COLD STORAGE OF CONIFER SEEDLINGS

by
Forrest Deffenbacher

* * * * * * * * * * * * * * * * * * * *

In 1947 we were faced with the problem of how we could supply seedlings in good plantable condition to some forests that had much different weather conditions than we had at the nursery. It would be impossible to locate a nursery in the States of Washington or Oregon that would have comparable weather conditions to all planting sites. If a nursery were located where weather conditions would permit digging trees all winter to supply such forests as the Olympic and Siuslaw, the stock would be too far advanced in the spring for the Mt. Baker, Snoqualmie and Gifford Pinchot. If the nursery is located in a snow belt, such as the Wind River Nursery, lifting and packing cannot be done late enough in the fall or early enough in the spring to supply forests that have long planting seasons. Therefore, some method of storage is necessary.

Of the many methods tried, refrigerated storage appears to give the best results. It not only keeps the seedlings in good plantable condition, but also reduces the seasonal peak work loads in the nursery, because lifting operations can be carried on at a steady rate by a small crew. Refrigerated storage makes it possible to ship dormant stock whether it is ordered during early spring planting season when the nursery is snowed in, or during the late spring season after growth has started. It reduces the heel-in job at the planting site, as trees can be stored at the nursery and shipped as needed in small quantities to the planting crews.

Refrigerated storage of coniferous seedlings has brought up numerous questions. The following are a few of the questions that our first experiment was based on.

1. What is the optimum temperature and humidity?
2. What is the best method of storage? (bare-root, bundle, or crate)?
3. What is the maximum length of time different species can be stored under refrigeration and remain satisfactory planting stock?
4. What effect does cold storage have on mycorrhizal associations?

Since the original experiment was started we have added another:

5. What is the best packing material?

In answer to these questions, Forest Pathology and the Forest Service have been conducting cooperative studies and experiments for the past four years at the Wind River Nursery, Carson, Washington.

Temperature and Humidity

We found by experimentation that controlled temperature and humidity were necessary to prevent mold development and maintain the stock in otherwise good condition. A hydrothermograph should be installed in the cold storage room to obtain a graphic picture of the temperature and humidity. We found that a temperature of 34 degrees and humidity of 90 to 95 percent gave best results. When a

temperature above 34 degrees was maintained, mold would develop. When the temperature was reduced to 32 degrees, dehydration of the tops began, and also necessary humidity was difficult to maintain. We found that even with a 34 degrees temperature, if the humidity was allowed to drop below 90 percent, dehydration of the tops began.

Methods of Storage

We have tried three different methods of storage - bare-root, bundles and crate. Of the three methods, bundled stock has proved the most satisfactory. Too much dehydration of the tiny root hairs takes place when storing bare-rooted stock. When the stock is packed in crates or bundles the root hairs, being in moist shingle tow or moss, are kept moist and no drying takes place. We have found that aeration of the tops is a vital factor in the prevention and retarding of mold growth. This can be accomplished best by storing the trees in bundles with an air space of three to four inches between each layer of bundles. The more top that is exposed to moving air the less chance mold has for development. When seedlings are stored in crates, the ends of the crates prevent proper circulation around the tops of the trees. Not only is the capacity of the cold storage room increased when the bundle or crate method is used, but costs are reduced by eliminating one handling of the stock.

The efficient operation of a cold storage plant depends largely on insulation of walls, ceiling and floors. There are a great many satisfactory materials that may be used, such as glass wool, cord and sawdust. The type to use depends largely upon which type of construction is the most economical in the particular locality. A refrigeration engineer should be consulted as to insulation, type and size of refrigerant units to install.

Periods of Storage

Ponderosa pine, noble fir, Douglas fir and sitka spruce were the species used in our study of maximum satisfactory storage. The first two years of this study all plantings of stored stock were made in the nursery. Excellent survival results were obtained from this stored stock. However, the validity of this test was questioned due to the fact that nursery conditions might not give the same results as field plantings. Last year field plantings were made on an area adjacent to the nursery, and the same results were obtained as when planted in the nursery. Another objection arose in connection with this, namely, that the field planting was not statistically designed to give the proper analysis of planting on an average clear cut.

Therefore, it was decided that the planting plan for the spring should be designed so that it could be analyzed statistically, and also planted on an average clear cut of this region. It is hoped that with a planting plan of this type more acceptable results will be obtained.

Survival counts were made July 15 on the plantings made this spring. It appears from these counts that the stored stock is surviving as well as the check stock with one exception, ponderosa pine stored in sphagnum moss.

Mycorrhizal Associations

Mycorrhizal associations do not appear to be seriously affected by prolonged periods of refrigeration, but further observation and tests are needed to verify this.

Packing Material

We used two different types of packing material - shingle tow and sphagnum moss. When trees are packed and stored in sphagnum moss, more mold is present on the trees at the end of the storage period than when packed in shingle tow. The trees packed in sphagnum had started to grow on the root tips, while those packed in shingle tow were dormant. The new growth on the root tips of Ponderosa pine was much more advanced than on other species tested. It appears that shingle tow has some effect on keeping trees in a dormant state as well as retarding mold growth.

Mr. Eide: Is this just 2-0 stock you are talking about now? Was this just this year?

Mr. Deffenbacher: Yes. We have made other plantings for the three years previous.

Mr. Corson: In discussing that with the Pathology group in San Francisco, they tell us there is quite a number of mold spores in the sphagnum moss lying dormant, and when we used it for packing, it developed a mold.

Now, the other comment I had. With 34° storage we found this spring in checking some of our bales that the interior temperature of those bales was at least 3 degrees higher than the room temperature, after having been in storage over a winter. Therefore, you do have a temperature that is conducive to the development of mold; around 37-38° is about the threshold of mold development. So we dropped our temperature to 32° and found we were getting better results with it.

Mr. Deffenbacher: Well, we didn't find we could do that because of the dehydration of our tops at 32°. When you get freezing, you remove the moisture from your plant, that is, from your room.

Mr. Corson: We didn't find any dehydration of the tops.

Chairman Webster: How long did you store your seedlings?

Mr. Corson: Some of them were stored over the winter and some were stored for about 6 weeks, between 6 and 8 weeks this spring.

Mr. Augenstein: How long over winter?

Mr. Corson: We put them in about October or November.

Mr. Augenstein: Early October or late?

Mr. Lanquist: I believe it was on the 15th.

Mr. Augenstein: And when were they shipped out?

Mr. Lanquist: Oh, the last were shipped out about May, I think.

Mr. McDaniel: What was your mean temperature, 32°?

Mr. Lanquist: Well, the mean temperature there was between 33 and 34, something like that.

Mr. McDaniel: Can you control your machinery so it won't go below freezing?

Mr. Lanquist: Yes.

Mr. McDaniel: Constant temperature at 32° will not freeze.

Mr. Lanquist: Well, we can control it. It works very well. We had to rework the whole deal. We can control it all right. There is one thing I like to verify in Frosty's deal here. We stored trees in Sphagnum moss and we also stored them in peat moss and also in pine shavings. We realized that we don't know all there is to know about storage, so we have been running some small experiments on the side and we found that we did have mold in the seedlings that were packed in sphagnum moss and also on the seedlings that were packed in peat moss, but we had very little mold, if any, on the seedlings that were packed in pine shavings. The moisture conditions in the bales that were packed in pine shavings were better apparently than those that were packed in any of the mosses. We did have a little trouble, like I say, we don't know too much about this cold storage, and it is important if we are going to do it. I think we should all really dig into it and work on it.

We stored some one-year-old seedlings to be transplanted at one of our small nurseries in the valley, and we also stored some one-year-old seedlings that we intended for transplanting at our own nursery in Mt. Shasta. These one-year-old seedlings were packed in part sphagnum moss and partly in peat moss. Well, we shipped these seedlings down to this transplant nursery in February, I believe, and they in turn put them in storage in a little town by the name of Oakdale, near the nursery, and I believe they were in storage there for perhaps 3 to 4 weeks.

Mr. Corson: No, Karl, you are wrong on that -- only 2 to 3 days was the storage period there. It was at Modesto, the commercial storage plant, that was the one I was speaking of where we were able to maintain a 32° temperature.

Mr. Lanquist: Yes. Well, they transplanted those seedlings down there, and a great portion of these seedlings died; but here is the funniest part of it, that those seedlings we took out of our cold storage were the same age, same species, but not the same seed source, which I don't think has much bearing on it. We took these seedlings out and transplanted them in our nursery in Mt. Shasta, took them directly out of cold storage, let them stay for a day and transplanted them the next day. Well, losses on those seedlings ran probably about 8% or between 8% and 10%, which is perhaps normal in a transplant operation, especially when you use stored stock.

Mr. Lanquist: Now there is another thing I would like to say, seeing I am here. We stored many of our seedlings in crates. We designed a crate that has a 2-inch space on each end. First we put a piece of green core paper in the bottom of our crate. It is a lattice type crate. Then we put backing material and pack it and so on; then we have a spacer that is 2 inches. We put in a spacer at the end of the crate and another spacer, so it leaves perhaps 2 inches on each end.

Question: That crate is, you might say, entirely open in the end?

Mr. Lanquist: Well, it is almost open in the end with the exception of one brace in the middle. Now I will tell you another thing. We didn't get very much mold on any of our seedlings and we couldn't detect much on the roots, very little, and very little on the tops, but we have been trying to figure out why we should get losses on stored stock, so many losses, and nobody seems to be able to figure it out. We made some kind of deductions by looking through literature here and there and digging in old moldy files and so on, so we thought perhaps that gas exchanges would have some effect on stored seedlings. That is only a shot in the dark; it is only a guess on my part, but it is something that I believe the scientists ought to work on, if that is the case. Anyway, it is worthwhile shooting at, so we thought the reason we made these deductions was this: that the year before we stored stock in bales, in burlap bales, and we used some kind of a paper that wasn't too good, and this stock deteriorated. I mean the burlap and paper deteriorated very badly in storage. In fact, it was awfully hard for us to handle the bales. The seedlings almost fell out of the bales. But the funniest part of it was that we shipped about the same amount of seedlings, same kind, same age, same conditions apparently, down to this little nursery again, and they came through with only losses of 14%; so I thought, "Well, gosh, there must be some reason for this," because apparently this year we had ideal conditions and the other year we didn't; so that is the reason why I made these deductions that perhaps we wrap up these seedlings too tight and do not let the gas exchanges take place around the roots for instance. It is only a shot in the dark, and that is my story.

Chairman Webster: Karl, do you use peat moss, or do you use sphagnum as packing material, that is, around the roots?

Mr. Lanquist: Well, it was perhaps a 50-50 proposition there. We used sphagnum moss and peat moss; so I want to add this, too, we thought this year instead of using ocean wrap paper, we are going to try and experiment and use this plastic window screen you see. It is very fine and very strong, so you can really tear into it without breaking it, and we are going to try to eliminate this waterproof paper and pack it in pine shavings and wrap it in this plastic screen and put it in practice and see what happens.

Mr. Brown: My question, Mike, is partly answered by Doc Corson. I did want to ask him, though, if there wasn't any chemical reaction in that shingle tow; but I think Doc Corson has the answer to that, that maybe moss has the mold germ dormant in there. I wonder if there isn't some chemical reaction in that shingle tow? Then I wonder, too, if what you talked about was mainly pine?

Mr. Corson: Pine trees, yes.

Mr. Eide: This may be only a shot in the dark, but we are experimenting with storing seedlings by species, also the elevations?

Mr. Brown: There are so many different characteristics, perhaps we should try experimenting under different temperature and humidity conditions by species.

Chairman Webster: That sounds all right, but you are certainly giving the nurserymen a job when you start doing that.

Mr. Augenstein: First, in answer to your question. We have tried storing all species we raise with about the same results. I have two questions and two cautions. I would like to ask Ernie Wright if he noticed in storing with the shingle tow any dying back of the end of the roots? I think you mentioned you had root growth in your moss, but not in your tow, and did you notice any dying back?

Dr. Wright: It certainly wasn't very noticeable. There probably was a trace on Douglas-fir especially.

Mr. Augenstein: The question has been raised by some of our boys in the University at Missoula, and also getting back to his question about cedar shingle tow. Nothing will grow in it. They have tried it in Missoula. You can water plants with water from soaked shingle tow and they just won't germinate. In other words, it kills them when it comes up. They figured I was wrong in using shingle tow for storage or even baling, but we have been shipping trees since 1910 and getting in some years 100% survival.

Dr. Wright: You wash your shingle tow?

Mr. Augenstein: No, we just bring it in and soak it in a tub. Before we go on, this dehydration or the hydrization of the needles, ours dehydrate every year and look gray and yet we get good survival.

Chairman Webster: Do they come out of it?

Mr. Augenstein: Yes, they stay alive. We can green them right up before we ship them.

Chairman Webster: When needles on our stock dehydrate, they drop off.

Mr. Augenstein: Now, I have one thing to offer that we have bumped up against. I mentioned one at the last meeting, and that is do not let your stock freeze in storage. If it freezes we lose a lot of trees because those hair roots dry and when they leave the nurseries they look good, but we find as soon as they get out in the air, those roots will turn black and if you have a dry spring, you will lose your stock. This spring we lost one lot that was pulled early in October. We can't pull after it starts to rain. If it gets rainy and our stock gets a little wet, we have trouble, and checking in the spring. The botanists, Doc Waters, at the University at Missoula, found it had broken dormancy. The buds were still there, but that stock practically all died.

Chairman Webster: At what temperature do you store?

Mr. Augenstein: 31 to 34. The stock won't freeze.

Chairman Webster: You never do freeze your stock?

Mr. Augenstein: No. The little needle on the chart shows a very small variation, but it does go to 31 and up to 34.

Chairman Webster: I think we are making progress on this business of both seed storage and seedlings storage and as our meetings progress from year to year, I think we are going to bring out the answers that we are looking for.

Mr. Adams: I wonder if Karl doesn't have something on this exchange of gases. There was an article in one of the recent issues of "American Nurseryman", the commercial magazine, and one outfit is shipping bare root hardwood stock to Europe, and they use this pliofilm, which is impervious to moisture but will let the gases through, and they don't cover the roots. They just put in something that will retain the moisture in this package and ship it that way. We have to develop something like that, because we ship our stock. We take it out of the refrigerator and ship it to somebody, say in Southern California, and maybe it will be in a warm express car or a truck or something for 4 or 5 days. We shipped one lot back to Virginia this year and when they got it, it was Monterey pine. They said it was just a mass of pulp.

Mr. Youngberg: In connection with this business of shingle tow, I think one thing that a lot of botanists forget is the fact -- it gets back to the nutrition of trees again -- that there are certain principles in the nutritional up-take in coniferous trees that are entirely different from regular plants, and you will find that conifers will grow on an old cedar log or any other old log out in the woods, and I don't see any reason why shingle tow would be toxic to coniferous seedlings where it might be toxic to other plants. I can see you have been using it for a long time and they may have thrown up their hands in horror, but they are generally forgetting one thing. There are a lot of different relationships in coniferous seedlings that you don't have in normal plants, agricultural plants and floricultural plants.

Chairman Webster: I think that is a good point.

Mr. Augenstein: It might be toxic for some deciduous plants.

Mr. Youngberg: That might be possible.

Mr. Chapin: I think this dehydration or weight loss, moisture loss in storage is far more critical than we realize. We had a very similar experience to Karl's in taking stock out of storage, both seedling and field planting stock. We took identical lots and shipped one bunch to our Pullman nursery, which takes about a week to get there, and at the same time we transplanted in our own nurseries the identical lots of that stock. We got beautiful survival at Bellingham, and no survival

Mr. Chapin: (cont'd) by the time those were planted in Pullman; so we tried one other thing. We took a lot out of storage and baled them as we normally would. First we weighed them out and baled them as we normally would and then held them for the same length of time which it would have taken to go to Pullman. Then we re-weighed that stock and at the same time weighed stock directly out of the storage box. I can't quote you the figures, but there was a definite difference in weight of that material and the stock that had been baled for a week. We got very much poorer survival than we did on that taken directly out of storage, so I think there is a correlation between the weight loss or dessication and survival that could be worked out. We have already got to the point that unfortunately it won't be the same for each species.

Mr. Lanquist: What species were they?

Mr. Chapin: We used Ponderosa pine and Douglas-fir. We have worked with Norway spruce and it seems to be the best, that is, it is easier to store and the best survival of the coniferous species.

Chairman Webster: Thanks very much, Frosty. Our next topic is going to be handled by Dr. Ernie Wright on the "Effect of Mycorrhizae on Growth and Survival of Ponderosa Pine and Other Species."

Dr. Wright: After we get through here with this little paper which is going to be very short, we have some slides to show. They illustrate some of the points and Jim Augenstein has kindly brought over the roots of White Pine and Engelmann spruce which I believe have some mycorrhizae showing.

MYCORRHIZAE AND THE GROWTH AND SURVIVAL OF PONDEROSA PINE

by
Ernest Wright, Pathologist
Division of Forest Pathology
Portland, Oregon

* *

We have already discussed the importance of seed source in relation to the growth and subsequent survival of plantations. Now using the same seed source let us consider the importance of mycorrhizae on growth and survival of planting stock.

First perhaps we might attempt to define what a mycorrhiza is. A simple definition that has been offered is that a mycorrhiza is a fungus root. A more complete description might be that it is an association of two different living components forming a morphological organ on the roots of various plants. Actually one of the components is a fungus whose hyphae penetrate the cells of the root tips of a host plant and forms a mantel-like growth or net over the root tips. Some investigators regard this relationship as beneficial and symbiotic in character while others maintain that the fungus is in reality a parasite on the host plant. We are concerned with the effect of the mycorrhizae on the host plant and the forester is particularly interested since there are several reports which strongly demonstrate that mycorrhizal plants show a higher percentage of survival on adverse field planting sites. Since the object of the nurseryman is to grow the best possible stock, his interest in mycorrhizae is likewise understandable. It is this particular phase of the subject which will be briefly discussed here. We need not concern ourselves with the different types of mycorrhizae but rather let us confine our discussion to the external or ectotrophic mycorrhizae.