Moisture at and near the soil surface of the coarse, excessively drained soil (dry site) was rapidly depleted by evaporation, and thus the moisture supply was critically low much of the time.

Table 2.—Emergence of viable seed from five local sources in order of increasing moisture at seed-collection site

Seed source	Seedling emergence
	<i>Percent</i>
North Fryeburg	78
Acton	71
Alfred	75
Lovell	79
Lebanon	75

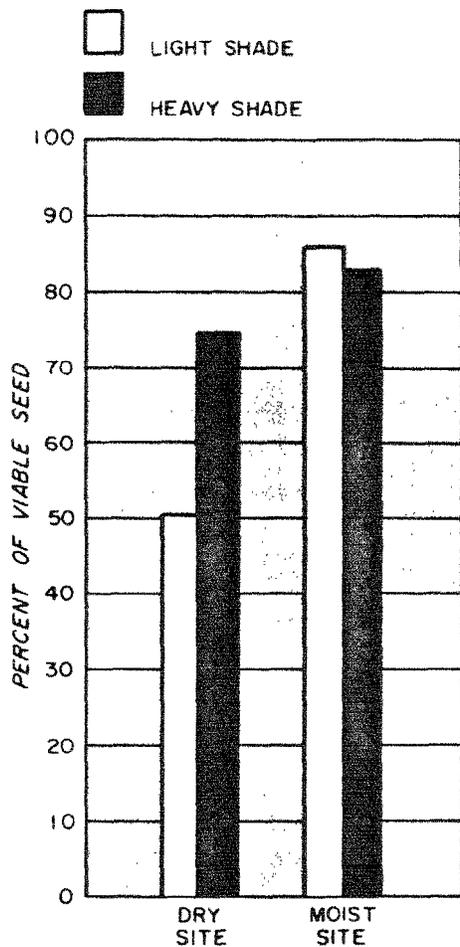


Figure 1.—Total seedling emergence as affected by planting site and shade intensity.

This lack of an adequate moisture supply is believed to be the major factor limiting seed germination and subsequent emergence on the lightly shaded plots on this site. Although moisture was still believed to be less than optimum on the heavily shaded plots, the periods of moist conditions favorable for germination were much longer. This was due to the greatly reduced insolation and air movement. After periods of light rainfall of 0.10 to 0.25 inches, the heavily shaded plots would remain moist at the soil surface for 1½ days or longer, whereas the lightly shaded plots were usually surface-dry in ½ day.

Available water in the imperfectly drained loam (moist site) was ample; this soil remained moist to the surface on all plots during the entire period of germination and emergence in May and June. As a result there was no increase in emergence under the heavy shade.

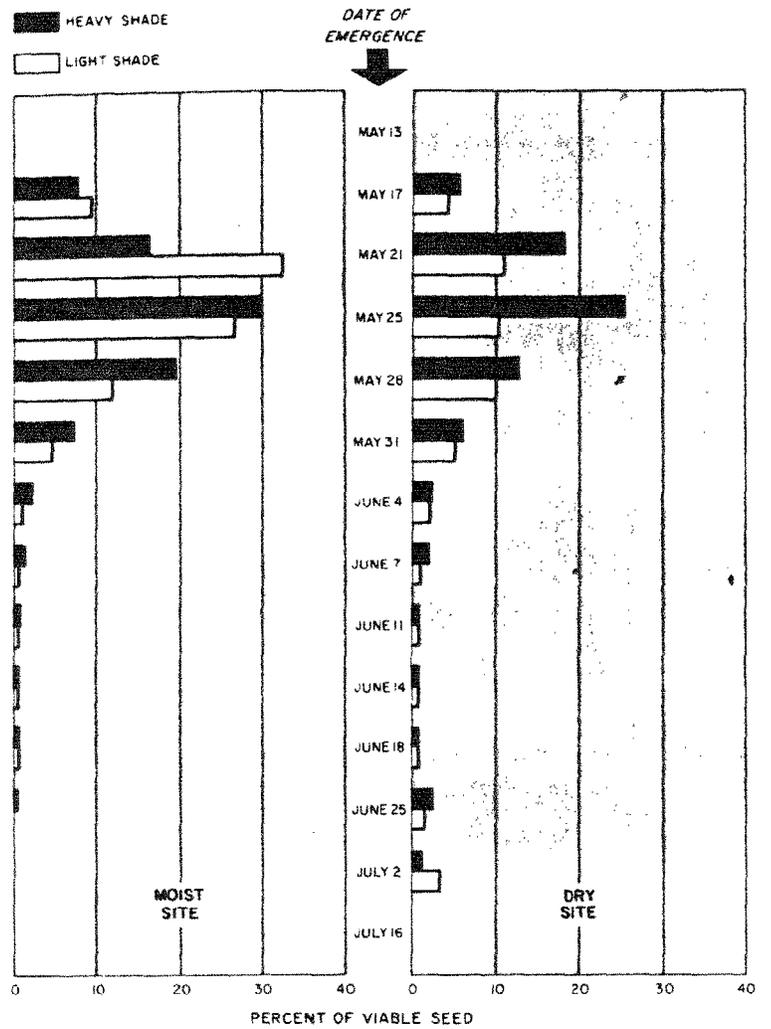


Figure 2.—Periodic seedling emergence as influenced by planting site and shade intensity.

Time of Emergence

The first seedlings appeared in mid-May, and by the end of the month 96 percent of the total emergence had occurred. Peak emergence occurred May 21 on the lightly shaded plots and May 25 on the heavily shaded ones (fig. 2).

These differences are the logical results of limiting environmental factors. In early May the soil moisture at both planting sites was near field capacity, and it was cold. On the moist site, seedling emergence did not occur until the soil began to dry and become warmer. Under the heavy shade, emergence was retarded, probably because of the cooler temperatures here.

On the dry site the soil dried rapidly, particularly at and near the surface. By the time temperature no longer limited germination, moisture on the lightly shaded plots was very likely inadequate. This resulted in an early peak emergence with a gradual decline in emergence as conditions (temperature and moisture) during the following 10 days became progressively less favorable. Under heavy shade, cooler moister conditions prevailed, and the emergence pattern was like that on the moist-site plots.

Seedling Survival

Seedling survival during the first growing season was uniformly good; of all the seedlings that emerged, 76 percent were alive at the end of October. Survival did not differ significantly among sites and treatments.

Apparently the variables of shade and site were important primarily during the critical period of germination and seedling emergence. After emergence had occurred, mortality was essentially similar regardless of these variables.

Seedling losses were related to the date of emergence. The later the emergence date, the more likely that mortality would be high (fig. 3). The seedlings emerging before May 26 averaged less than 20 percent mortality, but those emerging in late May and in June suffered much greater losses and averaged more than 60 percent mortality by the end of June.

TIME OF
EMERGENCE

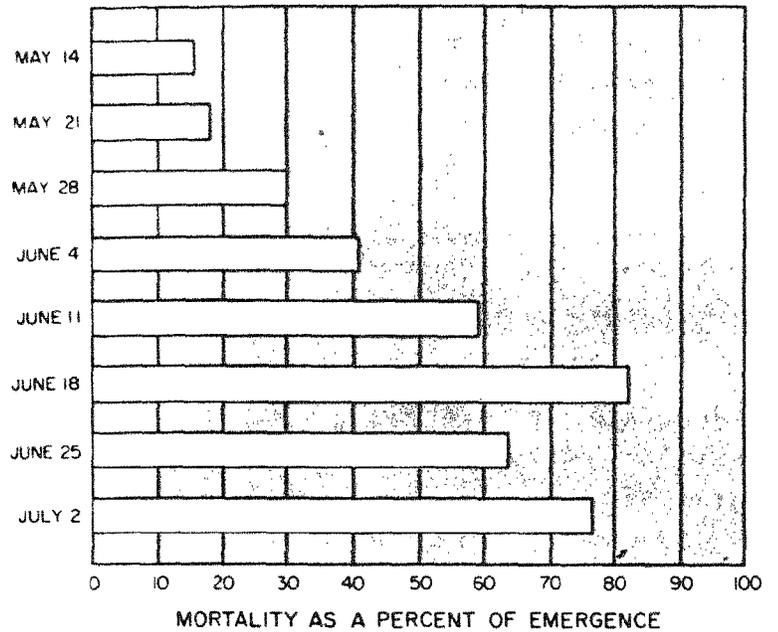


Figure 3.—Seedling mortality during first growing season as related to time of emergence.

There are several possible reasons for this rapid increase in mortality. (1) Weather conditions became less favorable as the season progressed, and losses from heat and from lack of moisture increased. (2) Those seeds occupying the more favorable microsites germinated earlier, but those situated under less favorable conditions tended to germinate late. And (3) germinative vigor may have been greater among the seedlings that emerged early in the growing season. Spurr (1944) found that the largest white pine seeds germinated first and that seedlings from these seeds survived better than those from the smaller seeds.

Regardless of the cause of mortality, survival was much poorer among seedlings that emerged in late May and in June. However, the overall effect of late emergence on seedling survival

was small because most of the seedlings had emerged before that time.

Causes of Mortality

The two most important causes of mortality were failure-to-establish and damping-off. The differences associated with site determined which of these causes would be preminent (fig. 4). On the dry site, failure-to-establish accounted for 60 percent of all losses; on the moist site, damping-off accounted for 66 percent of all losses. Seedlings of the five seed sources did not differ in their susceptibility to these and other causes of mortality.

Failure-to-establish occurs when a seed germinates on or near the surface and the root tip is unable to penetrate to a moisture supply in the soil before the root dries out and dies. The direct cause of such mortality is lack of sufficient moisture, but this lack of moisture is frequently complicated by soil crusting or compaction, which acts as a barrier to root penetration. Although

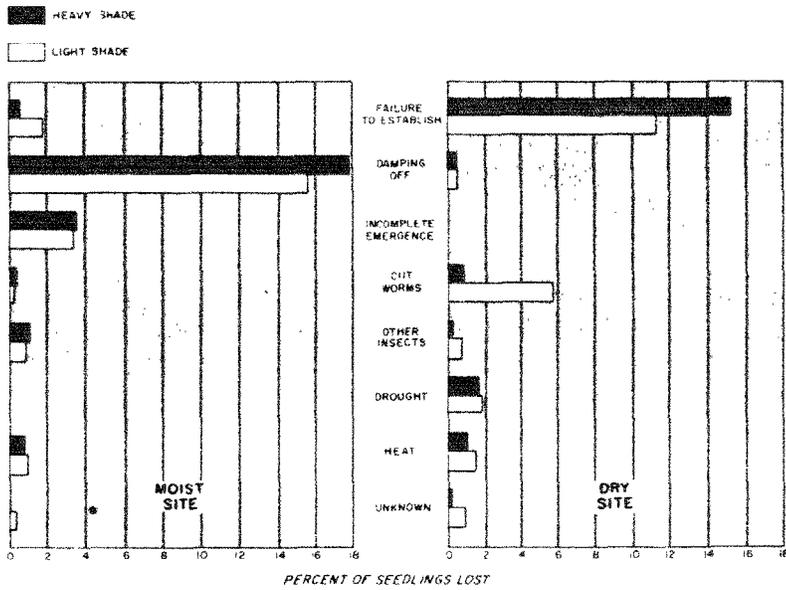


Figure 4.—Seedling mortality, by causal agents, in the first growing season.

this type of mortality is closely related to drought and is most common on dry sites, it differs from true drought mortality in that it can be overcome by planting the seed deeper.³

The failure-to-establish losses were low on the moist site, particularly on those plots under heavy shade. This was due to the better moisture supply, which enabled almost all seedlings to become established. On the dry site the failure-to-establish losses were most numerous on the heavily shaded plots. This was a reflection of the transitory nature of adequate surface moisture. Seeds exposed on the surface under light shade generally did not germinate, whereas many similarly placed seeds under heavy shade did germinate but then died before the root could reach moist soil.

Losses caused by damping-off fungi were closely related to planting site. The losses were negligible on the dry site and relatively high on the moist site. The high mortality on the moist site is believed to reflect not only the continuously moist conditions, but also the higher pH (about 6.0) of the Sutton loam. Both of these conditions would favor the development of damping-off fungi.

Other relatively minor causes of mortality were incomplete emergence, cutworms, drought, and heat injury.

Incomplete emergence⁴ occurred only on the moist site where soil strength was sufficient to resist extraction of the cotyledons.

Cutworms were most damaging on the dry site, particularly in the lightly shaded plots. The heavy shade cloth very likely was a physical barrier to the movement of these larvae and may have been responsible for the reduced damage under that condition.

Drought losses did not occur on the moist site and were

³As noted earlier, our planting procedure was to press the seed into the soil surface and then cover it with 1/3 inch of loose soil. During the winter, some washing and frost-heaving occurred; and in May approximately 20 percent of the seeds were exposed. Had the seeds been planted deeper, the failure-to-establish losses almost certainly would have been reduced; on the other hand, had the seed been sown on the surface with no soil covering, the losses would have been much greater.

⁴Incomplete emergence occurs when the seedling hypocotyl emerges in the normal manner but is unable to extract the cotyledons from the soil and become erect. The buried cotyledons decay and the seedling dies.

minor even on the dry site. This mainly reflects the favorable periodicity and volume of rainfall during this particular growing season — 1962.

Heat injury caused minor losses under all treatments but was most damaging on the lightly shaded, dry-site plots. Small pieces of dark-colored organic matter were almost always in direct contact with the stems of injured seedlings and caused a lethal buildup of heat.

SUMMARY

Five white pine seed lots, collected locally over a range of soil drainage conditions, were sown on two planting sites (dry and moist) under light shade (85 percent of full light) and heavy shade (40 percent of full light) to test the effects of planting site and shade on seedling emergence and seedling survival.

Local seed source had no significant effect either on emergence or on survival in the first growing season.

The modification of the seed-seedling environment induced by heavy shade tended to overcome the unfavorable conditions of the dry planting site. Moisture was conserved at and near the soil surface, and the increase in moisture greatly increased seedling emergence. On the moist site, where lack of moisture was not a limiting factor, heavy shade slightly reduced seedling emergence.

Total seedling survivals were about equal among sites and shade treatments, but seedling losses due to each of the two major causes of mortality — failure-to-establish and damping-off — were strongly influenced by the site and the shade treatment. Almost all the losses caused by damping-off fungi occurred on the moist site. Nearly all the failure-to-establish mortality occurred on the dry site, particularly on plots under heavy shade where conditions on the soil surface were temporarily favorable for germination of seeds, but were of too short duration to allow seedling establishment. Other causes of seedling mortality were minor.

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