Root growth capacity: One key to bare-root seedling survival

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More often than is generally recognized bare-root coniferous seedlings are planted that cannot possibly survive. For example, most of the true-fir (*Abies concolor* and *A. magnifica*) seedlings planted in the Sierra in 1978 never had a chance. In several plantations there are no survivors, and a preliminary survey has indicated that, overall, survival may be as low as 30 percent. On the other hand, the white fir seedlings planted during 1976 and 1977, at the height of the drought, came through with flying colors. Certainly not because of the drought, but because following transplanting, these seedlings had the capacity to develop extensive root systems—the key to bare-root seedling survival in California.

Why was the capacity high in 1976 and 1977 and low in 1978? We now believe that variation in the nursery climate was responsible and that most bare-root seedlings raised in California can be expected to respond similarly.

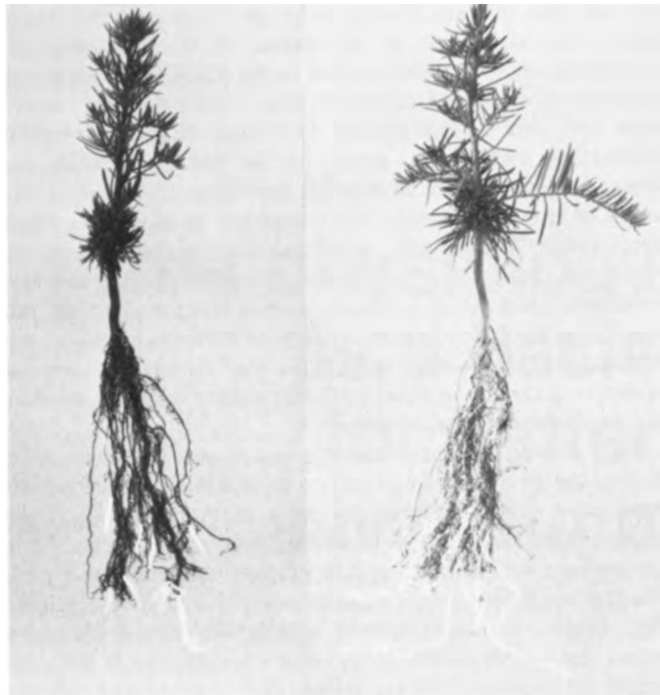
Since the early 1950's the University of California Department of Forestry has joined the California State Division of Forestry and the U.S. Forest Service in determining why some seedlings develop extensive root systems following transplanting and others do not. As a quantitative measure of this root growth capacity (RGC) we have used the root growth of a representative sample of seedlings in a standard test environment.

The seedlings are transplanted into watertight containers filled with a forest soil in which the soil water potential has been adjusted to -0.3 bars. The containers are then immersed in a 20°C water bath located in a room maintained at 25°C during a 12-hour day and at 20°C during the night. Light closely resembling sunlight is supplied by Xenon lamps. Water is added periodically to the containers to maintain the water potential between -0.3 and -0.5 bars. Twenty-eight days later, the seedlings are removed from the containers and all new root growth greater than 3 centimeters in length is recorded. Average elongation per seedling serves as a measure of the RGC the seedlings had when placed in the test environment.

We were handicapped in our early studies of the relationship among RGC, nursery climate, and cold storage by a lack of controlled environment facilities. Efforts to establish firm correlations were repeatedly complicated by variation in the nursery climate, the importance of which could not be assessed. But following the completion of four temperature-controlled greenhouses in 1972 and five controlled environment chambers shortly thereafter, the effect of climatic variation on RGC could be evaluated.

Early findings

Before these controlled environment facilities became available, however, we found that the RGC was low before the onset of cold autumn nights and increased steadily until a peak was reached two to three months later. Often the RGC then abruptly decreased. Sometimes, it remained at the peak level for a month or more and then decreased. In most cases it increased to a second, but lower, peak in the late spring. When RGC was plotted against time, the shape of the curve as well as the magnitude of points along the curve varied from one nursery to the next, and at any one nursery often varied from one year to the next.



Unseasonally warm early winter temperatures can reduce root growth capacity. Seen here are typical root elongations—one month after removal from cold storage—of seedlings grown with a two-week warm interruption in December, left, and without an interruption, right.

Later, we found that when cold storage was employed, the highest RGC that could be obtained subsequent to storage required that the seedlings be placed in storage when the RGC could, according to our estimate, be expected to reach its first peak. Initially, this estimate was based on the number of hours the seedlings had been exposed to temperatures lower than 10°C; later it was based on the number of nights the seedlings had encountered during which the temperature dropped to 5°C.

Once in a while, the RGC of seedlings removed from storage was too low to assure seedling survival following planting in the field, even though the seedlings had been place in storage when the RGC, according to our estimate, could be expected to reach its first peak. Still later, we found that seedlings can survive over a wide range of RGC's because the minimum acceptable RGC—the RGC at which field survival is not further increased when seedlings with a higher RGC are planted—varies with the species, the time of planting, and the environments encountered on the planting site.

Controlled environment findings

Only after controlled environment facilities became available, enabling us to follow the RGC of seedlings grown in various nursery climates under our control, was a hypothesis for the variability encountered in the RGC in our previous studies forthcoming. Unseasonally warm temperatures during late autumn or early winter appear responsible. Although this is still only a hypothesis, it is strongly supported by the RGC patterns obtained when seedlings are grown in controlled nursery climates, with and without warm interruptions.

When seedlings are not subject to a warm interruption (which in our studies means that once a 5°C temperature is initiated it is maintained throughout the study) the RGC steadily increases to a peak over one, two, or three months. How long it takes to reach the peak depends on the time that has elapsed after shoot elongation has ceased before cold temperatures are initiated. Once the peak is reached, the RGC generally decreases abruptly. Sometimes, depending on the species and seed source, it remains near the peak for a month or more and then decreases. Later, a second peak is reached, one that is generally lower than the first although in a few seed sources it is higher.

In our studies, when seedlings are subject to a warm interruption, the temperature is raised to 20°C for two weeks, six weeks after a 5°C temperature is initiated, and then the temperature is returned to 5°C. The result: the RGC decreases abruptly by 50 percent or more.

The RGC is always reduced when seedlings are placed in cold storage. When they have not been subject to a warm interruption the magnitude of the reduction is not uniform and depends on the length of the time the seedlings are exposed to a 5°C temperature before being placed in cold storage. Invariably the minimum reduction in the RGC occurs when the RGC reaches its first peak or shortly thereafter. Consequently, since the RGC is high to begin with during this period, a minimum reduction leaves these seedlings with the highest RGC. This means there is a better chance that seedlings placed in storage during this period will come out of storage with a RGC above the minimum acceptable level than if they were placed in storage either at an earlier or a later date.

On the other hand, when seedlings are subject to a warm interruption before being placed in cold storage, the RGC, already reduced by the warm night interruption, is further reduced by storage. In all cases the effect is sufficient to reduce the RGC of 70 to 80 percent of the seedlings coming out of storage to below the minimum acceptable level characterized by field survival.

Before we can characterize a climate as one with warm interruptions that can affect RGC, we must determine the minimum temperature and duration required for a warm interruption to be deleterious. Should warm interruptions prove to be anywhere near as effective in reducing RGC as our studies suggest, and should they prove to be as widespread as temperature records indicate, a strong case can be developed for moving nurseries subject to warm interruptions to locations where such interruptions rarely occur, or for identifying those species that can be grown without the danger that their RGC's will be reduced below a minimum acceptable level by warm interruptions.

In favorable years at some nurseries ponderosa pine seedlings, for example, are produced with an RGC considerably above the minimum acceptable level. At such nurseries, warm interruptions that reduce the RGC of these seedlings by 100 cm or more can be tolerated, because after such a reduction the RGC is still above the minimum acceptable level. But when true-fir seedlings are produced, we do not have this kind of latitude. The maximum RGC is much lower and any significant reduction because of warm interruptions in the nursery can be expected to be directly reflected in lower field survival.

Summary

It now appears that if bare-root, cold-stored, true-fir seedlings, with a consistent minimum acceptable RGC are to be available for planting in the Sierra, new nursery locations may be required. Additional studies will be needed to determine whether this is so, and if so, where new nurseries should be located.

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Restocking harvested forestland.

Optimum initial stocking density in ponderosa pine plantations

Dennis E. Teeguarden

Under California laws, private owners of forests are required to maintain certain minimum tree stocking levels. The Z'berg-Nejedly Forest Practices Act of 1973 requires that within 5 years after a timber harvest, tree stocking must average no less than 300 points per acre. A tree with a diameter no more than 4 inches counts as one point; one 4 inches to 12 inches counts as three points, and each tree over 12 inches at breast height counts as six. Expressed another way, if all trees are harvested by clearcutting, the owner must have established on the site within 5 years at least 300 trees per acre. The state forester may require interplanting to raise stocking to the minimum acceptable standard.

The state's objective is to maintain and improve the productivity of commercial forests, but in developing ponderosa pine