DORMANCY AND COLD-HARDINESS OF CONTAINERZIED LOBLOLLY PINE SEEDLINGS[1/]

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Abstract.--Successful regeneration using containerized seedlings is dependent upon matching the physiological state of the seedling to the physical state of the environment. This paper discusses seedling dormancy and cold-hardiness as they impact regeneration success. Methods of inducing cold-hardiness and overcoming dormancy are discussed as well as the consequences of mismatching seedling and environment.

INTRODUCTION

In 1980, the Southeastern nurseries produced over one billion seedlings. Most of these seedlings were produced in bare root nurseries, but an increasing number are being produced in containerized nurseries. Containerized seedlings offer certain advantages unavailable with bare root seedlings. Included in these advantages are: (a) relatively short start-up time; (b) short crop rotation and (c) relatively long outplanting season. The last two factors can allow for multiple cropping in a conventional greenhouse. For southern pines, as many as three crops could be grown in a single year (Barnett, cited in Tinus and McDonald, 1979). Barnett proposes the following outplanting periods for each crop: May-June, September-November, and February-March (fig. 1). However, weather conditions can limit regeneration success during the prescribed outplanting seasons. Regeneration success during the May-June planting seasons is limited by adequate soil moisture and preciptation, and seedlings can be outplanted during this period without special physiological conditioning.

Successful establishment during the other two seasons, however, may be limited by the physiological state of the seedling at time of outplanting. Two physiological criteria which are major determinants of regeneration success during these periods are the levels of dormancy and cold-hardiness attained by the seedlings. The focus of this paper will be the manipulation of these parameters to ensure establishment success.

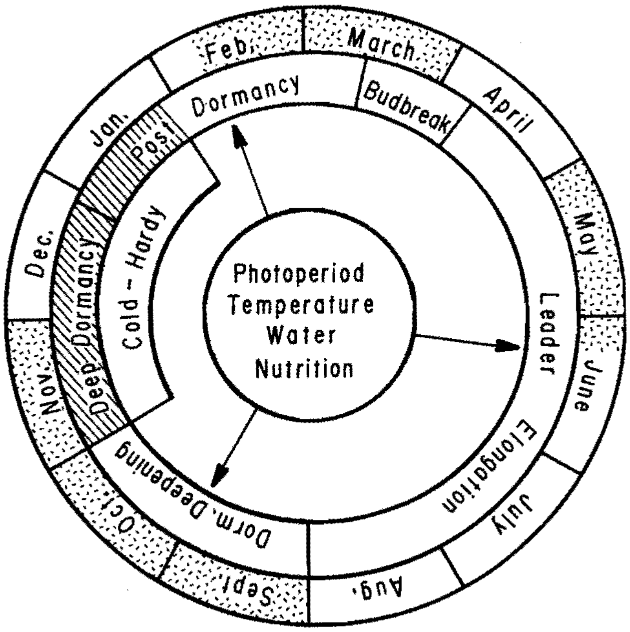

Figure 1. Growth cycle for loblolly pine. Stipled area represents outplanting seasons after Barnett (Tinus and McDonald, 1979).

DEFINITIONS

Cold-hardiness and dormancy are independent but frequently correlated biological processes. In a typical growth cycle, a seedling will become dormant prior to the development of cold-hardiness (fig. 1). Dormancy is the cessation of height growth, which will not resume without exposure to low temperature. In other words, the chilling requirement must be satisfied prior to the resumption of growth in the spring. Seedlings with a satisfied chilling requirement will grow normally and rapidly the next spring (fig. 2A).

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However, seedlings without a satisfied chilling requirement will not grow normally if at all the following spring (fig. 2B).

Cold-hardiness is the ability of a plant to survive subfreezing temperatures. The level of cold-hardiness varies seasonally from about -2°C in summer to about -40°C during mid-winter. Cold-hardiness in the fall is usually preceded by the cessation of height growth and loss of hardiness in the spring is succeeded by bud break. Unhardened or dehardened seedlings when subjected to subfreezing temperatures suffer membrane rupture, loss of intracellular water and solutes, rapid desiccation, and death (fig. 2C).

COLD-HARDINESS

Cold-hardiness can be induced by placing the seedlings outdoors in the fall, exposing them to progressively lower temperatures (Mexal, et al., 1979). Lengthening the exposure period from 0 to 6 weeks significantly increased the level of cold-hardiness as well as survival and growth (Table 1). Seedlings left in a heated greenhouse maintained their low level of hardiness (-4.3°C) throughout the exposure period. Failure to acclimate the seedlings has resulted in establishment failures following winter planting (Goodwin, 1974).

Cold-hardiness can also be accomplished by the induction of dormancy through short photoperiod (Mexal, et al., 1979). The photoperiod tested was 8 h and resulted in hardiness levels comparable to outdoor exposure to low temperatures. Growing at low density and subjecting the trees to water stress (-800 to -1700 kPa) has been proven to promote cold-hardiness of containerized Douglas-fir seedlings (Tanaka and Timmis 1974). Fertilization does not seem to impact the ability of a seedling to become cold-hardy; except in the extreme cases (Levitt, 1956, Timmis, 1975, Christersson, 1975). Still, many growers reduce nitrogen levels and fertilize with KCL in the fall to promote "hardiness". However, Hinesley and Maki (1980) failed to demonstrate any benefit to potassium fertilization in the fall. The effects of fall fertilization on cold-hardiness have not been adequately demonstrated.

It is important to understand the differences between the cold-hardiness of shoots and that of roots. Seedling root systems are usually well-insultated from very cold temperatures by the rooting medium, typically, soil. Because of this insultation, root systems are neither required nor capable of attaining the same level of hardiness as the shoots. However, containerized root systems, especially if they are outdoors, can be subjected to lethal temperatures. Seedlings

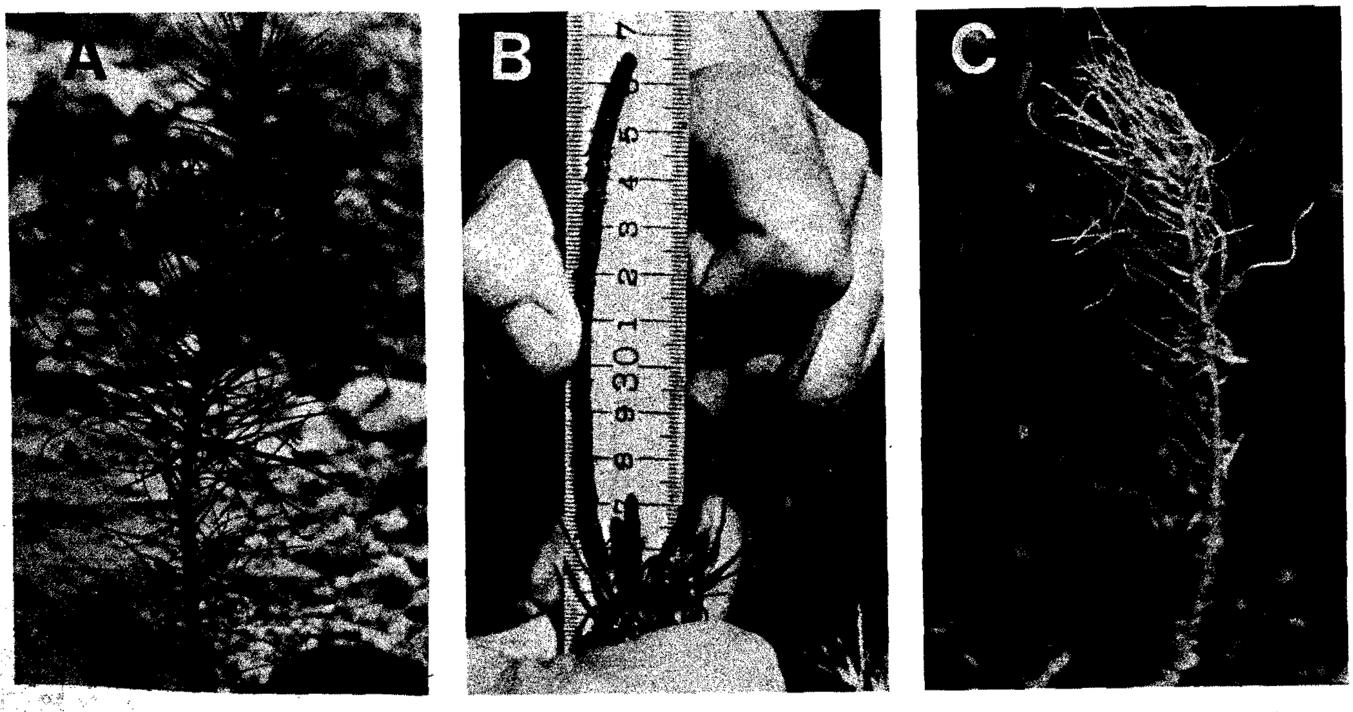

Figure 2. Containerized loblolly pine seedlings: (A) growing normally, (B) growing abnormally due to incomplete satisfaction of the chilling requirement and (C) dead from freezing temperatures.

Table 1. Cold-hardiness and field performance of containerized loblolly pine (Mexal, et al., 1979). All values are significantly different ($\alpha = .05$) according to Duncan's Multiple Range Test.

Exposure (wks)	Cold-hardiness (LT_{50})[1/]	First year field survival (%)	Height Growth (cm)
0	-4.3°C	28	3.9
2	-6.4°C	52	10.1
6	-13.6°C	76	18.2

[1/] Temperature at which 50% of the seedlings are killed.

often are placed on raised beds to promote root pruning. This allows for circulation of subfreezing air and increases the chance for root damage.

The damaging effects of lethal temperatures on root systems are not immediately obvious as they are in shoots. Seedling mortality, or even morbidity will not be obvious until the shoots are placed in a favorable environment. Significant damage to a container crop occurred in 1980 as a result of exposure to -10°C in early February. Survival for eleven provenances averaged less than 50% when brought into a greenhouse on 15 February; compared to over 90 percent on 24 January (Table 2). If seedlings are to be overwintered outdoors, precautions must be taken to prevent this damage. Precautions as simple as protecting with styrofoam sidewalls should provide adequate root protection for most regions.

DORMANCY

Dormancy is induced in the fall by short photoperiods and cool temperatures. Once a seedling has become dormant it will not resume growth until its chilling requirement has been satisified. The chilling requirement, or the amount of exposure to low temperature which will permit height growth when placed in a favorable environment varies with the species (Table 3) and can vary with the temperature regime. Generally, exposures of 4 to 12 weeks to temperatures less than 5°C completely satisfy the chilling requirement of most species. Loblolly pine requires about seven weeks exposure to natural conditions during November and December to completely satisfy the chilling requirement (Garber and Mexal, 1980). Following exposure for seven weeks, the terminal buds will expand rapidly and uniformly when placed in a growing environment. Partial satisfaction will result in slow budbreak or perhaps no bud break at all.

Table 2. Survival of loblolly pine seedlings grown outdoors and placed in a greenhouse on the dates listed below. Seedlings were exposed to -10°C on February 2, 1980. Survival was measured after 60 days. Number in parentheses represents the number of sources from a region.

Provenance	January 24	February 5	February 15
Alabama/Mississippi (2)	98%	70%	48%
Arkansas/Oklahoma (4)	97%	55%	46%
North Carolina (5)	94%	45%	58%

Table 3. Chilling requirement for dormancy release of conifers.

Species	Exposure: Length (wks)	Exposure: Temperature (°C)	Source
Picea glauca	4 - 8	$\leq$ 5°	Neinstaedt 1966
Pinus monticola	4 - 5	$\leq$ 5°	Steinhoff & Hoff 1972
P. sylvestris	8 - 10	Natural (Nov.-Dec.)	Jensen & Getherum 1967
P. strobus	8	$\leq$ 5°	Berry 1965
P. taeda	7	Natural (Nov.-Dec.)	Garber & Mexal 1980
Pseudotsuga menziesii	8 - 12	$\leq$ 4.4°	Van den Driessche 1975
coastal			Wommack 1964
mountain		4°	Wells 1979
Tsuga heterophylla	8	$\leq$ 5°	Nelson & Lavender 1979

Failure to break bud and grow the first summer following outplanting will negate much of the benefits of container planting. The effect is short term, however. The chilling requirement of the bud will be satisfied the following winter and subsequent growth will be normal. As an aside it is not known if small containerized seedlings which have not formed a terminal bud have a chilling requirement. However, this does not negate the requirement for cold-hardiness.

While there is information available regarding the natural chilling requirement for loblolly pine, there is no information on the artificial manipulation of the chilling requirement. Van den Driessche (1975) found cold-storage could partially satisfy the chilling requirement of Douglas-fir seedlings; and Tinus and McDonald (1979) stated that most species have the chilling requirement satisfied by four to five weeks of cold storage. Lavender and Hermann (1970) found exposure to low levels of light during storage of Douglas-fir was also important to subsequent growth. This information is not published for southern pines. Yet it is crucial to the development of management strategies for containerized seedlings.

MANAGEMENT PRESCRIPTIONS

Maximum survival and growth of containerized seedlings is the management goal of a container production facility. To attain these goals, careful attention must be given to the cold-hardiness and chilling requirements of the seedlings. Attaining the proper level of cold-hardiness is probably the more important of the two since cold damage can quickly result in death. However, failure to overcome bud dormancy can also negate many of the potential benefits ascribed to a containerized seedling. At the very least, one entire growing season will be lost. The loss may be much greater if competiting vegetation is not controlled, and the seedlings become shaded.

In addition to growth loss, seedling establishment may suffer if the chilling requirement is not satisfied. Ritchie and Dunlap (1980) indicated the root growth potential (RGP) of Douglas-fir seedlings reaches a maximum when the chilling requirement is completely satisfied. Therefore, not only is rapid shoot growth assured by satisfaction of the chilling requirement, but also rapid root growth to ensure survival from summer drought.

Much of the regeneration with containerized seedlings will occur during the fall and winter. To achieve high survival and growth potential, the seedlings should be placed outdoors during September or early October. Water stress and nutrient depletion can be initiated when the seedlings achieve target size, if desired. Outplanting of cold-hardy seedlings can occur throughout the winter. In certain regions, where precipitation is adequate, containerized seedlings can be outplanted during September and early October. The seedlings will acclimate naturally in the field; thereby becoming cold-hardy and also satisfying their chilling requirement.

If the seedling crop does not achieve target size until November or December, outplanting is best delayed until the spring. In that case, the chilling requirement of seedlings must be met prior to outplanting. This is best accomplished by reducing the greenhouse temperature and protecting the seedlings from freezing. Chilling for about seven weeks should satisfy the chilling requirement. Outplanting can occur in March in most regions.

Regeneration success depends on the physiological status of the seedling. Success with containerized seedlings is dependent upon matching the physiological state of the seedling to the physical state of the environment at time of outplanting. Careful attention to the physiological state of the seedling and managing the crop accordingly will ensure regeneration success.

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