two or three generations of rooted cuttings a year in growth chambers as an assembly line.

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ROOT REGENERATION OF EVERGREEN PLANTS

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Abstract. The root regeneration potential of 6 species of bare-rooted conifers and broadleaf evergreens was studied in raised sawdust beds under natural conditions at Corvallis, Oregon. All plants were successfully rooted; however, a definite seasonal periodicity in rooting was found for all species studied except for *Prunus laurocerasus* 'Otto Luyken' which rooted relatively well throughout the sampling periods. All species rooted well during the July harvest period, and all but *Rhododendron* 'Mrs. G.W. Leak' and *Picea jezoensis* rooted well at the December harvest date. Generally, poor rooting was found among most species between the August through November harvest periods. Auxin and night interrupt with incandescent light treatments did not influence the rooting pattern. Root regeneration was significantly reduced in the 6- and 8-year-old versus the 4-year-old *Abies procera* plants, but n o difference in rooting was found among 4- and 6-year-old *Picea pungens* plants.

INTRODUCTION AND LITERATURE REVIEW

Relatively large evergreen plants are "balled-and-burlapped" at harvesting to insure maximum transplanting survival. This practice is costly, time consuming, and requires skilled labor and/or expensive equipment. The work involved is heavy and difficult, making it unattractive to laborers which has resulted in nurserymen having difficulty in obtaining the required personnel. If this situation continues, nurserymen must either find a better alternative to produce these plants, or harvest them by a less expensive procedure. Because of this problem, the primary objective of this study was to determine whether bare-rooted evergreens could regenerate new roots under the natural conditions of Corvallis, Oregon.

Generally, it is agreed that root regeneration following harvesting is necessary for transplant survival (43). Failure to produce new roots results in a retardation of plant growth or even death. Because of this fact, one of the criteria for this study was to determine whether it was possible to regenerate new roots from bare-rooted evergreens.

From literature, there is general agreement that the important factors influencing root regeneration are the physiological condition of the plant at harvesting and the environment to which the plants are exposed during the root regeneration process. It is well known that rooting of transplants are periodic, and the exact nature of this periodicity in rooting is unclear (2,14,15,24,25,26,41,42). Most researchers believe that periodicity arises as a result of two low temperatures, moisture stress, poor aeration, and low light intensities (10,11,17,21,27,28 31,34). Others, however, believe that periodicity is caused by the physiological status of the plant (14,24,25,26,41,42).

Of the environmental factors, temperature, moisture, aeration and light intensity were found to be most important for root generation. Generally, relatively warm soil temperatures (1,12,17,22,27,28,43), prevention of water stress (11,12,14, 31,32), good soil aeration (18,19,29,30,35), and relatively high light intensity (7,20) are beneficial to rooting.

Physiologically, the plant's age and developmental status are important in the root regeneration of transplants. The influence of tree age on root regeneration potential is not well understood. Most of the reported work has been done on plants less than 3 years of age. Generally, the older the plant, the less root regeneration potential it has, and thus the greater the risk of transplanting.

There is good evidence suggesting that the observed seasonal periodicity in rooting is a result of the physiological status of the plant at the time of harvesting and during the rooting period. Some researchers believe that roots become dormant and in this physiological condition rooting is nil (16). Others do not follow this belief and claim that root growth can occur at any time (10,11,13,17,21,27,28,31,34,37).

Recently, Veerkamp (unpublished data) at Oregon State University and others (40,41,42) have reported that seasonal periodicity in root regeneration does occur in conifers. Plants harvested at periodic times throughout the year and transplanted under several controlled controlled environmental conditions suggest that rooting was best after January until spring growth began at which time rooting dropped slightly. After the spring vegetative flush of growth ceased, rooting potential again increased for several weeks. Later, during the summer and fall period, rooting was nil or very poor. The fact that the environment during the rooting period was kept constant throughout the sampling period suggests that the physiological status of the plant at harvesting was important in regeneration of new roots.

Attempts to explain the rooting periodicity on the basis of the chemical makeup of plants were not well established. Nutritional (3), carbohydrate and hormonal (4,5,6,33,34) relationships have been associated with the potential of root regeneration.

Physical methods to increase the root surface area prior to transplanting is commonly done and generally this procedure improves transplanting survival. Undercutting, root pruning, and wrenching practices are designed to provide planting stocks with compact, fibrous root systems with low shoot/root ratios (9,23). In such situations, as much as 50% of the root system may be severed without causing detrimental effects to the growth and transplantability of most plants studied (9,23,38).

Another factor that should be considered in root regeneration studies is the differences that may exist between different genetic materials. Although this is considered to be important, little research has been designed to show this relationship.

In order to partially satisfy the primary objective mentioned earlier, the following experiments were designed to determine whether 1) it is possible to regenerate roots from bare-rooted evergreen plants under natural conditions in Oregon, 2) the age of plants influences rootability, and 3) different plant types have similar root regeneration potentials.

MATERIALS AND METHODS

The plants used in these studies were dug with shovels and the majority of the soil remaining on the root system was removed by vigorous shaking. They were then placed in an open pickup bed, watered, and transported to the rooting area (approximately 2 hours away, Portland and vicinity to Corvallis, Oregon. At Corvallis, the roots were immediately washed of remaining soil with a high pressure water stream, root pruned to approximately 25 cms, and transplanted into approximately 1-year-old Douglas fir, *Pseudotsuga menziesii*, sawdust contained in a 8 m × 4 m × 50 cm raised bed. The plants were then watered manually until the sawdust was completely soaked, after which time an automatic irrigation system was turned on for 5 minutes every 2 hours between 6 am and 6 pm. Low angle pulsating Rainbird sprinklers with a 7/64" orifice were placed 2 meters above the top of each corner of the raised bed. Each sprinkler watered a 90° area from one side of the raised bed to the other side. Preliminary testing by spacing 250 ml beakers spaced 1 meter apart throughout the surface of the sawdust suggested that the distribution of water throughout the area was relatively equal.

Three separate experiments were conducted. In the first study, the objectives were to determine the relationship of harvest dates, auxin, and night interrupt treatments on root regeneration of bare-rooted evergreen plant. To answer these objectives, twenty each 7-year-old *Picea jezoensis* unpruned seedlings were bare-rooted on 7-19-71, 8-20-71, 9-21-71, 10-27-71, 12-8-71, 2-25-72, and 3-21-72. On each sample date, the plants were cleaned and root pruned as described previously and divided equally into the following treatments: 1) control (C); 2) 4 hr night interrupt (NI) between 10 pm - 2 am with incandescent light providing approximately 63 $\mu w/cm^2$ of irradiance; 3) roots sprayed until run-off with a 10% Jiffy Grow treatment. The plants were transplanted into the sawdust beds, and 3 months later the data on new root development were determined.

The second study was designed to determine the relationship of harvest dates on rootability of 3 broadleaf evergreen plant species, *Rhododendron*, 'Mrs. G.W. Leak' (8-years-old from cuttings); *Prunus laurocerasus* 'Otto Luykens' (5-years-old from cutting); and *Mahonia aquifolium* (4-years-old from cutting). Forty plants of each species were harvested on 7-19, 8-8, 8-29, 9-19, 10-10, 10-31, 11-21, and 12-12-73. The numbers of new roots produced were determined 3 months after planting in the sawdust beds.

The objectives of the final study were designed to determine the relationship of harvest dates and age on root regeneration of 120 *Abies procera* (4-, 6-, and 8-years-old) and 80 *Picea pungens* (4- and 6-years-old) seedlings. Plants were harvested on 7-10, 7-31, 8-23, 9-12, 10-1, 10-22, 11-12, and 12-3-73, and placed in the sawdust beds for 3 months before determining the number of roots produced.

The temperature 75 cm and 2.5 cm above the sawdust surface and 25 cm within the sawdust bed was monitored with a Weather Measure thermograph from September 15 to December 9. The daily maximum and minimum temperatures were plotted (Figure 1).

The data were analyzed statistically by analysis of variance and the difference between the means was determined by Snedecor's planned comparison test (39).

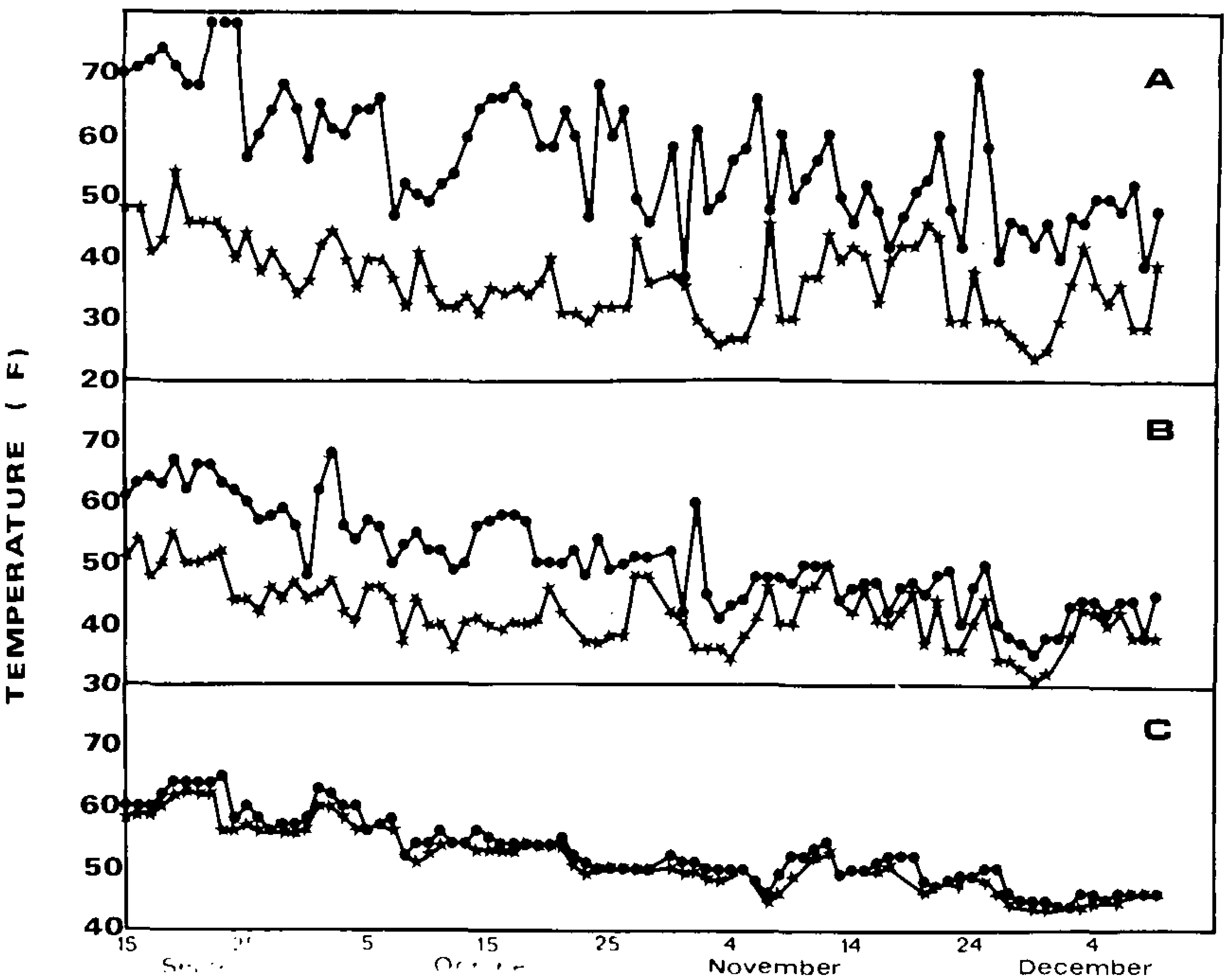

Figure 1. Daily maximum and minimum temperatures (°F) at 3 positions: A. 75 cm above the sawdust, B. 2.5 cm above the sawdust, and C. 25 cm below the sawdust surface.

RESULTS AND DISCUSSION

Seasonal periodicity in root regeneration was established for nearly all plants studied (Figures 2,3,4). The only exception occurred in *Prunus laurocerasus* 'Otto Luyken' which regenerated new roots relatively uniformly throughout the sampling period (Figure 3). In all other plants studied, generally good regeneration of roots occurred in plants sampled during July. In addition, *Abies procera*, *Picea pungens* and *Mahonia aquifolium* rooted well in the December sampling period. Generally, these results are in agreement with those reported by others. One exception to previous findings is the consistently good rooting observed on all plants studied during the July sampling date. Prior studies have shown this to be a poor time for root regeneration to occur. Although an explanation for this difference is not possible, we do know that the plants and the environmental conditions studied were different from those used by others. The fact that all the plants rooted well during the July sampling period suggests that the environment could be a

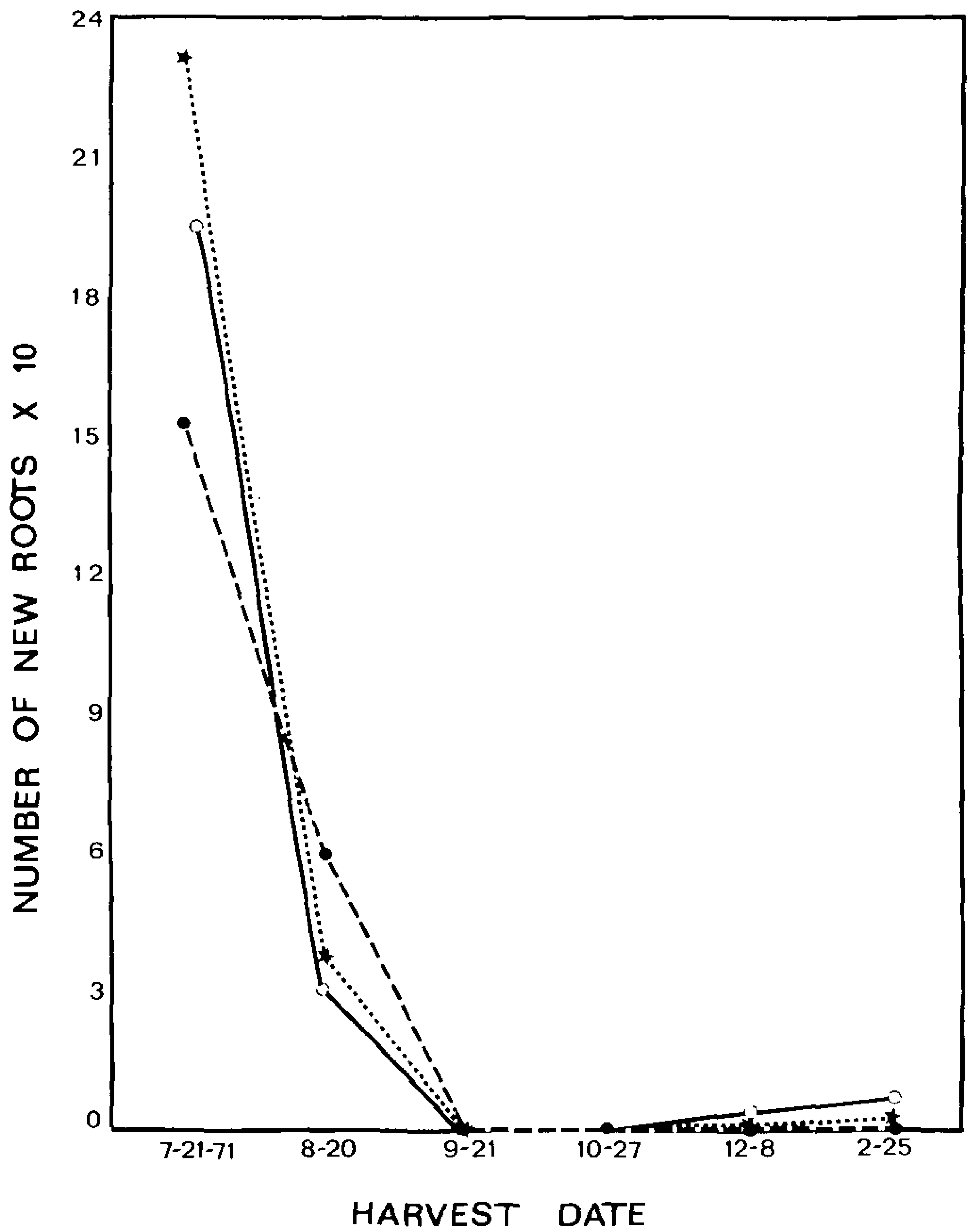

Figure 2. Numbers of new roots produced on 7-year-old seedling of *Picea jezoensis* transplants treated with either 1) 10% Jiffy Grow (★-----★), 2) 4 hrs night interrupt (○——○), and 3) natural conditions (●——●) at 6 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed.

primary factor responsible for the good rooting. In Oregon, this period usually has warm temperatures and high light intensity. These factors, in addition to good aeration (provided by the sawdust beds), and adequate water to reduce water stress (over-
head irrigation) are considered to be important environmental factors essential to root regeneration (1,7,8,11,12,14,17, 18,20,22,27,28,29,30,31,32,35,36,37,43). The explanation for the results at the other sampling periods could be due either to the unfavorable environmental or physiological conditions.

The relatively good regeneration of roots observed throughout the sampling period in *Prunus laurocerasus* 'Otto Luyken' suggests that its root regeneration potential is less sensitive to either environmental or physiological influences as compared to that of the other plants studied. This finding is an exception to that reported by others (16,41,42,43).

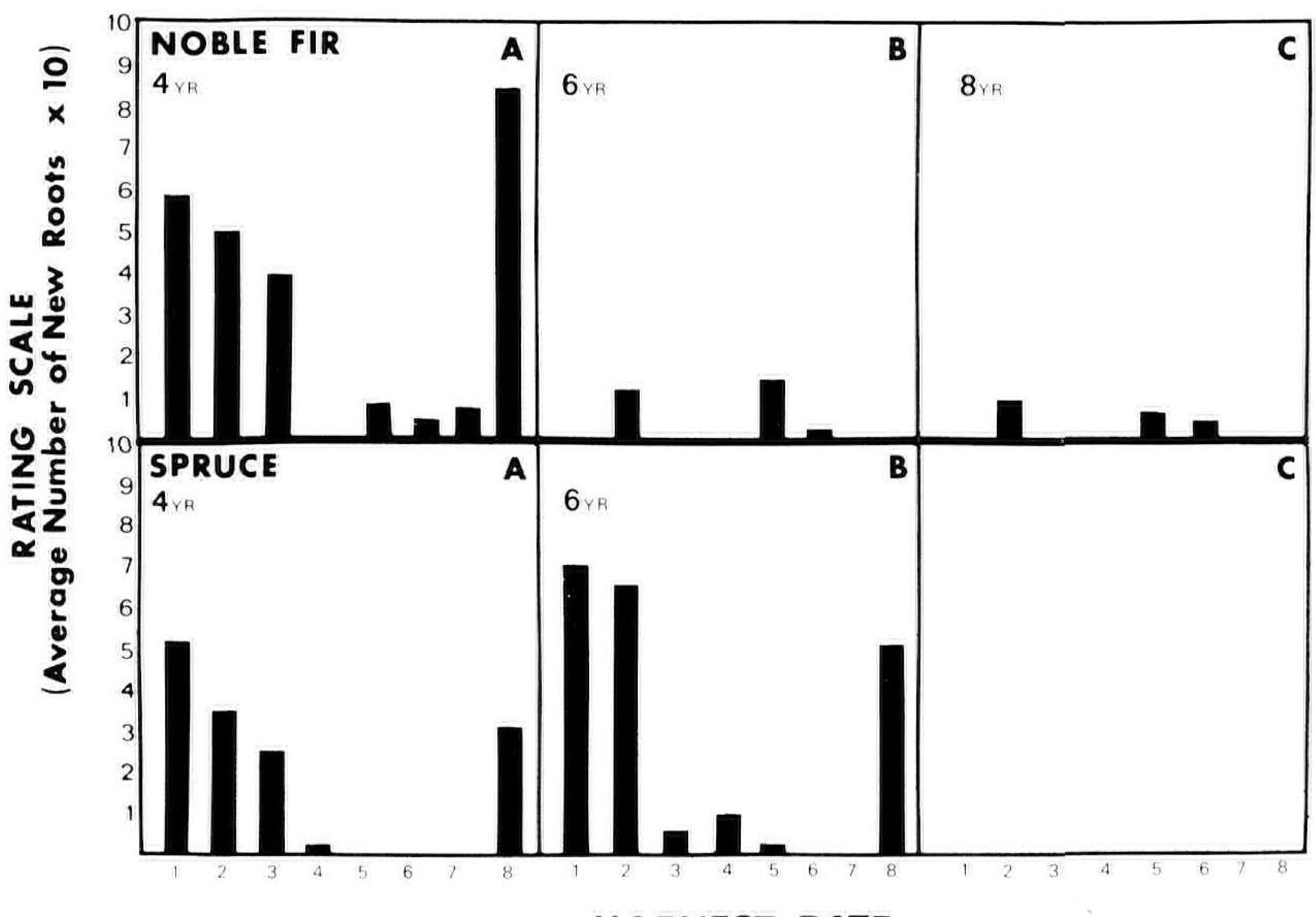

Figure 3. Numbers of new roots produced on bare-rooted 4- and 6-year-old *Picea pungens* and 4-, 6-, and 8-year-old *Abies procera* at 8 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed. Harvest date: (1) 7-10, (2) 7-31, (3) 8-23, (4) 9-12, (5) 10-1, (6) 10-22, (7) 11-12, (8) 12-3-73.

In *Picea jezoensis*, no significant differences in rooting were found among the auxin (Jiffy Grow), NI and the control treatments (Figure 2). The rooting pattern was similar throughout the sampling period. Best rooting occurred during July, followed by a significant decrease during August. No rooting occurred during the September and October sampling dates and

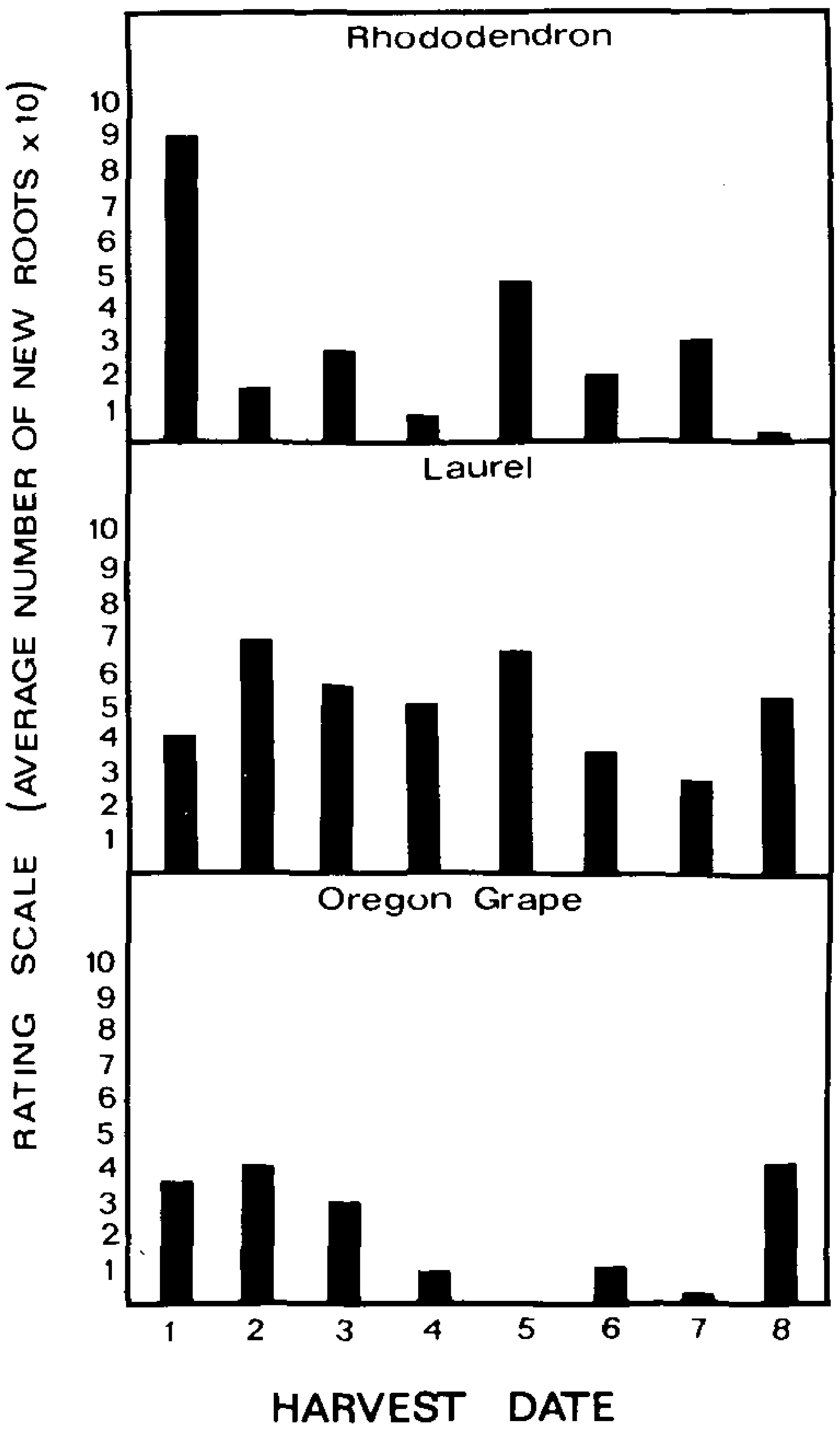

Figure 4. Numbers of new roots produced on bare-rooted 8-year-old *Rhododendron* 'Mrs. G.W. Leak', 5-year-old *Prunus laurocerasus* 'Otto Luyken' and 4-year-old *Mahonia aquifolium* at 8 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed. Harvest dates: (1) 7-19, (2) 8-8, (3) 8-29, (4) 9-19, (5) 10-10, (6) 10-31, (7) 11-21, (8) 12-12-73.

only marginal but non-significant rooting occurred in the December and February sampling periods. As with the other studies, these results are preliminary and only suggest that auxin and NI treatments have no effect on root regeneration under the conditions studied.

Statistical differences in root regeneration were found between plant ages in *Abies procera* but not in *Picea pungens*. Generally, good rooting was found during the July, August, and December sampling dates in 4-year-old *Abies procera* and poor to no rooting at the other sampling periods. Poor rooting was observed for the 6- and 8-year-old at all sampling dates. In *Picea pungens* no differences between the 4- and 6-year-old plants were found at all sampling dates studied. Generally, rooting during the July and December sampling periods was good and poor rooting at the other times.

Although the differences observed for the different age groups in *Abies procera* may be a result of age effects *per se*, it should be pointed out that plant size (increasing with age) may have imposed a different stress level on the plants, thus affecting rooting. The 6- and 8-year-old plants were at least 1.5 and 2.5 times the size of the 4-year-old plants, respectively. Since no tests were conducted to measure stress conditions, these observations are speculative. Strangely, although the 4- and 6-year-old *Picea pungens* plants were of different size (approx. 1.5 x) no differences in rooting were observed. It's possible that in this species either age differences may not have an effect on rootability or their capacity to tolerate stress conditions may be better.

As stated previously, the overall objectives of these studies were to determine whether root regeneration was possible under the natural environment of Corvallis, Oregon. From these studies we can conclude that root regeneration of evergreens is possible. In addition, these studies suggest that successful rooting may depend on the sampling and rooting period, genetics of the plant, and the age or size of the plant. Auxin (Jiffy Grow) and NI treatments were not found to influence rooting. Better controlled studies are in progress to determine the influence of specific environmental factors and the physiological condition of the plant on the root regeneration of evergreen plants.

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THE USE OF PERIODIC MOISTURE STESS TO INDUCE VEGETATIVE BUD SET IN DOUGLAS FIR SEEDLINGS

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Abstract. Periodic moisture stress of up to -16 bars prior to irrigation was not effective in inducing vegetative bud set in Douglas fir seedlings. Increasing stress decreased terminal bud dimensions, root weight and shoot weight and caused slight increases in shoot/root ratio but did not result in reduced shoot growth after outplanting.