A PROGRESS REPORT ABOUT OVER-WINTER COLD STORAGE OF CONIFERS IN NEW YORK STATE

Ralph D. Nyland*

Results discussed here today eminate from research established in 1967 as a cooperative project between the Applied Forestry Research Institute, State University College of Forestry at Syracuse University, and the Division of Lands and Forests, New York State Department of Environmental Conservation. They constitute a status report summarizing general findings and presenting interim recommendations that might prove useful to others contemplating or using over-winter cold storage for conifers. More complete results, supported by tabular data, will be published by AFRI in the near future.

HISTORY

The Division of Lands and Forests of the New York State Department of Environmental Conservation has for many years stored trees in controlled-temperature chambers at the nurseries at Lowville and Saratoga, New York. Their interest in cold storage arises from the several benefits it promises to New York State. First, storage can be used to provide trees for early shipment to regions of the state that normally are ready for planting before the nurseries can begin spring lifting. Secondly, stored seedlings can provide a buffer for meeting production quotas at times when unusually foul spring weather or other unforseen hindrances delay or slow normal lifting. But perhaps more important, it holds promise for easing our burgeoning spring rabor problems.

We experience in New York difficulty recruiting sufficient seasonal workers to complete on schedule spring workloads. With growing urbanization about the nurseries, the managers forsee more severe difficulty in future years and look for ways to operate with decreasingly available work forces. If we could store confidently large quantities of trees over winter, the nurseries could extend lifting time by operating in both spring and fall, thereby satisfying production quotas with the limited manpower available. While in the long run mechanical harvesting likely provides a better alternative, over-winter cold storage could help temporarily until suitable mechanical harvesters have been made operational.

With these uses in mind, our research strives to evaluate cold storage and its 'effects on survival and growth, to define clearly the problems hindering over-winter cold storage, to seek solutions to these problems, and to perfect storage techniques.

* Project Leader, Applied Forestry Research Institute, State University College of Forestry at Syracuse University

PROBLEMS WE'VE IDENTIFIED

Based upon past performance and research, I have identified as our major problems:

1. Molding of stored trees

2. Dessication of the plants during storage

3. Erratic response of some species to storage

While we have observed 100 percent survival in many replications of our outplantings, our data generally show an average survival for stored plants slightly lower than the average for fresh-dug seedlings. However, when we successfully control storage •conditions to our satisfaction, survival has generally proven acceptable (occurring above 80 percent) , except for balsam fir and Scotch pine. Those two species have reacted erratically, surviving well on some occasions and performing poorly on others.

So we've not completely solved the problems. But we have made sufficient progress in overcoming them that I feel a variety of species can be successfully stored over winter if handled properly. Our greatest difficulty lies in reproducing annually under operational conditions the proper combination of .factors to insure regular success.

MOLDING IN STORAGE

Early during our 1967 storage trials, we observed mold developing on all species within both cold storage chambers. First signs of fungus appeared about the jute twine used to bind the seedlings into 50-tree bundles, and among the dead needles on the lower portion of the seedlings. At the time, the temperatures were fluctuating between 32 and 35 F.

After contemplating possible actions, we decided to reduce the temperature to below freezing, hoping to inhibit fungi growth. The treatment worked effectively, except for one sample of white spruce that had early molded to a rather heavy degree.

To ascertain more precisely the value of temperature control as a means for inhibiting fungi development, I collected samples from the storage chambers and gave them to Dr. Salval Silverborg, of our College's Department of Forest Botany and Pathology. Dr. Silverborg cultured out 45 different species. He developed pure cultures and tested growth ai. a range of temperatures, finding that only 4 grew to any degree at 32 F. But these did riot develop importantly at sub-freezing temperatures. The tests confirmed our hope that low temperatures would restrict fungi development.

Of the nine species we've studied, balsam fir, white pine, and white spruce show the greatest propensity to mold importantly. Red pine frequently has molded lightly, but not seriously. Norway spruce, Douglas fir, Austrian pine, and Scotch pine have generally not molded to any important degree during our investigations. And since we usually lift larch before needle drop in the fall, it has regularly molded heavily about the dead needles. In every case where I've observed heavy molding, I've also obtained heavy mortality upon outplanting, except for larch. The data clearly shows that the presence of heavy mold portends poor survival.

All factors considered, I'm convinced that we must exert real effort toward-preventing molding during storage, and that by using sub-freezing temperatures we can accomplish that task. We've oriented all phases of our research toward finding ways to enhance success from storage at temperatures between 28-30 F. However, at the same time we also take other precautions that seem helpful in detering molding. I've frequently observed that mold first appears on dead needles and other non-living plant materials included in bundles of stored trees. Consequently, we now select only healthy, vigorous 2-0 seedlings or take the stock from low density seedbeds where the seedlings tend to contain a minimum of dead needles in the lower crowns . And we can replace the jute twine with rubberbands, plastic twine, or some other inert material.

We've been cognizant of published warnings against storing trees with wet foliage. And we've wondered about their importance. So in 1968-69 at both nurseries we watered heavily seedlings of several species, lifted, pulled, and bundled the wet trees, and stored them in a replicated arrangement at sub-freezing temperatures alongside dry-foliage controls. In no case did fungi develop on either wet or dry trees . The only difference we observed between the treatments was an abundance of soil particles clinging to the roots and lower stems of the wetted plants. The trials gave us no reason to discriminate against wet foliage when lifting seedlings for storage at sub-freezing temperatures.

DESSICATION BY FREEZING

Application of sub-freezing storage for inhibiting mold development in our trials has increased the likelihood that trees will dehydrate over winter, unless we take precautions to reduce moisture losses from the stored plants. At present, we're employing two approaches to accomplish this goal. First, by controlling carefully temperature we reduce relative humidity fluctuations and, thereby, reduce evaporation from within the chamber. And by shielding the plants with protective coverings we hope to retard moisture loss from the trees.

From the start of our work we experienced difficulty maintaining adequate temperature control in the storage chambers. The thermostats allowed air temperature to fluctuate over a four to five degree range. To keep it below 30 degrees, we refrigerated it to about 26 degrees several times daily. Upon repeated warming-cooling, the air regularly picked up moisture from within the chamber and deposited it as ice upon the refrigerator coils. Over a span of time, we could observe evaporation of ice and moisture from the floors and packing materials, we detected gradual decreases of the seedlings' internal moisture content, and noticed yellowing of exposed foliage on stored plants. Upon outplanting, many trees dropped needles from the terminals and in some cases died back along the terminal shoot.

We know, based on our experience at Saratoga in 1969-70, that by using a good quality thermostat we can control temperature fluctuations to within a degree of the 30 $^{\circ}$F target level, keeping relative humidity above 90 percent and fluctuating no more than 2 percent. We observed less rapid ice buildup on the refrigerator coils, and found that defrosting costs were reduced by more than half. So while we've made no formal tests of the actual benefits realized from the better temperature regime alone, it appears likely that we have gained better control over our storage.

Repeatedly, our work has shown benefits from protecting the trees during storage. In 1967 and 1968, we compared survival of plastic-bag-stored trees with that of regular shelf-stored ones. In each year, for a variety of species the internal moisture content of bag-stored trees remained higher than in seedlings stored on open shelves with roots covered by sphagnum or excelsior. And bag-stored seedlings quite regularly have survived better than others, comparing favorably with fresh-dug stock. We've attributed these successes to the protection afforded by the "closed" environment of the sealed plastic bag and the resultant reduction of moisture loss from the foliage.

In 1969-70 we tried three approaches to protect the seedlings under production circumstances:

1. wrapping them in jelly-roll bundles, gaining some protection from the wrapping paper;

2. inserting and sealing the trees in kraft bags creating a "closed" environment; and

3. covering crates of jelly-roll bundled seedlings with plastic "tents", thereby protecting them on top and sides.

In 1969-70 all three techniques resulted in an overall higher moisture content than previously detected among our unprotected treatments. Survival has remained good on most species among all of the methods. But bag-stored trees showed lesser amounts of terminal needle browning following outplanting.

Perhaps the primary value of our closed-bag storage trials lies in the understanding we've gained about the potential dangers from dessication at fluctuating low temperatures and the realization that by isolating the plants in some type of closed environment we can retard moisture losses during storage. Comparable benefits could likely be obtained in a variety of ways. I've considered using over-sized wrapping paper stapled on the ends to cover the entire crown of the seedlings . I've thought of storing the stock in large palletized wooden boxes and sealing the box tops with polyethylene sheeting. I think, based on our trials at Saratoga last year, that placing plastic tents over the crates of normally prepared jelly-roll bundles offers real promise. All should afford an important degree of protection to the plants. However, I am presently most intrigued about storing trees over winter in polyethylene-lined kraft bags. Beside offering the protection we seek, they compare favorably with jelly rolls in reducing space required for storage and in shifting packaging operations to the fall, thereby relieving pressures during-spring rush. In addition, they offer the potential of direct field packing. They can be filled more rapidly than comparable numbers of trees can be wrapped in a conventional jelly-roll bundle. And they appear suitable for in-field machine packaging as a part of anticipated mechanical harvesting operations .

RECOMMENDED PROCEDURES

Utilizing the experience we've gained from investigating in detail the reaction of conifer seedlings to over-winter cold storage, I've formulated the following tentative procedures for use in New York:

1. Utilize only healthy, vigorous trees, preferably selected from low density seedbeds or from 2-0 stock

2. Delay lifting until the trees show signs of full dormancy, usually by mid-October

3. Immediately upon lifting, package the trees into either polyethylene-lined kraft bags or jelly-roll bundles, and move the bundles into storage facilities pre-chilled to just below freezing

4. If stored in jelly-roll bundles, further protect the seedlings by placing plastic tents over the stacks of palletized crates

5. After the chamber has been loaded, reduce air temperature to 28-30 °F, maintaining it within as narrow a range as practicable

6. Keep relative humidity above 90 percent

7. Regularly monitor air temperature, relative humidity, and seedling condition, taking immediate corrective action upon detection of any deficiency

Early observations of the palletized handling system long used at the Lowville Nursery showed that mechanization brought considerable savings of labor input, as well as speeding and making more flexible the handling procedures used to place trees into storage and to remove them for shipment in the spring.

Also, palletization makes feasible the fall processing of seedlings into bags and jelly rolls, thereby permitting us with little extra cost or added effort to provide the protective packaging we consider so necessary. We consider all of these advantages essential. But mechanized handling has become so routinely accepted in New York that we no longer include it on the list of recommended storage procedures.

WHAT, MORE RESEARCH

We have found tentative working solutions to several important questions identified by our research and experience. Results to date bring important progress to our cold storage operations. For example, we better understand the usefulness of cold temperatures for inhibiting mold development and the need for protecting seedlings at those cold temperatures. We know that the spruces, larch, and some of the pines can be successfully stored using presently available techniques. We are encouraged by the savings resulting from mechanization of seedling handling, and suspect real benefits from being able to move stock quickly from the field to its assigned place in a pre-chilled storage chamber. And we're heartened to now better understand where our problems lie and to some degree what they involve, feeling that this understanding, too, marks important progress for us.
In my judgement, our primary problem lies in consistently controlling all. the factors prerequisite to successful storage, primarily in reducing the moisture loss from plant tissues during storage. Our task remains to find more effective ways to accomplish this under operational conditions.

Recognizing the unknowns about over-winter cold storage should help importantly in further improving our production procedures. But additional research must proceed this advance. For example, we need to learn why balsam fir and Scotch pine react so erratically; perhaps by studying the nature of the species more than the storage process itself. We should gain more experience using protective packaging, combined with close temperature control in order to inhibit fungi development and reduce dessication at low temperatures. We should study more the importance of seedling quality and condition upon storability, propensity to mold or dessicate, post-storage survival and growth. We lack sensitive means for evaluating and comparing root development between treatments, so have gained, to date, little precise data about that. We must yet study effects of storage upon above-ground growth, an analysis that awaits completion of our field observations. And we could be greatly aided by some basic studies of the physiology of plants subjected to cold storage under artificial refrigeration, especially the effects of freezing and dehydration upon plant tissues.

All factors considered, I have concluded that over-winter cold storage can prove practical with most coniferous species, provided we adhere to the guidelines listed above. However, we still experience difficulty in consistently reproducing these conditions on an operational basis. For the present, we should likely limit large-scale production storage to those species that have historically reacted favorably in post-storage planting tests, avoiding balsam fir, white pine, Scotch pine and Japanese black pine. The spruces, larches, red pine and Douglas fir seem to store safely at 28-30 °F if healthy and vigorous, and if protected properly during storage.