A PHENOLOGICAL STUDY OF PONDEROSA PINE SEEDLINGS

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Effective cultural operations at a nursery are often influenced by the growth activity occurring within plants. This study was undertaken to determine the growth pattern and growth cycles of ponderosa pine tops and roots. The work was done while the author was assistant nurseryman at the Bend Pine Nursery.[1]

Ponderosa pine *(Pinus ponderosa* Laws) is produced at the Bend Pine Nursery for the reforestation of sites within an area of longitude 117° to 124° West, latitude 42° to 49° North, and elevations from 1,500 feet to 6,500 feet. Within this area are climatic, edaphic, physiographic, and biotic factors that have produced variations in the species to make it more adaptable to its natural environment. Seed collected from these localized sites act differently when sown at the nursery.

A careful study of the species and its variations may give a nurseryman an opportunity to adopt techniques in the management of his nursery to produce a more satisfactory tree for field planting.

Method 1-0 [2]-Three seed lots were selected from the 1965 sowing schedule representing variations in growth habits at the nursery in past years. These seed lots were collected on the Winema, Rogue River, and Okanogan National Forests.

Germination tests from Oregon State University Seed Testing Laboratory indicated that the Rogue River and Winema lots would germinate best with 4 weeks of stratification, and that the Okanogan lot would germinate best without stratification. The Winema and Rogue River seed lots were soaked in water 15-18 hours, then drained of excess water, and placed in plastic bags. The bags were then placed in cold storage at a temperature of 34°F. for 30 days. The Okanogan lot was soaked 15-18 hours in water before the presowing treatment.

The seed treatment on all lots was as follows: The seed was placed in a small cement mixer. Sufficient latex was added to coat the seed, and ap

1 Bend Pine Nursery is located 3.5 miles northeast of Bend, Oreg.

2 1-0 in this paper refers to the first growing season.

epicotyl starts to grow, the roots have developed proximately 1 gram of Captan 75 Seed Protectant per pound of seed was added. Anthraquinone, used to deter the birds from the seed as growth emerges, was applied to form a yellow coat when dry. The seed was sown on April 25, 1965. The weather for the following 30 days was typical for the area. The days were warm, usually 60-70° F., with cool to cold nights (fig. 4) during this period. Under these conditions, seed usually does not germinate in less than 30 days. Germination commenced on May 26th and was considered complete on June 1 St.[3]

Observations under "Results and Discussion" below were as follows: Small sections of the row were lifted with a spade. Two seedlings from each location were placed in a polyethylene bag until 10 seedlings had been collected. The samples were then taken to the nursery laboratory and gently washed in running water to remove adhering soil. Physiological differences from the preceding date were carefully noted. Ten seedlings were staked in each seed source for measurement on the study dates. However, after the first several attempts, the 1-0 seedlings were so tender that an accurate measurement could not be made without disturbing the seedling so that it died or showed signs of being suppressed by the next study date. For this reason, only measurements made on the seedlings in the laboratory are presented in the text.

Results and Discussion of 1-0.-As the radicle emerges from the seedcoat, it turns down, and after penetrating the soil 3-5 cm., the hypocotyle arches above the ground as an inverted J. The cotyledons then start to elongate and straighten lifting the remainder of the seed from the soil. By the time that the cotyledons start to emerge from the seedcoat, the radical has penetrated the soil 5-7 cm. When the cotyledons reach their full length (2.5-6 cm) , the epicotyl starts to elongate. At this stage of development, the seedling is very suc

3 Germination is described as the emergence of the cotyledons with attached seed from the ground surface.

culent and is easily broken off. Soon after the lateral branches, and the primary or taproot has penetrated the soil 8-10 cm. This development occurs within the first 2 weeks after the seedling makes its first appearance above the ground.

By June 25th, or 30• days after germination, the juvenile needles at the top of the epicotyl had almost reached the tips of the cotyledons. The roots had white tips that were from 1-3 cm. long, and buds were found on the lateral roots of the more vigorous plants indicating that additional branching was starting. The older roots were starting to turn tan to brown in color, indicating that suberization had started. The roots were not nearly so brittle. Most of the seed coats had been shed from the cotyledons.

The observation of July 9th showed considerable growth on both the tops and roots. Some roots had white tips, 3-4 cm. long. Signs of dichotomous branching were noticed at this time, indicating the possibility that mycorrhiza were starting to form. At this development the tap or primary root was 20 cm. long, and on some trees the root exceeded this length. The Winema source had a more fibrous root system than the Rogue River or Okanogan sources.

White tips were still very noticeable on July 25th but did not appear as long as the preceeding sampling date. The apex of the epicotyl had almost reached the top of the cotyledons. Observations made on August 6th showed little difference other than that growth was proceding at a uniform rate. The Winema source was about 1 cm. taller than the other two sources.

The roots of all trees had white tips on August 20th. Two of the 10 trees checked from the Okanogan source had lateral branches starting to develop. These trees had clusters of mycorrhiza. On September 3d, the amount of white on the tips was less even though some mycorrhiza were still present. The lateral branches of the Winema and Okanogan sources were approximately a cm. long. On this date several of the primary or tap roots exceeded 30 cm. Secondary roots were from 12-20 cm. in length, and branches from these roots were as much as 6 cm. long.

A continued decline was noted in root activity for the next two dates. However, the tops showed no sign of forming buds. Observations made on October 15th showed that the new growth on the root tips consisted of a small white cap on the tip of each root. Many of the trees had taken on a purple cast, indicating that they had started to hardening-off for winter. Buds had formed on three of the Winema trees, and by October 29th the apex of all the trees of each of the sources had swelled noticeably. On this date very small white tips were observed on the roots.

Method 2-0[4]. For this part of the experiment, an Umpqua, Winema, and Wallowa-Whitman source was chosen, since there was not an Okanogan or Rogue River source that was scheduled to be carried over to 3-0. These sources were selected so observations could be made during the third growing season.

For the top-growth study, 10 trees were selected and staked in the nursery bed for periodic measurement. These trees were measured biweekly throughout the study period. The height measurement was taken from the base of the cotyledon to the tip of the bud (tables 4-6). The diameter growth was measured just below the cotyledon (tables 1-3). Root activity was measured by carefully lifting a section of a row with a shovel; two or three seedlings were selected from each of the four or five locations and placed in a polyethylene bag for each source. After 10 seedlings were selected, they were taken to the nursery laboratory and gently washed in running water to remove any adhering soil. The roots were carefully observed to determine the activity taking place. Activity of the roots is an ocular estimation of the percent of white tips found on the trees compared to the total number of root tips (fig. 1-4).

Results and Discussion of 2-0.-The study was started on February 2, 1965. The ground had not been frozen for 30 days except for a light crust early in the mornings. Several warm days (50-60° F.) preceded the first sampling date (table 7). About 10 percent of the root tips were growing at this time. Most root tips showed a small white cap, some beginning to swell noticeably. A few had elongated over a cm.

The roots continued to grow at an accelerating rate during each biweekly period until the root activity had reach 100 percent by the first week in April. At this time the lateral buds had started to

4 2-0 refers to the second growing season in the seedbed.

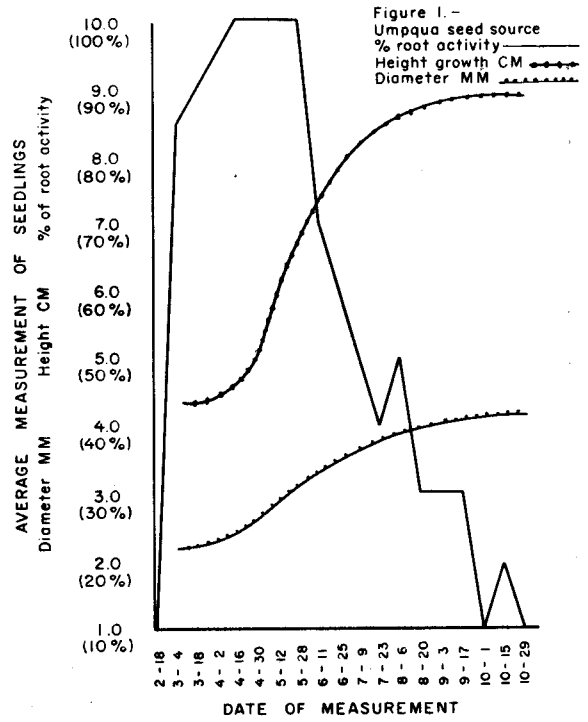
Figure 1.–
Umpqua seed source
% root activity
Height growth CM
Diameter MM
AVERAGE MEASUREMENT OF SEEDLINGS
Diameter MM Height CM % of root activity
10.0 (100%)
9.0 (90%)
8.0 (80%)
7.0 (70%)
6.0 (60%)
5.0 (50%)
4.0 (40%)
3.0 (30%)
2.0 (20%)
1.0 (10%)
2-18 3-4 3-18 4-2 4-16 4-30 5-12 5-28 6-11 6-25 7-9 7-23 8-6 8-20 9-3 9-17 10-1 10-15 10-29
DATE OF MEASUREMENT

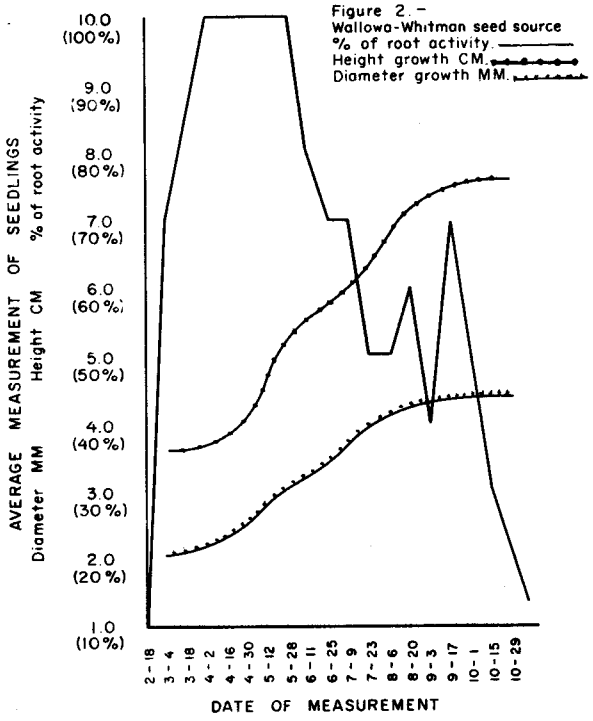
Figure 2.–
Wallowa-Whitman seed source
% of root activity
Height growth CM.
Diameter growth MM.
AVERAGE MEASUREMENT OF SEEDLINGS
Diameter MM Height CM % of root activity
10.0 (100%)
9.0 (90%)
8.0 (80%)
7.0 (70%)
6.0 (60%)
5.0 (50%)
4.0 (40%)
3.0 (30%)
2.0 (20%)
1.0 (10%)
2-18 3-4 3-18 4-2 4-16 4-30 5-12 5-28 6-11 6-25 7-9 7-23 8-6 8-20 9-3 9-17 10-1 10-15 10-29
DATE OF MEASUREMENT

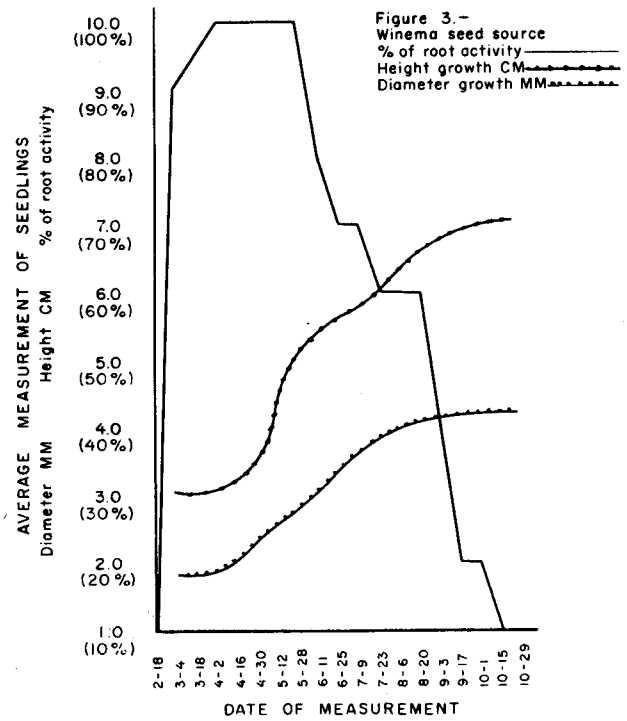
Figure 3.–
Winema seed source
% of root activity
Height growth CM
Diameter growth MM
AVERAGE MEASUREMENT OF SEEDLINGS
Diameter MM Height CM % of root activity
10.0 (100%)
9.0 (90%)
8.0 (80%)
7.0 (70%)
6.0 (60%)
5.0 (50%)
4.0 (40%)
3.0 (30%)
2.0 (20%)
1.0 (10%)
2-18 3-4 3-18 4-2 4-16 4-30 5-12 5-28 6-11 6-25 7-9 7-23 8-6 8-20 9-3 9-17 10-1 10-15 10-29
DATE OF MEASUREMENT

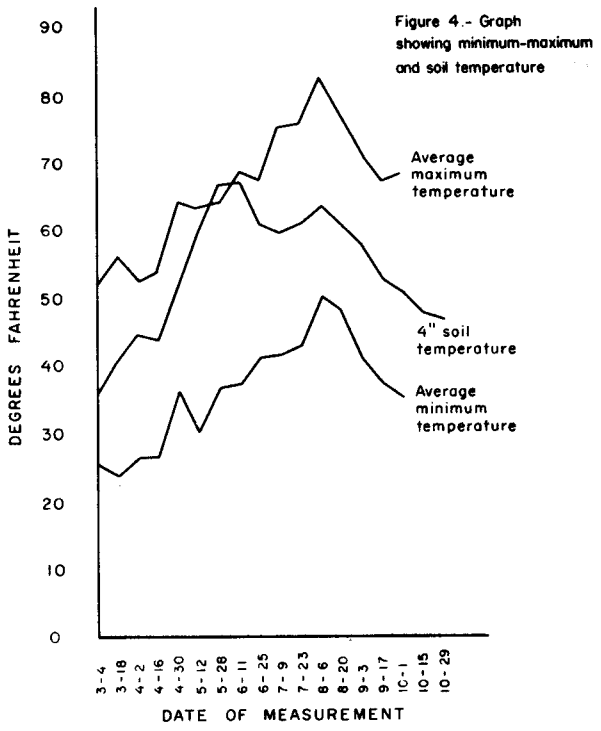
Figure 4.- Graph showing minimum-maximum and soil temperature
DEGREES FAHRENHEIT
90
80
70
60
50
40
30
20
10
0
Average maximum temperature
4" soil temperature
Average minimum temperature
3-4 3-18 4-2 4-16 4-30 5-12 5-28 6-11 6-25 7-9 7-23 8-6 8-20 9-3 9-17 10-1 10-15 10-29
DATE OF MEASUREMENT

TABLE 1.—*Diameter growth of Winema seed source*

Date measured	Tree number (diameter in mm.)										Average diameter
	1	2	3	4	5	6	7	8	9	10	
3-4-65	1.7	1.8	1.8	2.1	1.5	1.8	2.2	2.0	2.0	1.5	1.84
4-16-65	1.7	1.9	1.8	2.2	1.5	1.9	2.2	2.0	2.1	1.6	1.89
4-30-65	2.2	2.6	2.4	2.5	1.8	2.2	3.0	2.6	2.5	2.2	2.40
5-12-65	2.5	2.6	2.5	2.5	2.0	2.5	3.0	2.7	2.6	2.5	2.54
5-28-65	3.0	2.6	3.0	2.8	2.4	2.8	3.0	2.8	3.0	2.5	2.79
6-11-65	3.2	2.6	3.1	3.1	2.6	3.0	3.1	3.1	3.1	2.7	2.96
6-25-65	3.5	3.0	3.2	4.0	2.5	3.5	3.8	3.5	4.0	3.5	3.45
7-9-65	3.5	3.4	3.4	4.0	3.0	3.6	4.5	3.7	4.2	3.7	3.70
7-23-65	3.5	4.0	3.5	4.0	3.0	3.5	4.5	4.0	4.0	4.0	3.80
8-6-65	3.5	4.0	3.7	4.5	3.2	3.8	4.5	4.5	4.1	4.0	3.98
8-20-65	3.5	4.0	3.8	4.5	3.2	4.0	4.5	4.5	5.0	4.0	4.10
9-3-65	3.5	4.0	3.8	4.5	3.5	4.0	4.6	4.5	5.0	4.0	4.14
10-29-65	3.5	4.0	3.8	4.5	3.7	4.0	4.6	4.5	5.0	4.0	4.16
Diameter increase	1.8	2.2	2.0	2.4	2.2	2.2	2.4	2.5	3.0	2.5	2.32

TABLE 2.—*Diameter growth of Umpqua seed source*

Date measured	Tree number (diameter in mm.)										Average diameter
	1	2	3	4	5	6	7	8	9	10	
3-4-65	3.0	2.0	2.3	2.3	2.2	2.0	2.5	1.5	1.8	1.5	2.11
4-16-65	3.1	2.1	2.4	2.3	2.3	2.2	2.5	1.5	1.8	2.6	2.28
4-30-65	3.3	2.5	2.9	3.5	2.5	3.0	2.5	1.5	2.6	3.0	2.73
5-14-65	3.3	2.5	2.9	3.7	2.5	3.0	2.5	1.6	2.7	3.1	2.78
5-28-65	3.4	2.6	3.7	4.0	2.9	3.0	2.6	1.7	2.8	3.4	3.01
6-11-65	3.8	2.8	4.0	4.0	3.2	3.2	2.8	2.0	3.0	3.6	3.24
6-25-65	3.8	2.8	4.0	4.0	3.4	3.3	4.2	2.0	3.0	4.0	3.35
7-9-65	4.0	3.0	4.5	4.5	4.0	3.7	4.3	2.5	3.2	4.0	3.77
7-23-65	4.1	3.0	4.5	4.5	4.0	3.7	4.5	2.5	3.2	4.0	3.80
8-6-65	4.5	3.5	4.5	lost	4.0	3.8	4.5	2.5	3.5	4.0	3.87
8-20-65	4.5	3.5	4.5	"	4.5	3.8	4.5	2.5	3.5	4.0	3.92
9-3-65	4.5	3.5	4.5	"	4.5	3.8	5.2	2.5	3.5	4.4	4.04
10-29-65	*4.8*	*3.5*	*4.5*	"	*4.5*	*3.8*	*5.5*	*3.0*	*4.0*	*4.4*	*4.22*
Diameter increase	1.8	1.5	2.2	—	2.3	1.8	3.0	1.5	2.2	2.9	2.13

elongate, and the true needles were emerging from the base of the primary needles of the previous year. By the middle of April, the scales of the terminal buds had started to turn back. Elongation had started in the terminal bud by May 1st, and by the 15th height growth had increased about 1 cm. The needles had started to emerge from the bundle sheath. The roots were still classed as 100 percent active, but much of the new growth that had been observed 2 weeks earlier had now taken on a light brown cast and was considered to be hardening-off.

The root growth on June 11th had declined considerably. Some of the growth that had formed earlier in the spring was now about the same color as the roots of the past season. The terminal buds were now enlarging in about half of the trees. The true needles were 1.5-2.5 cm. long.

The amount of new growth on the roots declined during July, and by July 23d two or three trees of the Winema and Wallowa-Whitman sources had broken dormancy for the second time. The root activity on these two sources was observed to be greater than that of the Umpqua source. The individual trees that had broken dormancy showed more root activity than those of the same source that had not.

TABLE 3.—*Diameter growth of Wallowa-Whitman seed source*

Date measured	Tree number (diameter in mm.)										Average diameter
	1	2	3	4	5	6	7	8	9	10	
3–4–65	1.5	1.8	2.8	2.0	1.8	2.0	2.0	2.0	1.8	2.5	2.02
4–16–65	1.5	1.8	2.8	2.2	1.9	2.1	2.1	2.2	1.9	2.6	2.11
4–30–65	1.7	2.0	2.8	2.8	2.5	2.5	2.7	3.0	2.2	2.8	2.50
5–14–65	1.9	2.3	3.8	2.8	2.5	2.5	2.8	3.5	3.0	3.0	2.81
5–28–65	2.0	2.4	4.0	3.5	2.5	2.7	2.9	3.6	3.0	3.4	3.00
6–11–65	2.1	2.5	4.0	3.8	2.5	2.8	3.0	3.6	3.0	3.5	3.08
6–25–65	2.5	3.0	4.7	3.8	2.8	3.0	3.5	3.7	3.0	4.3	3.43
7–9–65	2.7	3.0	5.1	4.0	3.5	3.0	3.7	3.8	3.2	4.5	3.65
7–23–65	2.8	3.5	5.3	4.0	3.5	3.2	3.0	4.0	3.2	4.5	3.70
8–6–65	3.0	3.7	5.8	4.2	3.5	3.3	4.0	4.0	3.5	5.0	4.00
8–20–65	3.1	3.7	6.0	4.8	3.5	3.4	4.0	4.0	3.5	5.0	4.10
9–3–65	3.2	3.8	6.5	5.4	3.5	3.4	4.0	4.0	3.5	5.0	4.23
10–29–65	3.2	4.0	6.5	5.4	3.5	3.4	4.0	4.0	3.7	5.0	4.27
Diameter increase	1.7	2.2	3.7	3.4	1.7	1.4	2.0	2.0	1.9	2.5	2.25

TABLE 4.—*Height growth of Winema seed source*

Date measured	Tree number (height in cm.)										Average height
	1	2	3	4	5	6	7	8	9	10	
3–4–65	3.7	3.2	2.2	2.6	2.5	3.0	4.5	3.4	2.5	3.0	3.06
4–16–65	3.8	3.3	2.2	2.7	2.5	3.2	4.5	3.4	2.6	3.1	3.13
4–30–65	4.0	4.0	3.5	4.0	2.5	4.0	4.5	3.5	3.5	3.5	3.20
5–12–65	4.5	4.5	4.2	5.0	3.5	4.5	5.2	4.0	4.2	4.0	4.36
5–28–65	5.5	5.0	5.0	5.5	4.0	5.0	7.0	5.0	5.0	4.5	5.15
6–11–65	5.7	5.0	5.0	6.0	4.0	5.5	8.0	6.0	5.2	5.0	5.54
6–25–65	6.5	5.0	5.0	6.0	4.0	5.5	8.0	6.0	6.0	5.0	5.70
7–9–65	6.5	5.0	5.0	6.0	4.5	5.5	8.0	6.0	6.0	5.0	5.75
7–23–65	6.8	5.5	5.0	6.0	4.5	5.5	8.0	7.5	6.0	5.0	5.98
8–6–65	7.0	6.0	6.0	6.0	5.0	6.0	9.0	7.5	6.0	5.0	6.35
8–20–65	7.0	6.0	6.5	6.0	5.5	6.0	9.0	8.5	6.0	6.0	6.65
9–3–65	7.0	6.0	7.0	6.0	5.6	6.2	9.0	8.0	6.0	6.0	6.68
10–29–65	7.0	6.0	7.0	9.0	6.0	7.0	9.0	8.0	6.0	6.0	7.10
Height increase	3.3	2.8	4.8	6.4	3.5	4.0	4.5	4.6	3.5	3.0	4.04

The root activity on August 20th seemed confined to the ends of the main lateral roots. Very few white tips were found on the fine roots hairs, and these were on the outer edge of the roots system. During this period the clusters of mycorrhiza became very evident and were the most pronounced in the trees of the Wallowa-Whitman. Some clusters were 5-7 mm. in diameter. Eighty percent of the Winema and Wallowa-Whitman seed sources had now broken dormancy for the second time. The bed density of these two sources was less than that of the Umpqua. Beds that are thinner are more likely to break dormancy than those that have a normal density of 20 or more trees per foot of row.

The Wallowa-Whitman source was horizontally root-pruned on September 2d at about 8 inches. On September 17th root activity had increased from 40 percent on September 3d to 70 percent on the 17th. Additional activity was noted on this source well into October. The root growth on the Umpqua and Winema had practically ceased by the 15th of October, while that of the Wallowa-Whitman was 30 percent. Observations made on lifted stock during the fall of 1966, which was milder than 1965, indicated root activity of 20-30 percent up to December 1st.

TABLE 5.—*Height growth of Umpqua seed source*

Date measured	Tree number (height in cm.)										Average height
	1	2	3	4	5	6	7	8	9	10	
3–4–65	5.0	4.0	5.0	4.0	4.5	4.0	7.0	2.5	3.0	4.0	4.30
4–16–65	5.2	4.1	5.5	4.2	4.5	4.0	7.2	2.6	3.2	4.2	4.47
4–30–65	6.0	4.3	6.0	4.5	6.0	4.0	7.5	3.0	4.0	5.5	5.08
5–14–65	6.7	5.4	7.0	5.5	6.5	4.2	7.5	3.0	4.6	6.7	5.71
5–28–65	7.0	6.0	8.0	7.2	7.5	6.0	7.5	3.8	6.0	8.5	6.75
6–11–65	7.2	6.3	10.0	8.0	8.0	6.5	7.8	4.2	6.0	9.0	7.30
6–25–65	8.0	6.6	10.0	10.0	8.0	6.5	9.0	4.4	6.0	10.0	7.84
7–9–65	8.0	6.5	10.0	10.0	8.0	6.5	12.0	5.0	6.0	10.0	8.20
7–23–65	8.0	6.5	10.0	10.0	8.0	6.5	12.0	5.0	6.0	10.0	8.20
8–6–65	8.0	7.0	10.0	lost	9.0	6.5	12.0	5.0	6.0	10.0	8.17
8–20–65	9.0	7.0	10.0	"	9.0	6.5	12.0	5.0	6.5	11.0	8.44
9–3–65	10.0	7.0	10.0	"	9.0	7.0	13.0	5.0	7.0	11.0	8.78
10–29–65	10.0	7.0	11.0	"	9.0	7.0	13.0	5.0	7.0	11.0	8.89
Height increase	5.0	3.0	6.0	—	4.5	3.0	6.0	2.5	4.0	7.0	4.55

TABLE 6.—*Height growth of Wallowa-Whitman seed source*

Date measured	Tree number (height in cm.)										Average height
	1	2	3	4	5	6	7	8	9	10	
3–4–65	2.0	3.5	7.0	5.0	2.5	2.5	2.5	4.0	3.5	3.5	3.60
4–16–65	2.1	3.5	7.5	5.0	2.6	2.7	2.6	4.0	3.5	3.6	3.71
4–30–65	2.5	3.5	8.0	5.0	3.0	3.0	3.0	4.0	3.5	4.5	4.00
5–14–65	3.2	4.5	8.5	6.0	3.6	3.5	3.0	4.2	4.5	5.5	4.65
5–28–65	3.5	5.0	10.0	7.3	4.0	4.0	3.0	5.0	5.2	6.5	5.35
6–11–65	4.0	5.0	10.2	7.9	4.0	4.0	3.0	5.2	5.7	6.7	5.57
6–25–65	4.0	5.0	11.0	8.0	4.5	4.0	3.0	5.5	5.8	7.0	5.78
7–9–65	4.5	5.0	11.0	8.0	4.0	4.0	3.0	6.0	6.0	8.0	5.95
7–23–65	5.0	5.0	11.0	8.0	4.0	5.0	4.0	7.0	6.5	8.0	6.35
8–6–65	5.0	6.0	12.0	9.0	5.0	5.0	4.0	8.0	7.0	8.0	6.90
8–20–65	5.0	5.0	12.0	9.0	5.5	5.5	4.0	8.0	8.5	8.5	7.15
9–3–65	5.0	6.0	13.0	9.0	6.0	5.5	5.0	8.0	9.0	9.0	7.55
10–29–65	5.0	6.0	13.0	9.0	6.0	5.5	5.0	8.0	9.0	9.0	7.55
Height increase	3.0	2.5	6.0	4.0	3.5	3.0	2.5	4.0	5.5	5.5	3.95

Summary

The following conclusions on growth of ponderosa pine seedlings at the Bend Nursery were determined from this study:

1. The roots and tops of 1-0 seedlings grow simultaneously throughout the growing season.
2. Roots of 2-0 ponderosa pine seedlings will usually show some white tips when soil temperatures are above freezing.
3. Root growth takes place for 6 to 8 weeks in the late winter and early spring prior to commencement of top growth on 2-0 trees.
4. Root activity decreases prior to the culmination of height and diameter growth of 1-0 and 2-0 seedlings.
5. A second flush of height growth during July and August is accompanied by an increase in root activity and diameter growth. Root activity was not observed to precede the second flushing.

6. Root-pruning on one seed source was observed to stimulate root growth for 4 to 6 weeks.
7. Individual sources did not show marked variation in their behavior that could not be attributed to other causes, such as bed density.
8. For this type of experiment, a more accurate way needs to be devised to measure root activity.

TABLE 7.— *Average air and soil temperatures*

Last day of period	Average daily air temperatures for the period— Maximum	Minimum	Average soil temperature at 4 inches
	Degrees F.	Degrees F.	Degrees F.
3–4–65	52.3	25.9	36.2
3–18–65	56.3	24.1	41.3
4–1–65	52.9	26.8	45.0
4–16–65	54.0	26.9	44.0
4–30–65	64.1	36.2	52.0
5–12–65	63.3	30.1	60.0
5–28–65	64.0	36.7	66.7
6–11–65	68.7	37.6	67.0
6–25–65	67.7	41.7	61.0
7–9–65	75.4	41.6	60.0
7–23–65	75.8	43.3	61.0
8–6–65	82.2	50.5	64.0
8–20–65	77.2	48.5	61.0
9–3–65	71.3	41.4	58.0
9–17–65	67.2	37.2	53.0
10–1–65	68.3	35.1	51.0
10–15–65	---- Gage broken	----	48.0
10–29–65	---- " "	----	47.0