# *FROST HEAVING ...*

## seedling losses can be reduced

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*Frost heaving causes serious losses to direct-seeded white pine. Shading, both during the growing season and during the dormant season, significantly reduces losses. Retaining some portion of the natural plant cover on areas to be direct seeded is recommended to provide shade and reduce frost heaving.*

During late fall and early spring, exposed soils freeze almost nightly and thaw again the following day. The mechanical lifting and falling of the soil that accompanies this freezing (frost heaving) often kills small plants such as tree seedlings. A recent Forest Service study to evaluate the importance of frost heaving and the effects of shade on seedling mortality indicates that heavy losses from frost heaving can be avoided if some portion of the natural overstories are left to shade direct-seeded sites.

### Methods and Materials

The study was established on an old field in southwestern Maine that had been plowed and disked before sowing. The soil was a Windsor loamy sand subject to periodic drought. White pine *(Pinus strobus* L.) was sown during November in 18 small (2 by 3 feet) plots containing 5 rows of 20 seeds each. The small plots were randomly assigned a shade level of either 85 or 40 percent of full light during the growing season.

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 Lumite saran shade cloth attached to the top and sides of the hardware-cloth covers.

At the end of the first growing season, all but five seedlings in each row were removed, leaving 25 well-spaced plants per plot. The nine plots from each of the two growing season shade treatments were divided into three subgroups of three plots (replicates) each, and were randomly assigned dormant season light intensity treatments of 40, 85, and 100 percent of full light.

Analysis of variance was used to test the significance of the shade effects in this randomized block experiment.

Regular weekly observations of seedling condition during the dormant. season beginning in October were supplemented by daily field checks during periods of active frost heaving. Observations were discontinued after a heavy snow in December and resumed following the spring melt.

### Results and Discussion

Frost heaving results from the formation of ice lenses at and just beneath the surface. The severity of a given heave depends primarily upon an adequate supply of water and a suitable temperature regime.

Frost heaving is frequently considered a problem only on moist clay and silt soils and of little

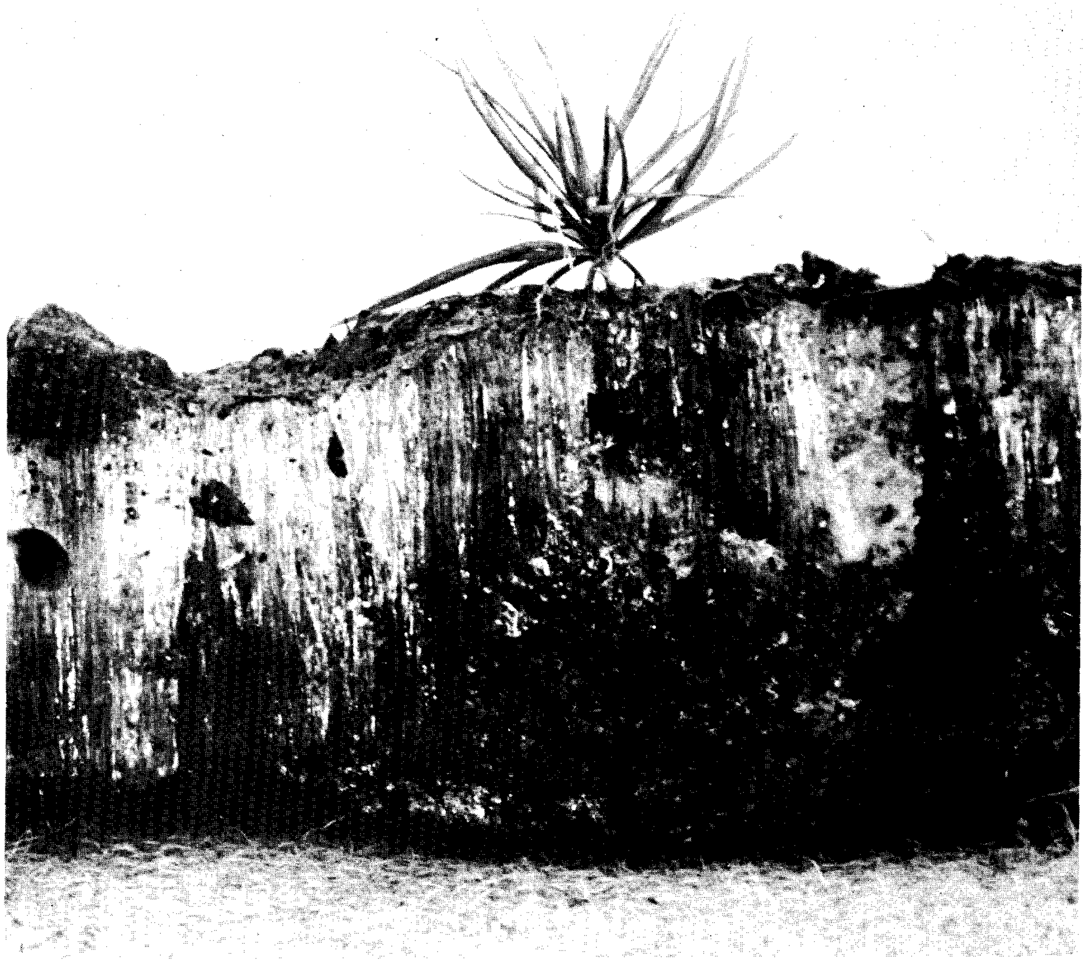

Figure 1.—Stalactite frost has lifted the soil surface 1 to 2 inches. The frost action has not lifted or damaged the seedling.

importance on a coarse-textured loamy sand such as the study site. However, even a coarsetextured soil is quite moist during the late fall and early spring, and consequently, frost heaving does occur.

*Frost* types.-The most spectacular frost type observed was *stalactite1* frost, in which many small vertical columns of ice formed just below the soil surface and lifted it as much as 3 inches (fig. 1). This type of frost characteristically forms a discontinuous pattern, and in any one heave most of the seedlings were left undamaged.

*Honeycomb* frost, characterized by a rigid but porous structure, was the most common. The maximum lift of this frost type never exceeded 2 inches.

A third type, *concrete* frost, had a very dense structure and very small ice lenses throughout the frozen layer. Concrete frost caused little lifting, so very little seedling damage was associated with it.

1 Frost types follow the classification by F. A. Post and F. R. Dreibelbis. (Some influence of frost penetration and microclimate on the water relationship of woodland pasture and cultivated soils. Soil Sci. Soc. Amer. 17: 95-103. 1942.)

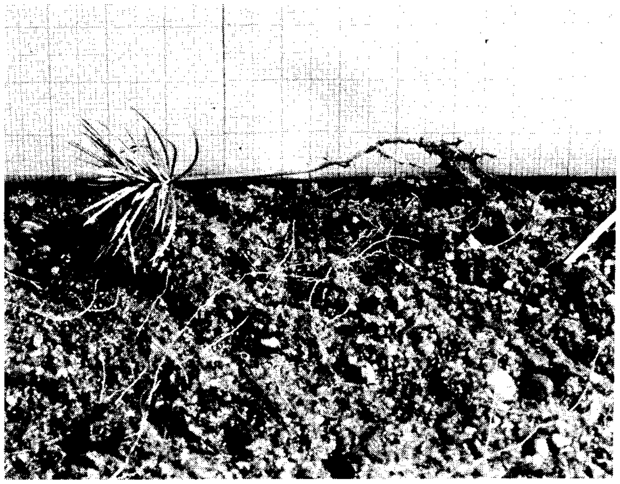

Figure 2.—This seedling has been lifted out of the soil by repeated frost heaves.

*Time of heaving.*-Frost heaving of the stalactite type began in mid-October, but few seedlings were injured at that time. By mid-November, when honeycomb frost was most common, the moist soil was frost heaving nightly, killing some seedlings.

In late November and December, the days and nights became colder, and often the soil did not thaw during the day. On very cold nights, concrete frost formed, occasionally to depths of 1 to 2 inches. No further thaws occurred after December 10; and the concrete frost penetrated steadily deeper, reaching an average depth of 8 inches before a heavy snow cover in late December ended any further penetration.

After the spring snow melt (April 4 to 6), the soil began to thaw from the surface downward. At this time, the relatively impervious concrete frost acted as a drainage barrier, holding the melt water on or near the surface. Disastrous frost heaving of the stalactite and honeycomb type took place. Within a week, the concrete frost melted and the natural soil drainage was restored. Frost heaving continued through April and into early May, but diminished in frequency and magnitude. The last damaging instance occurred May 3.

The total number of heaves during the entire dormant season was 32; about 60 percent occurred in the fall. However, those which occurred in the early spring were the most damaging.

*Mortality caused by heaving.*-Seedling losses caused by frost heaving took several forms. A characteristic mortality occurred when a seedling was lifted by successive heaves until the root system was exposed on the surface (fig. 2). This *heaving out* of seedlings accounted for 35 percent of all losses.

Even more important, but less noticeable, were losses that occurred after only *partial heaving.* Seedlings lifted only one-third inch often died. A common characteristic of these seedlings was severe root pruning-much of the fine root system was torn away when they were heaved only slightly. Occasionally, the root systems were suspended in subsurface air pockets caused by the frost heaving. Typically, the tops of these seedlings turned red during the first warm weather in the spring, even though the soil was moist at this time. Forty-four percent of the seedling mortality occurred after only partial heaving.

*Stem girdles* (fig. 3) caused by mechanical'

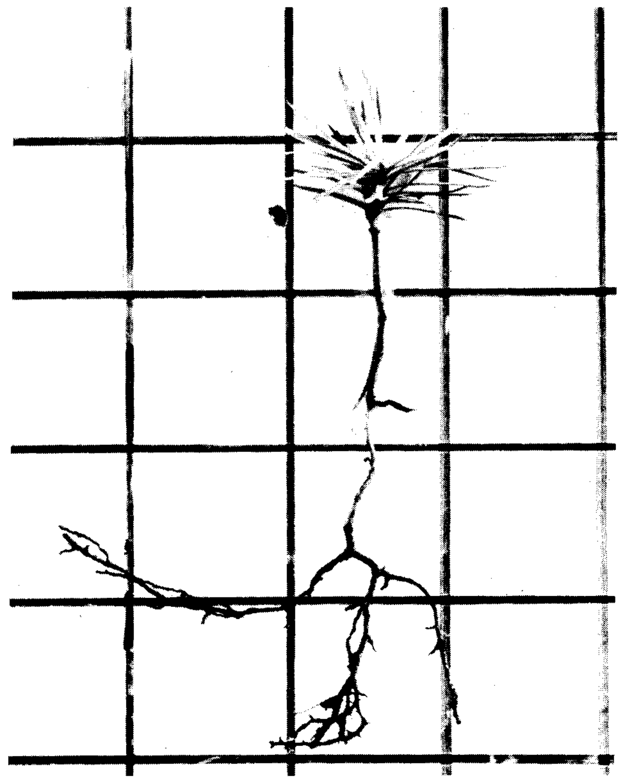

Figure 3.—Mechanical abrasion due to the heaving of frozen soil has caused the girdling of this seedling just above the root collar.

abrasion of the seedling stem accounted for 11 percent of all losses. Girdling occurred when there was a firm bond between the frozen soil surface and the seedling stem. As the soil surface was lifted by frost,. the soft epidermis and cambium were ruptured and forced upward, girdling the seedling just below the point of frozen soil attachment.

*Seedling decapitation* (fig. 4), a minor cause of mortality was grouped in the study with losses caused by girdling. Decapitation resulting from frost heaving can be confused with other unrelated seedling losses (e.g., animal browsing). Often when stalactite frost formed, the frozen soil moved up the seedling stem until it reached the point of cotyledon attachment. If the ice lense continued to lift, the epidermal-cambial cylinder was severed at this point, and the seedling top was lifted off the stem. Where heaving was less severe, the cambium was broken just beneath the cotyledons; but the top was not lifted off.

Ten percent of the mortality occurred when the largest seedlings were severed at or just below the ground line. Severing occurred when the seedling root system held, and the force of the frost heave snapped the primary root.

*Effect of light intensity.* Shading levels, including both the growing season and the dormant season treatments, greatly affected (statistically significant at the 1-percent level) seedling mortality caused by frost heaving (fig. 5). The direct effects of the three light intensities during the dormant season are easily explained. The two light intensity treatments below full light (85 percent and 40 percent of full light) tended to moderate temperature fluctuations at the soil surface.

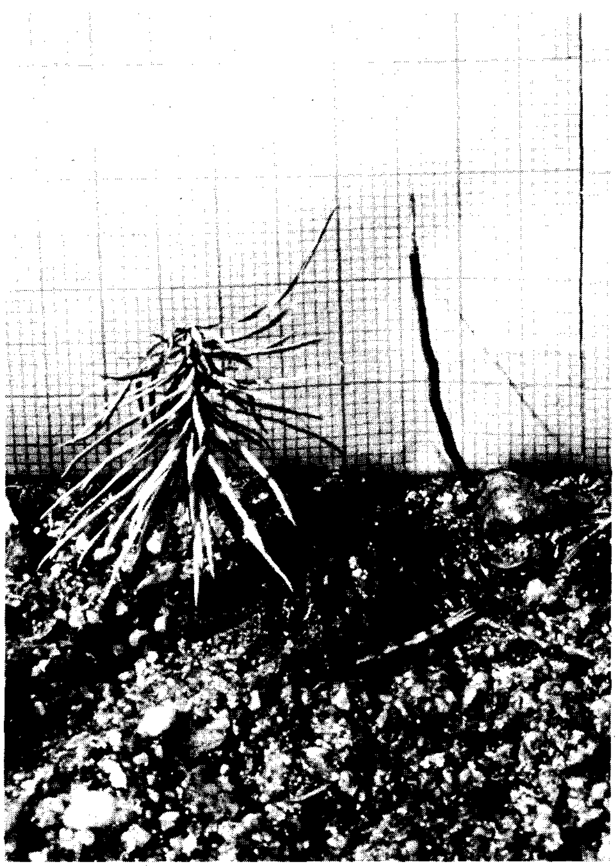

Figure 4.—This seedling was decapitated by a stalactite type of frost heaving. The frozen soil surface was lifted by the stalactite frost, severing the shoot at the point of cotyledon attachment.

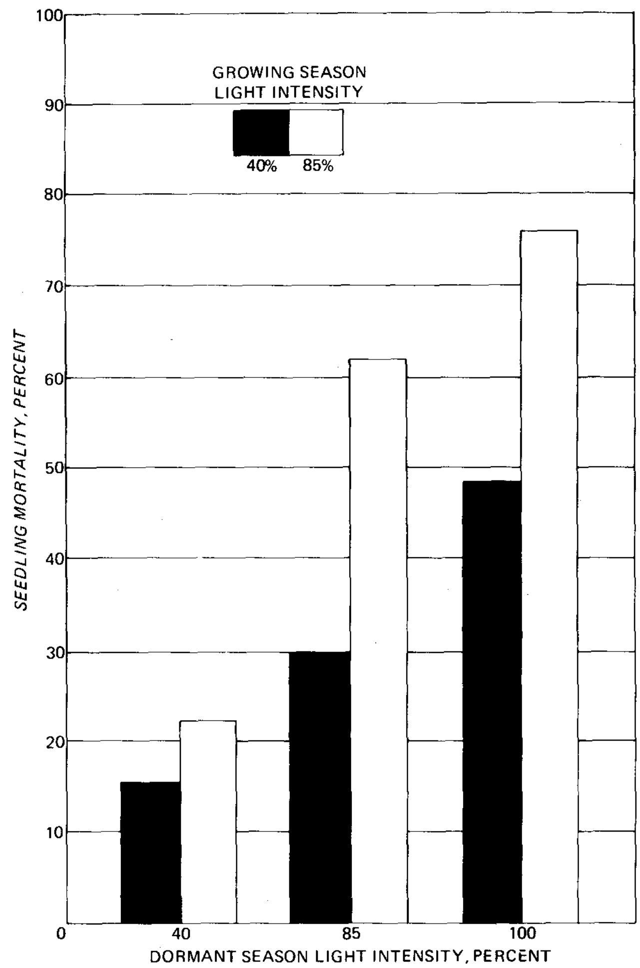


Figure 5.—Seedling mortality as influenced by light intensity.

Often, the most damaging frost heaves occurred on nights when the air temperature was only 1 or 2 degrees below freezing. The heavy shade cover (40 percent of full light) provided sufficient protection so that frost heaving did not occur at such times. Even more important were the daytime effects when the shade covers (both 85 percent and 40 percent) reduced radiation intensity and consequently prevented the soil from thawing. The unthawed surface was not subject to a new heave the following night. . Shading during the dormant season reduced the frequency and magnitude of the frost heaves by reducing incoming solar radiation on the soil surface during the day and by conserving soil heat at night. The heavier the shade, the more the mortality was reduced.

Less obvious was the influence of the growing season shading. Seedling losses on plots that were lightly shaded during the growing season were 22 percent greater than heavily shaded plots. Soil density variations at and just below the surface probably caused this difference.[2] On the lightly shaded plots, the impact and puddling caused by heavy summer rainstorms created a relatively compact dense surface structure while the shade-cloth covers on the heavily shaded plots absorbed the impact of the individual raindrops, preventing surface compaction. So, under light shade, a dense surface layer developed that was much more subject to frost heaving than the loose porous surface layer that existed on heavily shaded plots.

[2]Beskow, Gunnar. Soil freezing and frost heaving with special applications to roads and railroads. Swedish Geo logical Society, Series C, 375. 130 pp. 1935.

## Conclusions and Recommendations

Seedlings growing on exposed mineral soil are susceptible to heavy mortality due to frost heaving, even on the excessively drained sandy soils typical of the drier sites in New England. Almost 75 percent of the seedling losses were on the most exposed plots during the first dormant season. Shading during the growing season and more 'importantly during the dormant season, can greatly reduce losses. Similar benefits result from the natural shading of partial or complete overstories of dominant vegetation where trees are direct seeded on a mineral soil seedbed in an understory.[3]

Thus, direct seeding techniques that take advantage of shade from existing low value or otherwise undesirable vegetation are best adapted to conditions in this region. Site preparation should be held to the minimum necessary to control competitive vegetation and prepare favorable seedbeds. Catastrophic losses due to frost heaving are unlikely to occur where part of the natural overstory is retained on direct seeding site's.

[3]Graber, R. E. Direct seeding white pine in furrows. *In* Proc. Direct Seeding in the Northeast-A Symposium. Univ. Mass. Exp. Sta. Bull., pp. 99-101. 1965.