and some of the saprophytics. There has been recent work just reported in our meetings at Mexico City that there may even be spirochete-like organisms, lacking cell walls, that are involved in this type of mycoplasm disease. This whole group of diseases usually causes deformity and yellows-type symptoms and are very often spread by leaf-hoppers. People talk about mycoplasmologists now — so we apparently have a brand new field of investigation.

PRESIDENT MAIRE: Thank you very much, Dr. Converse. Let me give you your certificate here in appreciation for your being with us today and sharing this information with us.

MODERATOR McNEILEN: To start this next session, Jay Allison of the Weyerhaeuser Company will tell us about control of freeze damage in their forest tree seedling nurseries. Jay Allison:

FREEZE-DAMAGE CONTROL IN FOREST NURSERIES

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In 1967, the Weyerhaeuser Company established the Washington Forest Seedling Nursery. This was the first in a series of six major nursery units to support the company high-yield forest regeneration requirements. The Washington Nursery is 160 acres in size and is located about 15 miles southwest of Olympia at the south end of an open prairie. The site slopes gently to the south and has a mean elevation of 140 feet.

By 1969 the nursery had over 53 million seedlings in three age classes; 1-0, 2-0, and 2-1. In October of that year, an unexpectedly severe freeze occurred that killed or seriously damaged about 12 million seedlings, mostly in the 1-0 age class.

In September of 1970, another early freeze occurred. The 1-0 blocks were protected by sprinkling, and losses were minimal. Well capacity was not adequate to sprinkle the 2-0 beds and they were extensively damaged. Although the incidence of mortality in the 2-0 stock was low, the quality was poor and subsequent field performance of the seedlings produced was below standards.

It was apparent that, if the nursery was going to meet production objectives, a more effective means of reducing freeze-damage was needed. Before making a substantial investment for freeze-damage protection, a number of questions needed to be answered. Were the early freezes of 1969 and 1970 "freak" events not likely to reoccur for many years? What alternative methods of control are available? What would be the cost and the reliability of each alternative control method? Finally, what level of risk of crop loss would be acceptable?

To answer the first question, the daily temperatures from Centralia, Oakville and Olympia were compared to the four years of data collected on site at the Washington Nursery. Daily minimums correlated well with the data of the Olympia Airport, if a correction of —1.5° F was applied to account for generally lower autumn temperatures at the nursery.

Temperatures measured on clear, still nights at various levels above the nursery showed that the temperature at seedling height could be as much as 2.5° F colder than at the normal five-foot instrument level (3). Therefore, an additional adjustment of —2.5° F was applied to the Olympia data for a total difference of —4° F.

The daily mean minimum temperatures for each month at the Olympia Airport are published in "Washington Climate" by the Agricultural Extension Service (4) covering a 30-year period. The standard deviation of mean lows were obtained from the Climatological Handbook of the Columbia Basin States (2). From these data, corrected to ground level at the nursery, the probability of any given minimum temperature occuring by a certain date was derived.

The next step was to obtain meteorological data during radiation cooling periods at the Washington Nursery. Three factors were of particular interest: (1) mean minimum temperature for the whole nursery, (2) distribution of minimum temperatures over the nursery during periods of radiation cooling, and (3) the vertical temperature variation or inversion patterns. First, six minimum-registering thermometers were permanently fixed 6 inches above the ground at scattered points throughout the nursery. These were read each morning from September to November after nights of radiation cooling. The average of these six represented the nursery mean low for the night.

To obtain a pattern of low temperature distribution or "cold spots", a 100 yard by 100 yard grid pattern was laid out. This resulted in 90 data collection points uniformly distributed over the nursery. Minimum registering thermometers at these points were read after at least three nights of radiation cooling. The minimum at each point was compared with the mean nursery minimum temperature. The average differences were used to construct temperature-difference iso-therms for the nursery. Various areas were from 2½° F warmer to 4½° F colder than the mean low of the nursery as a whole. Warmer minimums seemed to occur over 1-0 blocks. Trees near the two north corners of the nursery showed a definite "shelter-belt" effect as did the building complex near the center of the nursery.

To obtain temperature inversion information a 36 foot mast was erected. Temperature-sensing diodes were located every six feet up the mast. Readings were recorded at half-hour intervals through the night. The strongest inversion measured was 8° F at the top of the mast. Cold-air cells moving down from the Mima Prairie made the strength and stability of inversions highly variable. Data on wind direction and velocity and cloud cover was also collected.

These on-site meteorological studies were made in September and October before data collection was hindered by the need to apply freeze-damage control measures. Similar data collected during the operation of control techniques was used to evaluate their effectiveness.

To make these data meaningful it is necessary to know the temperature at which freeze damage to Douglas fir seedlings will occur. This critical temperature for freeze damage changes as the trees become dormant. Temperature history, application of fertilizer, and irrigation schedules before the onset of frost danger undoubtedly influence the freeze-hardiness of the stock. The best information available at the time of this study was the work of John Alden (1). His data for Douglas fir seedlings suggests that a severe crop loss can be expected nearly every four years at the Washington Nursery unless protective measures are employed. (Figure 1)

Protection against potentially killing freezes that would occur more frequently than once in fifteen years was selected as a design criteria.

With this background it was possible to make a knowledgeable evaluation of the control measures available. The following methods were considered for their degree of protection, reliability and cost:

Oil-fired heaters	Foam blankets
Gas-fired radiators	Wind machines
Greenhouses	Various row covers
Overhead sprinkling	Wind breaks
Artificial fog	Control of nutrients and water

Greenhouses were rejected principally on cost. Fueled heaters also require a large capital investment and relatively high operating costs. Both wind machines and artificial fog depend on a pronounced low-level temperature inversion. The vertical temperature data showed that inversions over the nursery were rather weak and transitory and total dependence on either wind machines or fog would be risky.

By far the cheapest source of night-time heat was found to be the latent heat released by freezing water. It was decided to expand and modify the existing Rain-bird overhead irrigation system to provide simultaneous coverage of all 1-0 and 2-0 blocks. This required the drilling of a third well, installation of another pump, some changes to the piping system and additional thermostatic controls. Catch basins for collection of run-off water were also prepared.

The advantages of this choice were that most of the system was already in place for irrigation. It was expected to give the required level of protection (3). It could be manually or automatically operated. It is independent of temperature inversions and is unaffected by light winds. It creates no air pollution, it is quiet, and it had been successfully used to protect 1-0 seedlings in 1970.

The undesirable aspects were well recognized. Experience had shown that sprinkler heads would build up enough ice to stop rotation if the temperatures dropped below about 17° F. Prolonged operation could overtax the wells. Leaching of the nursery soil was of concern as was handling the run-off water. Sprinkling must be started at 32° F regardless of the critical temperature or line freezing can occur.

But these disadvantages were judged to be acceptable risks and the irrigation system was upgraded for freeze-damage control.

The sprinkler heads used were Rain-bird 14V-TNT quick-acting and 20E-TNT slow-acting heads with 7/64" orifices rated at 2.6 gallons per minute at 55 psi. Sprinkler lines are 48 feet apart with heads spaced every 30 feet to give about 75 gallons per acre-minute of coverage. Three wells, with a combined capacity of over 7,000 gallons per minute, supply the system through mains ranging from 12 to 6 inches in diameter. Cross connection or isolation is possible by manually operated valves.

The first real test of the system occurred on the night of October 27-28, 1971. By 7:30 p.m. the temperature was 29° F and all three pumps had come on automatically. All 1-0 and 2-0 blocks were being sprinkled. By 2 a.m. control thermometers registered 16—18° F while the sprinkled thermometers registered 29—32° F.

Frozen sprinkler heads were first noted at 2 a.m. at the ends of some sprinkler lines. These were freed by removing the ice with the aid of propane torches. Between 2 a.m. and 5:30 a.m. the free-air temperature steadied at 15—16° F. Four men could not quite keep up with sprinkler head stoppage at the edges of the blocks. Where sprinklers stopped the temperatures within the beds dropped to 21 to 25° F. By 7:00 a.m. unprotected thermometers read 13° F. Except for end sprinklers nearly all of the heads functioned normally. The greatest frequency of sprinkler freeze-up occurred in those areas found to be the coldest in the study of minimum temperature distribution. The sun rose at 7:30 a.m. and the temperature quickly rose above freezing. Sprinkling was continued until the wet-bulb temperature exceeded 32° F.

Examination of the beds showed a 1/2 to 3/4 in. thick coating of clear ice on the seedlings Minimum-registering thermometers coated with clear ice read 27 to 32° . Near the edges of some blocks the ice had a snowy appearance. Thermometers encased in this type of ice registered from 16 to 26° F. The snowy ice was attributed to interruption of the sprinkling because of head freezing.

Sprinkling was repeated the next night but the free-air temperature dropped only to about 18° F. Sprinkler head freeze-up was much less severe and easily handled with a larger crew and the use of squirt bottles of ethylene glycol.

A week later the nursery was examined for evidence of freeze damage. Damage to lammas shoots in the unsprinkled 2-1 stock was quite apparent. A count showed damage to about % of the leader shoots. Damage to 1-0 and 2-0 stock was restricted to a thin band at the borders of the nursery and a couple of isolated spots where line failures occured. All-in-all the results were most gratifying compared to the freeze damage of the two previous years.

It is estimated that the temperature in certain areas would have dropped as low as 11° F were it not for sprinkling. Since minimum thermometers in these areas registered 29—30° F, the system performed better than expected.

Part of the success of minimizing damage in 1971 was probably due to a reduction of watering, holding back nitrogen fertilization, and applying potassium during the late summer. Still the stock was not as freeze-hardy as we would like for late October.

There were some problems with run-off after the first night due to blockages in the county road ditch. The fields and roads on the nursery were muddy for several days but never impassable. No lasting effects on soil texture or nutrient balance have been noted. And the seedlings suffered no visible damage from ice loading.

Several improvements will be tested in 1972. These include better lighting for patrolling sprinkler lines, changing the end sprinklers to segment types to increase the frequency of coverage and eliminate watering the roads, installing a wind break along the north side of the nursery to deflect cold air drainage from the Mima Prairie, and testing a row of fueled heaters along the south edge of one block to eliminate edge effects.

We are confident that the overhead sprinkling method, combined with certain cultural practices, will practically eliminate freeze damage as a dterent to meeting the Washington Nursery's production schedules in the future.

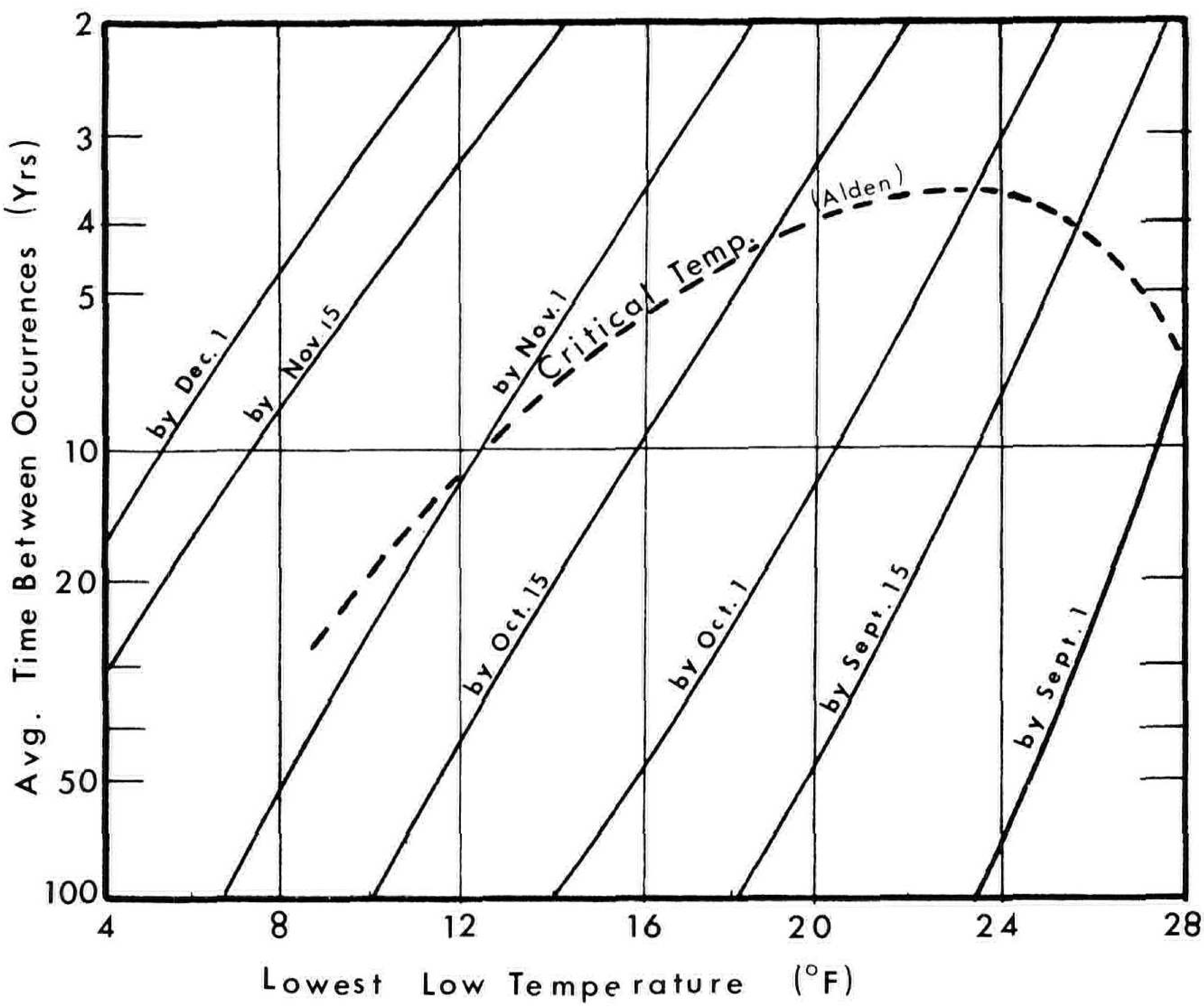

Fig. 1. Frequency of critical freeze temperatures at the Weyerhaeuser Washington Forest Seedling Nursery.

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MODERATOR McNEILEN: Thank you, Jay. Now Bob Miller from Dahlstrom and Watt Bulb Farm, Smith River, California is going to discuss the pros and cons of palletized growing of container stock.[1]

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[1] Mr. Robert Miller, Dahlstrom and Watt Bulb Farm discussed his experiences in the use of pallets for container stock.