CONIFEROUS SEEDLING PRODUCTION TECHNIQUES TO

IMPROVE SEEDLING ESTABLISHMENT 1/

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Abstract.--Both nursery and container-grown coniferous seedlings require programmed cultural techniques to permit completion of all physiological phases in dormancy. Failure to provide suitable environments to initiate, develop, and after-ripen winter resting buds and, finally, to satisfy chilling requirements will significantly reduce subsequent seedling vigor.

INTRODUCTION

The three critical areas that usually determine success or failure of seedling establishment are: the condition of the planted seedling, seedling handling and planting, and the environment at the planting site. The importance of planting stock condition frequently is neglected. Yet research results consistently show that proper physiological condition in general and dormancy in particular are critical factors leading to successful reforestation. How many times have you seen what appeared to be unexplained differences in seedling performance between trees lifted at different times during the season or lifted at the same time from different nurseries? In many of these situations declines in performance can be explained and corrected if the dormancy process is understood.

This paper gives a generalized management framework for seedling production based primarily upon research conducted on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and ponderosa pine (Pinus ponderosa Laws) seedlings. In addition, experience and the operational constraints of these species have contributed to the knowledge upon which this paper is based.

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NURSERY ENVIRONMENT AFFECTS POTENTIAL SEEDLING PERFORMANCE

Figures 1 and 2 show the problems associated with date of lifting and seedling dormancy in two groups of seedlings grown under different nursery regimes (I and II). For the seedlings grown in nursery environment I, second-year height growth was complete by mid-July, but in nursery environment II the seedlings were given high levels of moisture and nutrients throughout August and September and height growth continued during this period (fig. 1). The potential field

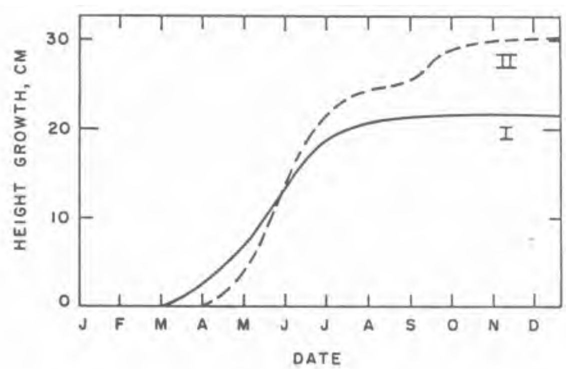

Figure 1.--Second-year cumulative height growth on Douglas-fir in two different nurseries (I and II).

survival[3/] of the seedlings in these two

3/Survival that may be expected for seedlings planted in areas of moderate environmental stress.

groups is drastically different. Although both groups of seedlings have a low potential for survival after lifting and outplanting during late summer and early fall, only those seedlings in environment I have a high potential for survival and growth when lifted between December and March 1 (fig. 2).

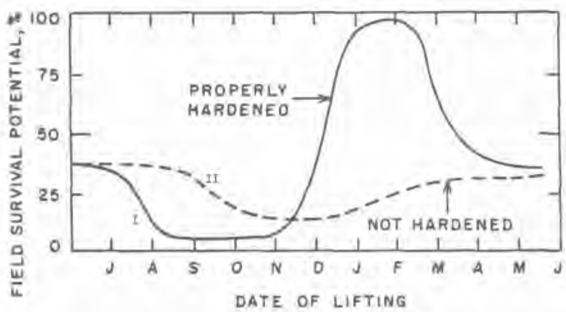

Figure 2.--Potential field survival of nursery stock that has been properly hardened off in late summer, I above. Failure to harden the seedlings results in loss of mid-winter peak, as shown in II above. This figure represents a synthesis of experience over several years with both Douglas-fir and ponderosa pine seedlings.

DORMANCY

Data obtained from laboratory trials and from empirical evaluation of nursery-grown seedlings have demonstrated that "dormancy" in Douglas-fir is not a single resting phase, but a series of physiological states, each with distinct characteristics and requirements. Conifer seedlings under natural conditions initiate dormancy in mid-summer, primarily in response to moisture stress. They generally do not resume shoot elongation until the following spring. This resting period may be divided into four physiological phases:

1. DORMANCY INDUCTION from early or mid-July to mid- or late September. During this period terminal buds are initiated, developed, and after-ripened largely in response to moisture stress. If plants are well watered, or exposed to long photoperiods, the buds may break and the seedlings produce a second or third "flush" of growth.

2. DORMANCY DEEPENING from mid- or late September to mid-November. Plants in this state have well-formed buds that will resume growth only slowly or not at all in response to a favorable environment. Seedlings in this state are susceptible to damage from desiccation, cold storage, or any disturbance caused by normal nursery handling.

3. DORMANT PHASE from early or mid-December until mid-February. Plants in this state are indistinguishable from those in phase 2 morphologically, but they have a strikingly different physiology, which results in a much greater resistance to environmental stress than the seedling encounters during the winter and/or during transplanting.

4. POST DORMANCY from mid-February until bud burst in spring. During this phase, seedlings gradually lose their frost resistance and will grow if placed in a favorable environment. The seedlings are no longer resistant to stresses that might be encountered during lifting, storage, or planting.

Awareness and appreciation for the significance of the phases in the dormancy period dictate that we design our nursery practices to insure that each phase is complete and that all metabolic shifts during each phase of the annual growth cycle have taken place. Only then will the seedlings have a maximum potential for growth and survival after transplanting to a field site.

NURSERY PRACTICES AFFECT SEEDLING VIGOR

Douglas-fir seeds normally germinate in April at elevations below 2,000 feet in the Cascade Mountains or the Coast Range. Unfortunately, northwest nursery soils are frequently too wet to work in early spring, so seeding is delayed until mid-May or later. Therefore, the earliest possible sowing of seed, which has been stratified for at least two months to assure rapid germination even in cold soils, is essential if seedlings are to develop at a maximum rate during May and June. During this period, temperatures are generally mild, and irrigation is effective in maximizing both photosynthesis and growth. Later, during July and August when temperatures are high, seedling growth is restricted even with irrigation.

Irrigation schedules from mid-July until the onset of fall rains are crucial to the future vigor of seedlings. Under natural conditions, dormancy in Douglas-fir and ponderosa pine is induced and maintained by increasing moisture stress until plants are so "hardened" they can not resume growth in response to early fall rains. If nursery irrigation is too heavy or too frequent to permit development of true, well-formed, winter resting buds by late August, plants may respond by producing a second flush of growth in late summer or early fall. Even though such growth may appear favorable because it increases plant size, in actuality it most often has an unfavorable effect upon future plant vigor in two ways. First, the additional tissue produced is frequently nonhardy and is killed easily by early frosts. Second, the second flush causes long delays in the normal sequence of seedling physiology from dormancy induction to dormancy deepening. As a result, seedlings that have second-flushed are not conditioned properly for winter chilling/, which is necessary to assure prompt, vigorous growth of shoots and roots in the following spring. A failure to develop well-formed winter resting buds on the seedlings by mid-August frequently results in a delayed bud burst the following spring. Seedlings that demonstrate delayed bud burst usually have reduced survival potential. These seedlings generally suffer decreased rates of survival and growth after planting, especially on droughty sites.

Early vigorous root growth is also an important factor in successful establishment. Seedlings not allowed to complete all four phases of the dormancy sequence, as a result of either nursery mismanagement or early lifting, have been shown to have impaired root growth the following spring.

RECOMMENDED NURSERY PRACTICES

The most effective way to fulfill all of the seedling dormancy requirements is through nursery practices that create a favorable environment (Environment I) during each phase. Nursery irrigation schedules should be tailored to produce a moderate moisture stress in both first- and second-year seedlings between mid-July and the initiation of fall rains. Superficially, this recommendation may appear to conflict with the need to cool nursery beds by irrigation during hot days (85°F. or more). The cooling effect of water, however, is achieved largely through evaporation from the soil surface and seedling foliage. Therefore, frequently spaced, very light irrigations, where moisture does not penetrate to the rooting zone, are most efficient at cooling while maintaining a moderate level of seedling moisture stress. This treatment also allows seedlings to maintain high levels of photosynthesis.

First-year seedlings should initiate their final winter resting buds no later than August 1 (preferably July 15), but second-year plants should enter dormancy about two weeks earlier.

Once the winter resting buds are well formed, the seedlings require a period of mild temperatures and increasingly shorter days to prepare them for the beneficial effects of chilling and to induce frost hardiness. During this period, normally from mid-August until early December, the plants have low tolerance to the stresses created by lifting, packing, and shipping. Therefore, nursery harvesting should not begin until early December .5/ If seedlings must be lifted before early December, the mortality frequently associated with early lifting may be reduced, but not eliminated by: 1) lifting only seedlings that were placed on an irrigation regime designed to induce moisture stress 2 weeks earlier than previously recommended (around July 1); 2) planting only favorable, northern exposures with such stock: 3) scheduling nursery and field operations so that seedlings are planted no later than 2 days after lifting, and 4) wrenching seedlings during summer and early fall. If possible, seedlings should be kept in a cool location between lifting and planting rather than in cold storage.

Research data demonstrate that properly controlled, cold, dark storage is not damaging to seedlings lifted between mid-December and late February. In fact, seedlings lifted and stored in late February may be the only practical solution for regeneration of high-elevation areas with bare-root stock in the spring. Foresters should be aware, however, that production nurseries generally do not have the same degree of control over the storage of millions of seedlings that is possible with experimental material. Unless production facilities are upgraded, reforestation projects should be planned to utilize seedlings with a minimum possible storage period.

GREENHOUSE PRODUCTION

The concept of producing planting stock in containers and maintaining it in greenhouses, at least during the period of active seedling growth, appeals to foresters because this technique permits: 1) production of seedlings large enough to outplant on many forest sites within one year; 2) a probable reduction in planting shock through minimal disturbance of

4/In common with many temperate-zone plants, Douglas-fir and ponderosa pine both require exposure around 40°F. to stimulate the transition from dormant to post-dormant condition. Research has shown that seedlings require a period of about three months of constant 40°F. temperature to assure vigorous shoot growth. Under natural conditions, however, a substantially longer period of low temperatures is required because the fluctuating temperatures common to northwest winters are much less efficient in satisfying the chilling requirement of the plant.

5/The date of completion of dormancy deepening may vary slightly depending on latitude and local climate at the nursery in question.

seedling root systems at time of planting; 3) production of planting stock of uniform size; and 4) increased speed of planting. In theory, the system permits greater flexibility in reforestation as seedlings may be germinated any time between early winter and late spring, grown to plantable size, and outplanted from mid-fall until mid-spring of the following year. These advantages often have not been realized because the importance of seedling dormancy has been overlooked. Hundreds of thousands of containerized seedlings have failed during recent years as the containerized systems have been developed. Many of these trees would have survived if the seedling had been physiologically ready for the field environment. The physiological constraints mentioned earlier must be satisfied if seedlings grown in greenhouses are to achieve maximum survival and growth after outplanting.

Tables 1 and 2 present suggested schedules for seedling production in greenhouses to assure that the seedling physiology enhances the establishment of successful plantations. Conditions such as 3a or 4 in Table 1 may be difficult to achieve in practice, but even approximations should stimulate development of desired seedling physiology.

CONCLUSION

The preceding discussion has outlined constraints placed on both nursery and field operations by the physiological requirements of the seedling. Both the seedling production and planting phases of reforestation are important links in regeneration. When these two operations are in phase with the physiology of the seedlings, reforestation will be more successful. This means that seedlings must be produced in such a way as to be physiologically ready to outplant into the field environment. In addition, the field forester must not demand his seedlings before they are ready to make the transition from the easy environmental conditions in a nursery or greenhouse to the harsher, less favorable field environment. Lifting from nurseries in the Douglas-fir region of the Pacific Coast States should not begin before December 1 and should be completed no later than March 1. Ponderosa pine nurseries in these same states should plan to lift in late winter or early spring and should complete this operation as early as practical. Specific recommendations for container seedlings are dependent on the outcome of field tests.

Table 1.--Greenhouse schedule for production of seedlings to be outplanted in the fall

1. December 15-January 15. Germinate seed.
2. January 15-June 15. Active seedling growth. Artificial illumination of about 1,000 ft.-cd. intensity should be supplied for 14 hours each day to supplement natural light until April 1.
3. June 15-August 1. Induce dormancy and develop winter resting buds. The following will stimulate a transition from active shoot elongation to dormancy:
    a) moderate moisture stress.
    b) 8-10 hour daily photoperiod.
    c) low nitrogen content of nutrient solution.
4. August 1-October 15. Maintain seedlings with winter-resting buds under a 10-hour photoperiod with a temperature range from 55°F. to 75°F. daily.

Table 2.--Greenhouse schedule for production of seedlings to be outplanted in the spring

1. February 1-March 1. Germinate seed.
2. March 1-August 1. Active seedling growth. No supplemental illumination required.
3. August 1-September 15. Induce dormancy and develop winter resting buds. The following will stimulate a transition from active shoot elongation to dormancy:
    a) moderate moisture stress.
    b) 8-10 hour daily photoperiod.
    c) low nitrogen content of nutrient solution.
4. September 15-November 15. Maintain seedlings with winter-resting buds under a 10-hour photoperiod with a temperature range from 55°F. to 75°F. daily.
5. Maintain seedlings in an unheated greenhouse with temperature programmed for about 40°F. until outplanting.

Question: You mentioned that moderate moisture stress is considered a stimulus for the induction of dormancy. What is moderate moisture stress, say, in bars of soil moisture tension? Did you mention the species--was it Douglas-fir?

Cleary: I don't know in terms of soil moisture stress, but in terms of plant moisture stress, it is in the neighborhood of 17 or 18 atmospheres during the day. The species were Douglas-fir and ponderosa pine.