the roots are packed in straw, depending on cultivar and size of the plants.

The 200- and 250-ft refrigerated area occupies the lower level of the building. It is insulated with styrofoam, and two units are used for cooling, one primarily for backup. Water from the units may accumulate and cause puddling. We spray the walls and floor with 50% Clorox solution to help avoid the development of disease problems that can easily occur under damp conditions. The floor is concrete and is thick enough that we can drive right into the storage area for loading and unloading.

It is always difficult to dig dogwood as early as it should be in the spring. Successful reestablishment is never easy later in the season. This past year we dug a small amount of our stock as soon as it became dormant and heeled the plants out in sand in the refrigerated building. We had very good results but want to repeat our trial before adopting this method as our usual procedure for dogwood.

We recently constructed a storage and shipping building for the storage of balled and burlapped stock, which enables us to take care of the stock during the time between digging and shipping. We are able to control the moisture level of the stock, and we do not have to heel-in the plants because the temperature inside is such that freezing rarely occurs. Another important advantage to this type of facility is that it allows for all-weather shipping, which is especially important during unusually wet or cold periods.

In conclusion, we have found that attention to the factors which determine success or failure in storage of dormant plants is vitally important if one desires to maintain a reputation of producing good quality plants.

STORAGE OF BARE-ROOT DECIDUOUS PLANTS

BEN DAVIS II

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The storage methods which will be covered here have all been used by Ozark Nurseries Company, with whom I have been associated for 21 years. Ozark Nurseries produces a broad line of field-grown deciduous ornamental and fruit plants, as well as coniferous evergreens. The firm is located at Tahlequah, Oklahoma, which is in the northeastern part of the state, in U.S.D.A. plant hardiness zone 7a. According to the U.S.D.A. map, the low

winter temperatures in this zone range from 0 to +10 degrees Fahrenheit However, we usually experience a few days in which the temperature drops to −5 degrees F. and, in some winters, to −10 or −15 degrees F.

The proper storage of bare-root deciduous plants enables the nurseryman to keep them in a viable, dormant condition through the fall, winter, and spring in such a manner that they are readily available for order-filling and shipment when and as needed.

There are three basic storage methods which accomplish this goal with varying degrees of success They are; (1) heeling outdoors in beds or trenches, (2) placing inside an air-cooled or common storage building, and (3) storing inside a mechanically refrigerated building.

No matter which method is used, it is important that plants be in good condition when they are placed in storage. This requires that they be grown with the best possible cultural practices so that they are vigorous and healthy and will have the proper levels of stored carbohydrates If plants are dug before they are fully dormant, they will not have a chance to store the proper levels of these essentials in their stems and main root system This lack of nutrients will cause them to store poorly and, in extreme cases, to die while in storage. *Prunus* species are especially susceptible to these conditions, while *Malus* species will generally tolerate a great deal of abuse Other species of deciduous woody plants with which we have had experience generally fall somewhere between these two extremes.

HEELING OUTDOORS

The principal advantage in heeling outdoors is that there is no large capital expenditure required Beds or trenches can be dug by hand or with a small loader or dozer The plant bundles are then stood in the trench and the roots are covered with soil by hand, after which they are thoroughly watered in When plants are needed to fill an order, the required number are merely pulled from the bed. Ozark Nurseries stored plants in this manner from its founding in 1895 until 1947, when the first air-cooled storage building was built.

There are several disadvantages to heeling outdoors. First, it requires a large amount of labor, something that is not always easy to get now. Second, if the weather is inclement or the ground is frozen, plants can not be removed from the heel bed. Third, if spring comes early, the plants will break dormancy, precluding further shipments. This can be a big drawback if one has northern customers who request late spring shipment. Nevertheless, if one has a strong back and not much money to get

started, heel beds are a legitimate way to store plants.

AIR-COOLED STORAGE

An air-cooled or common storage building is a big improvement over heel beds. The air-cooled storage depends on mother nature to help maintain plants in a dormant condition. Such a building can be above ground, with thick masonry or insulated walls, or it may be partially sunken into the ground, so as to allow soil to be mounded up around the outside walls. In either case, the building has a dirt floor. The dirt floor helps to keep the building cooler than outside temperatures in the fall, and warmer than outside temperatures when it is very cold. The dirt floor also helps to maintain proper humidity if it is managed properly. Our Yankee friends call this type of structure a "root cellar."

When the inside temperature is warmer than desired and the outside temperature is colder, cold air is drawn in through openings in the walls by use of fans until the desired temperature is reached inside. Care must be taken that outside air is not so cold as to freeze plants stacked near the air-intake openings. Grills should be kept over the openings to prevent the entry of rodents. When warm weather occurs, the inside temperature can be kept cool by keeping the building as tightly closed as possible As spring approaches, it becomes more and more important to take advantage of every cool night to chill the storage in anticipation of warm days.

An air-cooled storage gives the nurseryman more control over his bare-root inventory than he would have with heel beds, and it works fairly well in northern climates. However, the further south one goes, the less satisfactory it becomes. At Ozark Nurseries we used air-cooled storage from 1947 until 1974 fairly successfully; but in years when spring came early, we had difficulty in keeping plants dormant until our northern shipping was concluded.

In using air-cooled storage, it is important to water carefully to maintain the proper humidity. This requires daily watering of the walls, floor, and the plant stacks. If the storage is kept too wet or too dry, plants will be lost. It is best to train one individual for this job and then check on that person often to see that the watering is properly done. Each building will have certain spots that tend to stay too wet or too dry, and these spots must receive special attention. It is best to keep the humidity at approximately 80%. It is not practical to keep the humidity much higher than this with hand watering because you then begin to get wet spots in the storage which can cause rot. A well-managed air-cooled storage is a very good way to store plants until one can afford to take the next step to refrigerated storage.

REFRIGERATED STORAGE

The very best bare-root storage, and the most expensive, is the mechanically refrigerated and humidified storage. At Ozark Nurseries, we converted our air-cooled storage to this type in 1974. Finding the right equipment and a knowledgeable firm to install it was quite an educational experience. Most firms that sell and install refrigeration equipment do not understand the application of this equipment to the storage of nursery plants.

In our case, investigation revealed that installing the recommended insulation on the floors, walls, and ceilings of all of our storage buildings would cost more than the refrigeration equipment itself. Since the outside walls on most of our buildings were 18 inches thick and of double wall construction, we felt that we could install refrigeration capacity slightly larger than would normally be installed and cool the storage satisfactorily without the additional insulation. While this approach would use more electricity than normal, we felt that it would take many years for the cost of additional electricity to equal the cost of the insulation recommended. This was especially true when we considered that the refrigeration would only be operated during the coldest six months of the year.

We contacted four suppliers of equipment for quotations on the job. Two of these went strictly "by the book" and did not give what we felt was adequate consideration to cost effectiveness. One supplier flatly told us that a system could not be installed that would work under the conditions we proposed. Fortunately, the fourth supplier that we contacted took a common-sense approach and offered us a plan that was both workable and that fell within our budget for the project.

One very important point that needs to be made is that the cooling coils should have electric defrosting. Under the conditions of high humidity and low temperature, the units do not have adequate time to defrost naturally before they need to come on again to maintain the desired temperature.

In conjunction with the refrigeration system, we installed automatic humidifying equipment. Mechanical refrigeration removes large amounts of moisture from the storage, and this moisture must be replaced. After consulting with several other nurseries having this equipment, we decided on a system in which air and water are mixed in special nozzles to create water vapor. This avoids the problems that free water can cause in the storage and allows us to maintain the humidity at up to 95 percent if we wish.

The system which we use supplies water and air to the nozzles in two separate lines, both of which are under pressure. Timers are used to open and close solenoid valves in the air and

water lines. This system also has humidistats which override the timers. The humidistats keep the timers from switching on the valves when sufficient humidity has been attained.

We purchased the components for the humidifying system and installed it ourselves. In the process we made some mistakes which I will pass on to you so that you won't have to repeat them First, don't try to save money by using plastic pipe. Plastic pipe sags, even in very short spans, allowing air bubbles to become trapped in the water lines. These air bubbles tend to act as a cushion, holding open the check balls on the nozzles, so that when the water shuts off, there is a constant drip from the nozzles. It is better to use galvanized steel pipe, taking care to get each run of pipe level so that air does not get trapped in the water lines.

The second mistake that we made was in trying to run this system with well water Water tends to absorb air from the water system's pressure tank, contributing to the problem of air in the water lines Fortunately, we had city water available, so we hooked our system to city water. If your water system has a pressure tank, it is better to use a float tank and gravity system for the water lines that supply the humidifying nozzles.

Our system has been in operation for six years and, on the whole, we have been very pleased with it. I would like to give special credit to Rod Bailey of Bailey Nurseries in Saint Paul, Minnesota, who was very helpful in sharing their experiences with cold storage equipment. While some of our rooms do not stay as cold as we would like in the late spring, we can hold our temperature in the range of +35 to +45°F until very late in the spring. This is the performance that our equipment supplier promised, and we find it adequate for our needs.

When converting an air-cooled storage to mechanical refrigeration and humidification, certain new problems in storage management are encountered which need to be considered. It is important to keep accurate readings on the humidity and to regulate the humidifying system carefully. If the humidity is too high, mold becomes a problem. Most of the wall-mounted humidity gauges that are on the market are not very accurate and do not last very long. A sling psychrometer is essential to get accurate humidity readings. The humidity should be checked once each day in each storage room and adjustments made on the humidity controls if necessary Ohio State University recommends keeping the humidity below 90% and the temperatures as cold as possible to retard the growth of mold-causing fungi (2).

It is also vital to control fungus organisms in the storage with a regular spray program. Ohio State University recommends a combination of 2 lbs of Terrachlor (PCNB, Olin Corp.) 75% WP,

and 2 lbs of captan 50% WP in 100 gal of water, sprayed on the plants (2). We have found that spraying every week to 10 days, rotating among Benlate (benomyl, duPont), Botran (DCNA, Tuco) and captan, works well for us. Benlate 50% WP is applied at the rate of 1½ lbs per 100 gal of water. The captan 50% WP and Botran 75% WP are applied at the rate of 2 lbs per 100 gal of water. The higher the humidity and the warmer the storage, the more often spraying must be done. We apply the spray to the plant stacks and to the floor, walls, and ceiling of the building.

FALL STORAGE PREPARATION

Before the storage is used in the fall, two steps must be taken to get it ready. First, sprinklers are set up and run for about two weeks to get the floor thoroughly wet. Sprinkling is discontinued about one week before storage use is expected to begin in order to allow the surface mud to dry so that the floor is thoroughly damp, but not muddy. The damp floor is a major factor in helping to regulate the humidity.

Second, the storage is thoroughly sprayed to disinfect it. We spray the floors, walls, and all of the plant racks with Citcop 4E (a copper resinate, Cities Service) at the rate of 3 qts per 100 gal of water The ceilings of our buildings, which are aluminum and steel, are sprayed with captan 50% WP at the rate of 2 lbs per 100 gal of water. The reason for not using Citcop on the ceilings is to avoid excessive corrosion.

CONCLUSION

There are two publications on storage which I would like to mention. The first is, "Proceedings of the Woody Ornamentals Winter Storage Symposium, December, 1977" (3). This is available from Ohio State University, 2001 Fyffe Court, Columbus, Ohio, 43210. The cost is $5.00 and checks should be made payable to, Storage Symposium. The second publication is, "Storage of Nursery Stock" by J.P. Mahlstede and W.E. Fletcher, Iowa State University, Ames, Iowa (1). This publication was printed by the American Association of Nurserymen in 1960. It is now out of print, but the Horticultural Research Institute is cooperating with Dr. Mahlstede to publish a new edition. HRI expects this to be available in late 1981. Inquiries can be directed to the Horticultural Research Institute, 230 Southern Building, Washington, DC 20005.

If you are contemplating construction of a bare-root storage facility, you should do the following:

(1) Get the above mentioned publications and study them. They have a lot of valuable information that will enable you to make more knowledgeable decisions.

(2) Talk to fellow nurserymen about what they are using and their experiences with their facilities. You can learn from their experiences, but you should keep in mind your climate and the particular functions desired for your own facility. Not everyone's operation will be the same.

(3) Shop at least three suppliers of the equipment you will need. Listen to their proposals and try to determine which one seems the most knowledgeable about your particular application. The lowest bid is not always the cheapest in the long-run. You should also consider the supplier's ability to service the equipment after it is installed.

Some of the things that I have mentioned here might seem elementary or self-evident. However, I have found that when I take the elementary things for granted that is usually when I get into trouble. Careful attention to seemingly minor details is important when making such a large investment.

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STORAGE OF DORMANT PLANTS

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Forrest Keeling Nursery is located in northeast Missouri on the hills above the Mississippi River, almost equi-distant between the Gulf and the Canadian border. Here normal minimum temperatures range between 0° and −10°F, but recent cold winters have seen temperatures plunge as low as −25°F.

We are in-ground or field growers. Therefore, we do not have the over-wintering problems facing northern container growers. However, we do grow several million deciduous seedlings, liners, and other trees and shrubs harvested bare-root. These are mostly dug in the late fall or early winter when they are dormant and just before the ground freezes. This material requires most careful and attentive storage to retain its viability until it is ultimately planted by the customer the following spring.