LIFT AND STORAGE PRACTICES: THEIR IMPACT ON SUCCESSFUL ESTABLISHMENT OF SOUTHERN PINE PLANTATIONS

MELVIN P. GARBER and JOHN G. MEXAL

Weyerhaeuser Company, Southern Forestry Research Centre, Hot Springs, Arkansas

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ABSTRACT

Cool storage of bareroot southern pine seedlings has proven a successful method to increase the successful establishment of plantations. This paper attempts to relate the time of lifting, duration of storage, and planting date to the field survival and performance of southern pines. Limitations to successful implementation of cold storage programmes are discussed. The Weyerhaeuser system is presented as an example of an operational system. Its limitations and technology requirements are discussed.

INTRODUCTION

The increased utilisation of clear-cutting and artificial regeneration to enhance the productivity of commercial forest lands has placed added emphasis on seedling quality. Consequently, the nursery manager and nursery scientist are assigned the responsibility of producing increasing numbers of seedlings with high survival and growth potential.

The quality of the seedling can be lost or diminished if the transition between nurseryman and forester is not managed properly. Improper handling can result in reduced survival and/or poor seedling growth. Additional seedling and site preparation costs may also be incurred if survival is unacceptable and replanting or interplanting is necessary and would decrease the return from silvicultural practices.

Current regeneration practices in the South often necessitate prolonged storage (or holding) of seedlings during the post-lift pre-plant stage. The "prime" lifting season is approximately two months (late-December to early-February), whereas the planting season may be five to six months. Frequently, the lifting and planting dates can not be synchronised because extending the lifting season into the spring months when the seedlings are breaking bud can result in reduced survival. Late lifting also interferes with seed bed preparation in the nursery. Consequently, a large percentage of the seedlings are stored prior to planting. Seedling quality is also affected when the planting season is extended into the late spring and seedlings are handled and planted under less than favourable environmental conditions. Therefore, as the lifting and planting operations are extended into less favourable periods, the nurseryman and silviculturist

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require more reliable information on the relationship between lifting date, duration of storage, and field survival and performance.

Interaction of Lift Date, Storage Duration, and Survival

The planting season for loblolly pine (*Pinus taeda* L.) in the southeastern United States exceeds the traditional lifting season by approximately three months. The nurseryman can accommodate the longer planting season by lifting earlier in the autumn (November), lifting in mid-winter and storing for extended periods until planting is complete in late spring (May), or lifting into the spring (March) and cool storing for brief periods. The primary nursery constraints to extending the traditional lifting season would be gearing up in the autumn for small seedling orders, and seed bed preparation in the spring.

Wakeley (1965) first illustrated the relationship between lifting date and field survival for loblolly pine (Fig. 1). He reported survivals in excess of 80% if lifting occurred between 27 October and 15 March. Survival decreased markedly after mid-March. Apparently high survival was assured if the seedlings were not actively growing. The advent of cold storage minimised the need for lifting late into the spring.

While these and other data (e.g., Switzer, 1969) suggest seedling survival can be very high over a long lifting season, the data offer no indication of the storage potential of these seedlings. A storage trial with a single seed source of loblolly pine, planted in central Arkansas, illustrates that the survival potential (survival without storage) may be constant over a five month period whereas the storage potential changes (Fig. 2). Early lifted seedlings (2 November and late November) did not store well for extended periods (nine weeks). Similar results have been observed for ponderosa

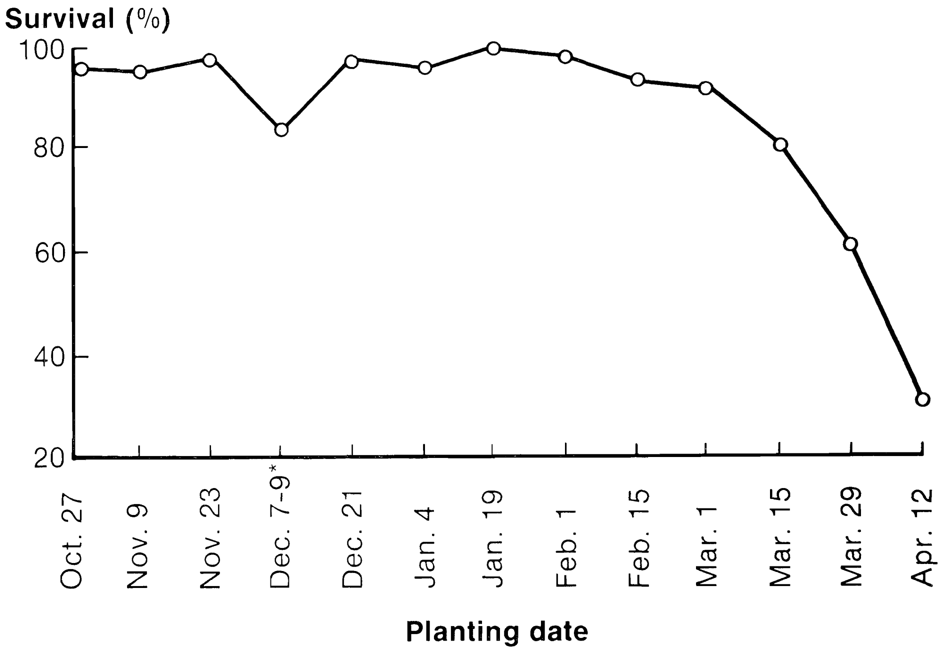

FIG. 1—Effect of planting date on the first-year survival of loblolly pine (Wakeley, 1954).

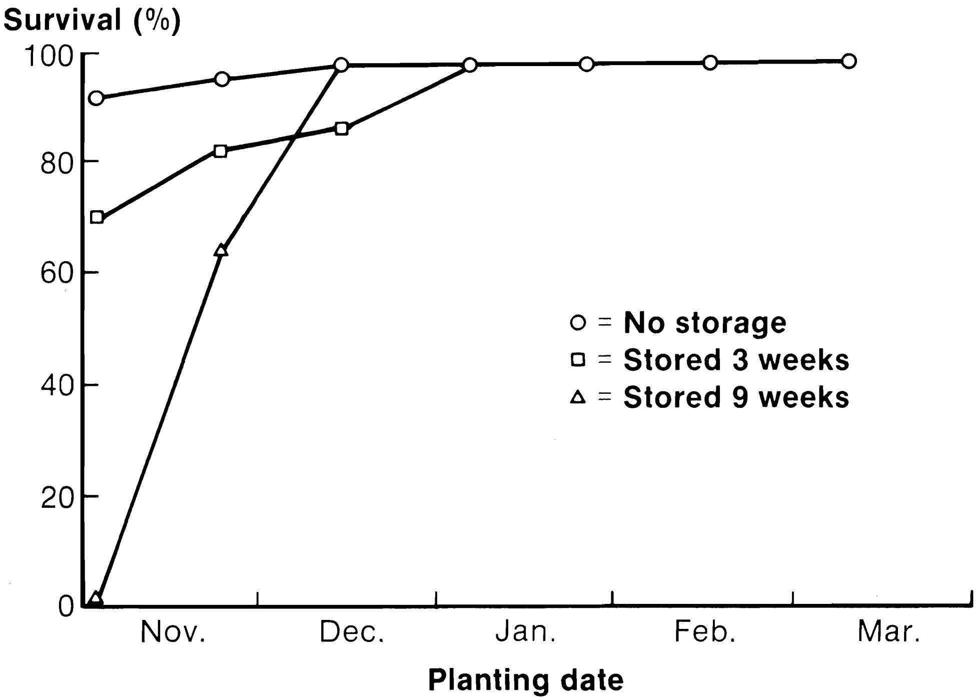

FIG. 2—Effect of lifting date and time in storage on the first-year survival of loblolly pine in Central Arkansas (Dunlap and Mexal, unpubl.).

pine (*Pinus ponderosa* Laws.) (Stone and Schubert, 1959) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Lavender, 1964). The storage potential of loblolly seedlings increased until seedlings lifted in mid-December no longer exhibited a reduction in survival with nine weeks of storage. Excellent survival with nine weeks of storage was observed for seedlings lifted through March 7 (the last lift date in the study). An initial conclusion might be that spring lifting is not detrimental to seedling storage potential. However, the March lifted trees had not experienced temperatures which would cause the terminal bud to swell. This points out the potential danger of comparing separate studies (different years or same year but different regions of the country) based solely on calendar date. A less subjective parameter would be the physiological or morphological state of the seedling.

Others (Dierauf and Marler, 1969; Rhea, 1977) have found that storage potential and consequently survival declines as the lifting season progresses into the late winter-early spring. In both studies, survival of March lifted trees was drastically reduced if the storage period exceeded eight weeks. Beineke and Perry (1965) found the decrease in survival with early summer lifting to be genotype dependent for slash pine (*Pinus elliottii* Engelm.) (Fig. 3). They did not examine storage effects, and it is not known whether such an interaction (based on provenance, half-sib, or full-sib progeny) exists for the storage potential of loblolly pine lifted in late spring.

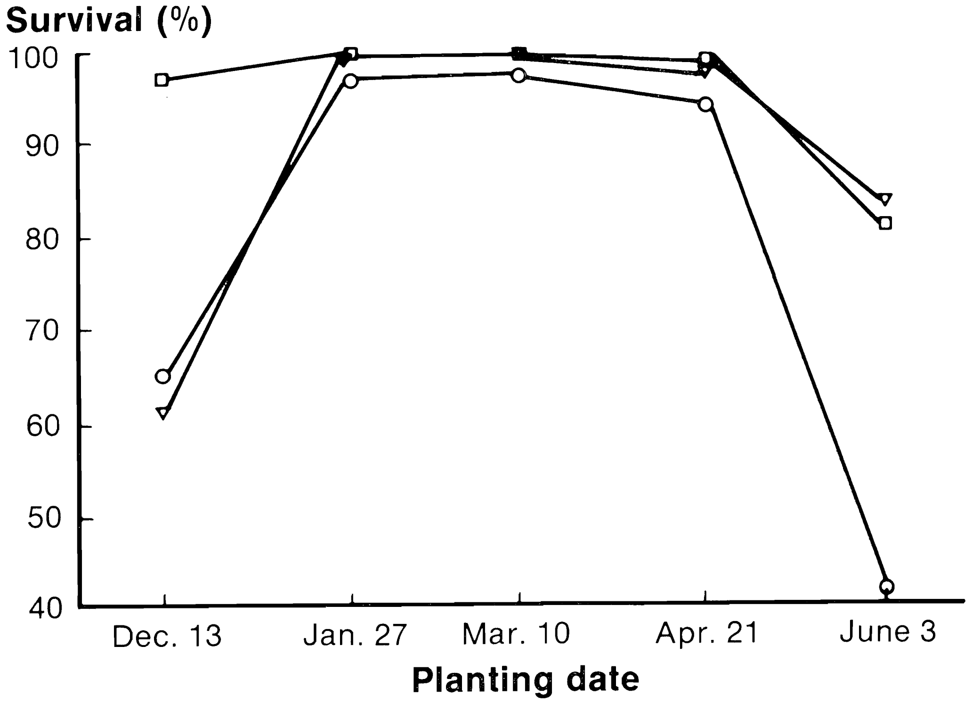

FIG. 3—Survival of three progenies of slash pine planted in North Carolina (Beineke and Perry, 1965).

Since seedlings exhibit decreased survival when lifted in the spring with or without storage, lifting in the winter and storing until seedlings are required for spring planting seems a more acceptable alternative to late spring lifting. In addition, the nurseryman wants to complete the lifting operation as early as possible to facilitate seed bed preparation. For effective implementation of these lifting procedures the storage potential of "dormant" seedlings and the effect of different stages of bud break on storage potential must be determined. The latter would be important when lifting is delayed into warm weather or an early spring occurs and the seedlings start to break bud. In such cases, the last trees lifted may have to be planted earlier than the winter lifted trees. To our knowledge there are no data on loblolly pine relating the stage of bud break, storage duration, and field survival.

Generally, emphasis of previous studies has been placed on the relationship of lift date and storage duration to survival, with less attention directed to the effects of lift date and storage duration on the growth of surviving seedlings. Dierauf and Marler (1969) provide data suggesting that lifting dates and planting which result in good survival will also result in the best growth regardless of the storage period (Fig. 4). These data are applicable only to late-winter and spring lifting. The success of early-winter lifted seedlings is dependent upon time in storage and environmental conditions following outplanting. Ursic *et al.* (1966) found the performance of seedlings lifted in December to be superior to other lifting dates if the trees were stored only one week (Table 1). However, if storage was extended to five or nine weeks both survival and

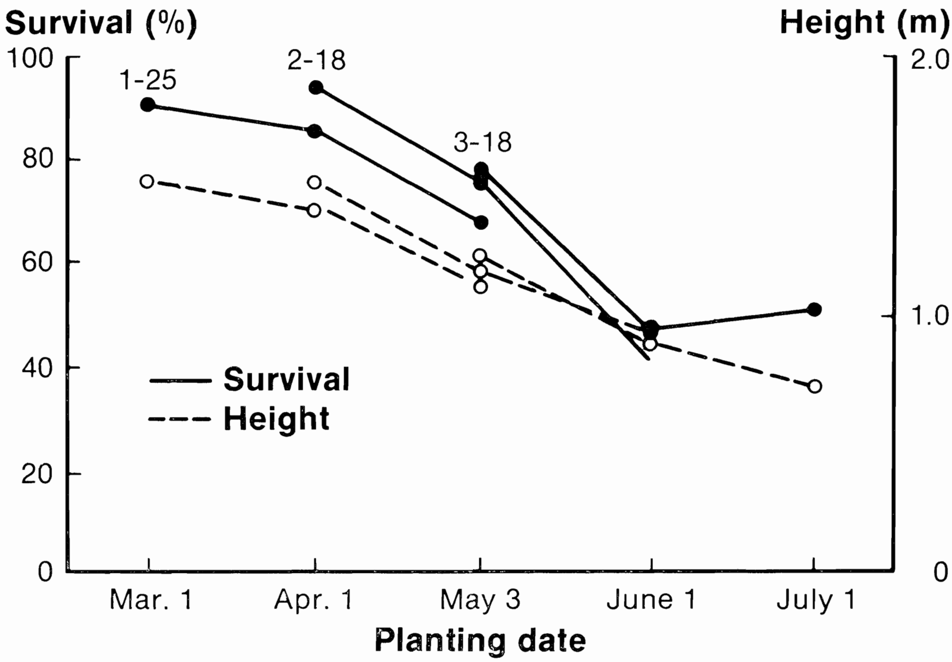

FIG. 4—Survival and height after three growing seasons related to planting date for each lifting date (Dierauf and Marler, 1969).

height growth were reduced. Apparently the survival of the December lifted trees was adversely affected by the storage duration, but the surviving seedlings experienced the same favourable growing conditions as later lifted trees and, therefore, performed as well or better. The height growth of early lifted trees (11 December) that were not stored for more than one week was equal to trees lifted in mid-winter and planted in the spring (March-April). This suggests that with short durations of storage, the lifting and planting of trees in the late autumn-early winter is a viable means of extending the planting season and would permit the nurseries to complete lifting by late winter. However, severe winter weather following outplanting also may adversely affect seedling performance. Survival surveys (Ursic *et al.,* 1966) resulted in the recommendation that loblolly pine not be planted north of latitude 33° until after 15 January, in spite of the high performance potential of earlier planted seedlings. Part of this improved

TABLE 1—The effect of lifting date and length of storage on the survival and growth of loblolly pine seedlings (Ursic **et al.**, 1966)

	Time in Storage (wks)					
	Survival (%)			Height Growth (cm)		
Lifting Date	1	5	9	1	5	9
11 December	92	75	38	17	13	12
4 January	85	65	90	15	13	19
2 February	78	86	88	13	15	15

performance may be related to continued biomass accretion through the winter (Perry, 1971). This growth may have increased survival and height increment following outplanting as much of the biomass increase occurred in the roots. Bilan (1961) found new root growth of transplants to be inversely correlated with planting date (Fig. 5). Again, it is presumed that greater root growth will be reflected in better establishment, and future shoot growth.

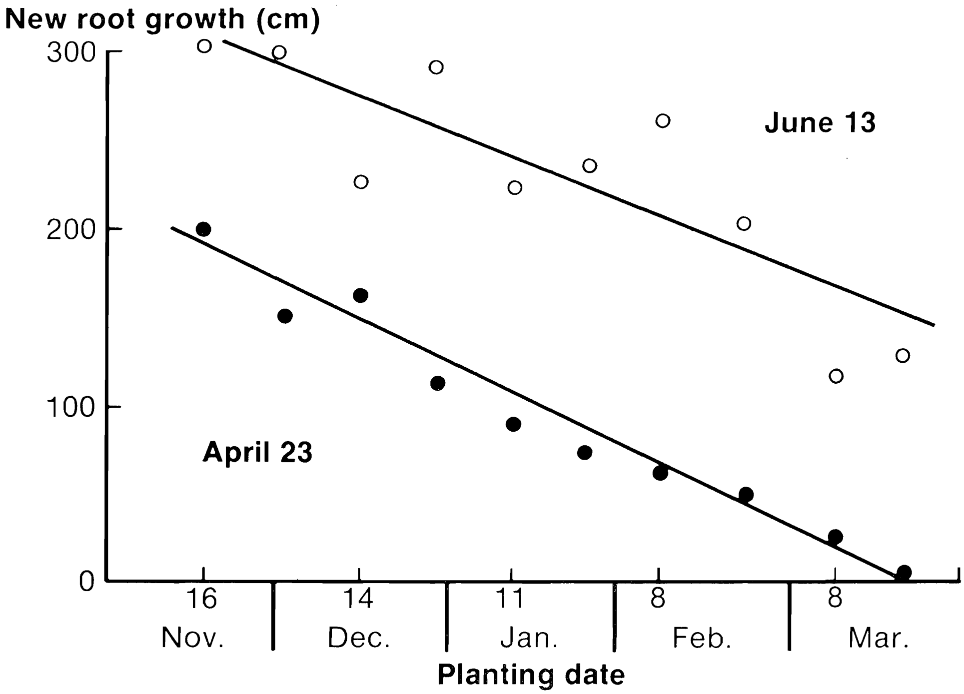

FIG. 5—Effect of planting date on the root growth of loblolly pine (Bilan, 1961). Root growth was assessed on two dates: 23 April and 13 June.

The length of time a seedling may be effectively stored may be dependent upon its state of "dormancy" (Garber, 1978). However, even with "dormant" seedlings storage tends to decrease the growth potential the following spring (Dierauf and Marler, 1969; Ursic *et al.*, 1966). Part of this may be attributable to degradation in storage. Storage, even for relatively short periods of time, results in significant weight loss for a variety of conifer species (Table 2). These weight changes, through respiration, represent depletion of available food reserves which are necessary for regrowth the following spring.

Acquisition, Loss, and Assessment of Storoge Potential in 1-0 Loblolly

The need to replace calendar date as an indicator of seedling storage potential is critical if seedlings are to be lifted at a "less than optimum" time in order to extend the lifting season. Likewise, an indicator of seedling vigour during storage is needed if seedlings are stored for extended periods. Also if nurseries are to complete lifting

TABLE 2—Effect of cold storage on coniferous seedling degrade measured as a percent loss of seedling dry weight

Species	Loss %	Time Period weeks	Source
Picea glauca	6	14	van den Driessche, 1979
Picea glauca	6-17	8	Navratil, 1976
Pinus radiata	5	6	McCracken, unpubl.
Pinus resinosa	4.5	14	van den Driessche, 1979
Pinus sylvestris	3	24	Langstrom, 1971
Pinus taeda	3-10	9	Dunlap & Mexal, unpubl.

earlier in the winter to minimise overlapping of cropping schedules, full scale lifting must be initiated as soon as possible.

Several alternatives to the use of calendar date for predicting storage potential have been suggested. Kahler and Gilmore (1961) suggested that "bark slippage" is a useful criterion. Such a criterion would be subjective and difficult to implement over several nurseries. The level of starch has also been related to seedling storage potential (Hellmers, 1962), with increased quantities of starch indicative of increased storage potential. However, before starch can be used operationally the relationship between absolute starch levels, storage time, and survival would have to be established. Even more essential is whether a certain quantity of starch will represent a threshold level for long term storage. Nurserymen would have to run routine starch analysis (probably at a lab remote to the nursery) in the autumn and early winter. The analysis would be costly but more importantly would probably not be timely since analysis could require at least one week. Also, previous reports have indicated great difficulty in reliably predicting plant status, such as vase life of cut roses (Kaltaler and Steponkus, 1976) and cold hardiness of woody plants (Sakai and Yoshida, 1968), based on starch levels. Likewise, the presence of a "resting" bud is not always indicative of a seedling with high storage potential since bud set in loblolly pine is known to occur at least two months prior to the start of a successful lifting season.

Most papers suggest that seedling survival is related to the state of dormancy. Despite the interest in developing criteria for time of lifting and agreement that the dormancy of the seedling at time of lifting may be related to its subsequent survival and storage potential, the dormancy of loblolly seedlings was not characterised until recently. Garber (1978) demonstrated that the chilling requirement for loblolly pine, as evidenced by the subsequent rate of bud break under warm temperature, was satisfied by mid-December, since additional chilling did not speed the rate of bud break. The results of Garber's study (Fig. 6) and a separate study (Dunlap and Mexal, Fig. 2), using a seed source of similar latitude, suggested that loblolly seedlings can be lifted and stored for extended periods once the chilling requirement for bud break has been satisfied. That is, in two separate studies carried out under similar temperature regimes the fulfilment of storage potential and chilling requirement occurred simultaneously.

Root growth capacity of seedlings at the time of lifting has been proposed as a predictor of seedling survival in the field. Switzer (1969) found a positive correlation between root growth and field survival of loblolly pine (Fig. 7). Root growth capacity may also be useful in evaluating seedling quality after storage. However, the technique

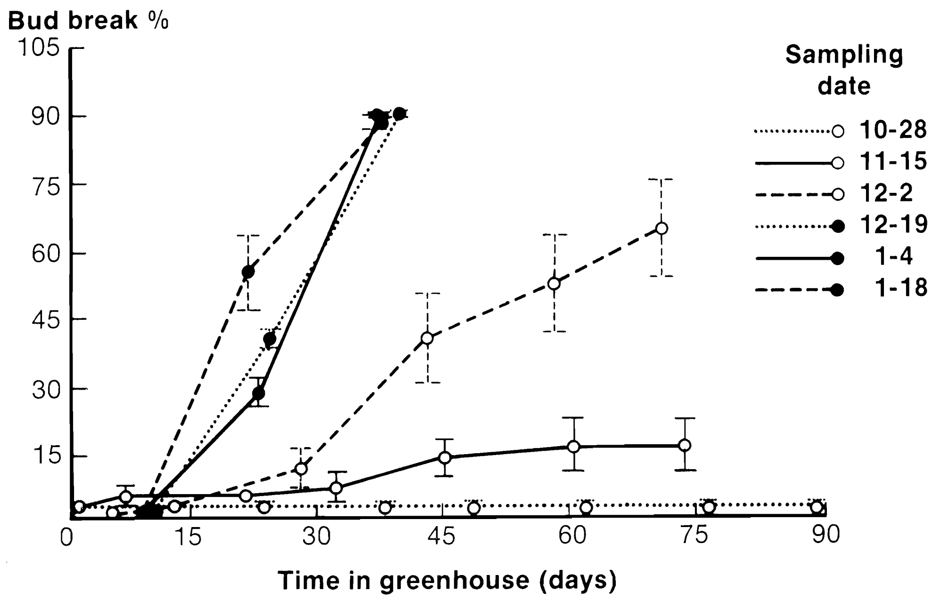

FIG. 6—Effect of sampling date on the rate of bud break of loblolly pine (Garber, 1978).

has limited use due to the time required for root growth capacity (RGC) determinations. The usefulness of RGC would be greatly enhanced if RGC could be related to an easily and rapidly measured parameter such as low temperature accumulation.

The storage potential for loblolly pine is low for "early" lifted seedlings and is also decreased when seedlings are lifted "late" in the spring. Unfortunately, guidelines relating date of lifting in the spring and storage are, as in the case of early autumn lifting, rather inconclusive. Reports on spring lifting agree that the storage potential of conifers decreases when the seedlings break bud (Lavender, 1964). There is, however, a need for guidelines relating the stages of bud break to storage potential. This procedure may prove subjective but could be implemented with a minimum of research and would represent a substantial improvement over the use of calendar date for lifting in the spring. An alternative and less subjective approach would be the accumulation of heat sums which has been used to predict flowering in loblolly pine (Boyer, 1978).

Cultural Practices and Seedling Storage Potential

The effect of pre-lift cultural practices on seedling storage potential has received relatively little attention. Although water may be withheld in the autumn to slow late season growth and promote bud set, the effect of seedling water status at the time of lifting on the storage potential has not been addressed. Other areas that should be investigated are the widely used practices of undercutting and top pruning. Undercutting can improve the survival of both Douglas fir and loblolly pine (Tanaka *et al.,* 1976) especially for early and late season plantings (Table 3). However, it is not known if there is a concomitant increase in storage potential. Another cultural practice, top pruning, is the practice of mowing all trees to a uniform height, which purportedly increases survival (Dierauf, 1976). However, as with undercutting the practice has not

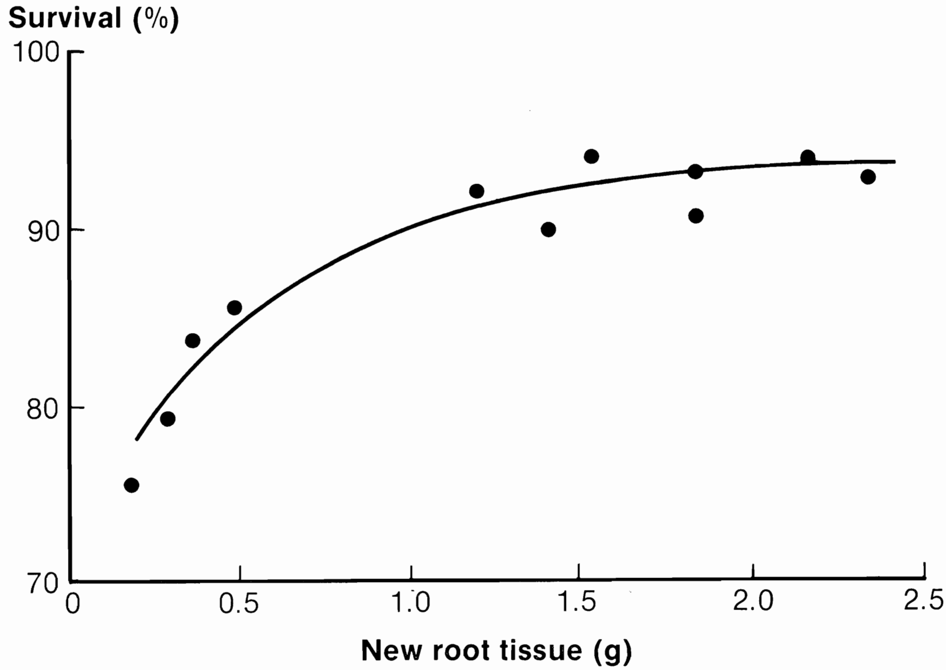

FIG. 7—Relationship of new root growth (weight) to field survival of loblolly pine (Switzer, 1969).

been integrated into a cold storage programme. The practice of autumn fertilisation with a potassium-enriched formulation to increase seedling "hardiness" may be considered questionable since significant and consistent enhancement has not been demonstrated. Another potentially beneficial area that has received little attention is the efficacy of available chemicals to induce or prolong dormancy. Cheung (1975) evaluated several growth retardants and inhibitors on Douglas fir and found ethrel most effective in suppressing growth, with minimal damage to the seedlings. All these cultural practices which regulate seedling bud set may also interact with storage potential. Future evaluation of such practices should include an examination of the seedling storage potential.

TABLE 3—Effect of root wrenching on the field survival of loblolly pine and Douglas fir (Tanaka *et al.*, 1976)

		Survival (%) Planting Date				
Species	Wrenched	8 November	1 October	24 January	16 October	17 April
Loblolly pine	Yes	88		98		97
	No	80		95		61
Douglas fir	Yes		79		96	
	No		58		72	

DISCUSSION

Weyerhaeuser Company's southern operations have made extensive use of cool storage for loblolly pine. Seedlings are generally machine lifted, graded, root-dipped in clay slurry, and placed in a kraft-polyethylene (K-P) bag prior to cool storage. The use of a clay-slurry dip is based on published recommendations. While the company uses K-P bags, a recent company study with early lifted seedlings (Nov-Dec) found the Forest Service bundle to be equally effective, despite extensive surface drying of the roots after long-term storage. The seedlings in the Forest Service bundle were not packed in moss or watered during eight weeks of storage. The moisture content of the K-P bag is not regulated during storage and is a function of the seedling water status and quantity of clay slurry when placed in storage. The storage temperature is 2°C. We have not extensively evaluated the effect of storage temperature on seedling performance but have followed published guidelines of low but above freezing temperatures. Freezer storage has not been evaluated for loblolly pine but is currently being used for Douglas fir in the Pacific Northwest (Ritchie and Stevens, 1979). The main advantage over cool storage for Douglas fir is the control of mould, which is rarely a consideration in the cool storage of loblolly pine. We will not belabour the virtues of freezer storage since it is a subject worthy of consideration in a separate technical paper. After seedlings are removed from cool storage they are shipped by refrigerated truck (long distance transport) or unrefrigerated van (short distances) to the planting districts which also have cool storage units. Seedlings are usually taken to the planting site in unrefrigerated trucks and can be subjected to ambient temperatures for one to two days prior to planting. The handling procedures from cool storage to planting are not well understood in terms of their effect on seedling survival and growth. Information relating seedling temperature after storage to field survival and growth would be helpful in refining the handling guidelines. During handling might the type of bag (K-P vs Forest Service) the seedlings are in have a pronounced effect on field performance? Handling procedures (other than cool storage) have not been addressed in this paper but represents an area that deserves increased attention of researchers. The effects of handling procedures from the time of lifting to planting of the seedling needs to be quantified in terms of field survival and growth. Non-subjective methods to predict seedling storage potential prior to lifting are required. Additional research into loblolly dormancy (from bud set to bud break) would be helpful in developing lift and store guidelines. Also the effects of nursery practices such as top-pruning, undercutting, and autumn fertilisation on seedling storage potential must be quantified if the nurseryman is to deliver to the forester a seedling with high survival and growth potential.

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