ROOT DEVELOPMENT OF CONIFER SEEDLINGS AS MEASURED BY A RADIOPHOSPHORUS TRACER

A Thesis

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ABSTRACT

Survival of transplanted seedlings is of major concern to all public agencies and private companies restocking logged and burned-over timber lands. The author has investigated some environmental and physiological relationships affecting survival of Douglas-fir, ponderosa pine, and Engelmann spruce seedlings.

Glass-front root-observation boxes were used to compare rates of root growth among the three species. Radiophosphorus (P^{32}) placement in the soil below seedlings' roots followed by transferal to needle tissue indicated root effectiveness. Ponderosa pine seedlings' roots penetrated deeper and retrieved more P^{32} from a deeper soil zone than did those of Douglas-fir and Engelmann spruce.

Douglas-fir seedlings were used for root-pattern comparisons in a nursery plantation. In trees of two ages, 2-1 and 2-0, root growth and activity, survival, and top-growth were compared. P^{32} was again utilized (injected into soil with a special steel probe) to evaluate root effectiveness and to measure both lateral and vertical root penetration.

The older 2-1 seedlings normally penetrated to a depth or lateral distance sooner than did the younger seedlings. The 2-0 trees retrieved a large percentage of their foliar radiophosphorus from only 3 inches below the surface, while roots of the older Douglas-fir were most active at 8 inches below the surface. During the second year of the study, the older seedlings showed superior lateral root extension. Top-growth differences were minor, although the younger seedlings did produce slightly more leader growth. Due to unusually moist weather during both summers, seedling mortality was very low.

A 2-0 ponderosa pine plantation was established on a vegetated area to investigate influences exerted upon tree seedlings by adjacent vegetation. Areas of 12-, 36-, and 60-inch diameter were cleared of vegetation (scalped) around the seedlings. Control trees had no vegetation removed from around them. After the first growing season, survival ranged from 48% on non-scalped specimens to 77 to 85% on scalped sites.

P^{32} injected into soil was used to evaluate root activity among the treatments. Controls obtained very little radiophosphorus compared to those with scalps. Vegetation adjacent to treated seedlings was sampled for isotope content. Forbs and shrubs absorbed the isotope from lateral distances exceeding 24 inches. Grasses were not as effective at this distance laterally but obtained a high percentage of radioactivity from greater depths. These results indicate that competing vegetation and rooting patterns of tree seedlings should both be considered before reforestation work is started.

INTRODUCTION

There are approximately 52 million acres of unstocked commercial forest land in the United States today (U. S. Dep. of Agr., 1958). This represents 11% of the total commercial forest area. Only 0.8% of the unstocked land was planted during 1952 (USDA, 1958), and in 1963 only 2.5% was planted (Tree Planters Notes, 1963). Even if all such plantings were successful, this would not be a substantial gain, considering the acreages denuded annually by logging, insects, diseases, and fires. All planting programs, however, are not successful, and thus the situation becomes even more unsatisfactory. During the 5 years preceding 1955, some 12 million forest seedlings were planted in California (Stone, 1955). Less than 50% of these trees were alive in 1955. In Idaho, many Douglas-fir (Pseudotsuga menziesii Franco) plantings have shown less than 10% survival after a single growing season (Loewenstein and Pitkin, 1961).

Attempts to restock land in the western mountain region are hampered by a lack of knowledge concerning the interaction of the various factors involved. Development of seedling root systems, in particular, is poorly understood. The importance of roots in determining the mortality of seedlings makes intensive root studies mandatory. This study was designed to reveal more about the behavior of seedling roots as affected by several variables. In particular, plant competition, soil moisture conditions, and temperatures of both atmosphere and the soil are of prime importance to root growth.

Conventional root observation techniques generally involve excavation of specimens. This obviously prevents continued study of the development of these same plants. Moreover, such excavations are slow and laborious even on young trees, particularly because every treatment requires several replications. The lack of a less time-consuming method has hampered investigations of root systems in the past.

Radioisotope techniques provide a way to study roots _in situ_ without disturbing the plant. Most studies using radioactive tracers in root system investigations have involved agricultural crops. The work with tree seedlings reported here represents an attempt to adapt the method to forestry.

One aspect of the field studies undertaken involved comparisons of root development of outplanted two- and three-year-old Douglas-fir nursery stock. A second phase of the investigation was centered on the effects of varying levels of competition on rooting of planted two-year-old ponderosa pines (_Pinus ponderosa_ Douglas).

A greenhouse experiment utilizing glass-front root observation boxes, the main purpose of which was to verify the suitability of procedures, also is outlined herein.

Creek site described below.

Meadow Creek Experiment

As indicated above, the 1964 nursery study was continued in 1965. Main emphasis, however, in the second field season of the project was placed on the influence of competition on root development and survival of outplanted seedlings.

During May of 1965 a plot was established on the University-of-Idaho Forest near Troy, Idaho, in an area vegetated with grass, forbs, and small shrubs. Important species represented were:

a) Shrubs

Snowberry (*Symphoricarpos* spp.)

Willow (*Salix* spp.)

Ninebark (*Physocarpos malvaceus* Green, Kuntze)

b) Forbs

Barberry (*Berberis repens* Lindl.)

Aster (*Aster conspicuous* Lindl.)

Yarrow (*Achillea lanulosa* Nutt.)

Dogbane (*Apocynum pumilum* Gray, Greene)

c) Grass

Pinegrass (*Calamagrostis rebescens* Buckl.)

Idaho fescue (*Festuca idahoensis* Elmer.)

Bluebunch wheatgrass (*Agropyron spicatum* Pursch, Scribn. and Smith)

Sedges (*Carex* spp.)

This site was on a 5% west-facing slope. Soil on the plot is a Santa series silt-loam, transitional between the western brown forest and brown podzolic great soil groups. It has a prominently-leached A2 horizon, a nearly impermeable fragipan at the 24-inch depth, and a high percentage of silt-sized volcanic ash. The pH is 6.5 with a 15-atmosphere water holding percentage of 8.1, and a 1/3-atmosphere percentage of 33.2.

The area was first divided into four blocks. Within each block, microsites were developed representing four competition levels:

a) Control, no vegetation removed.

b) Circular scalp, removing all vegetation within a circle of 12-inch diameter.

c) Circular scalp, 36-inch diameter.

d) Circular scalp, 60-inch diameter.

Forty-eight microsites of each size were randomly distributed within each block. On May 12, and 13, 1965, one 2-0 ponderosa pine seedling (root-pruned to 9 inches and graded at the nursery for uniformity) was planted in the center of each microsite. Planting bars were used for the operation, and the weather was warm and sunny at the time of planting.

Radioisotope placement patterns were similar to those used in tree experiments at the nursery in 1964, except that treatments involving an 18-inch radius were not employed. Thus, only 11 patterns were involved at Meadow Creek, rather than 14. Within each block, each isotope treatment was superimposed once on each microsite. For example, within each block, isotope injections at 3-inch depth and 1-inch lateral distance from the seedling were made to 1 control microsite, one 12-inch diameter microsite, one 36-inch diameter microsite, and one 60-inch diameter microsite.

These P^{32} injections were made between June 25 and July 2, with the time-span necessitated by isotope shipment delay. Technique and rates of isotope application were similar to those described above in the nursery experiment. Instrumentation for soil moisture and climatic data collection was similar to that used at the nursery during 1964. Leader length of the 2-0 ponderosa pine seedlings was measured four times during the 1965 growing season.

A plan of the Meadow Creek experimental plot is presented in Figures 5 and 6.

Foliage was sampled weekly for isotope analysis, which was conducted as previously indicated. Root elongation and relative activity patterns were obtained and subjected to statistical evaluation as indicated above for the nursery data.

It was of interest to ascertain whether or not competing plants located a considerable distance away were

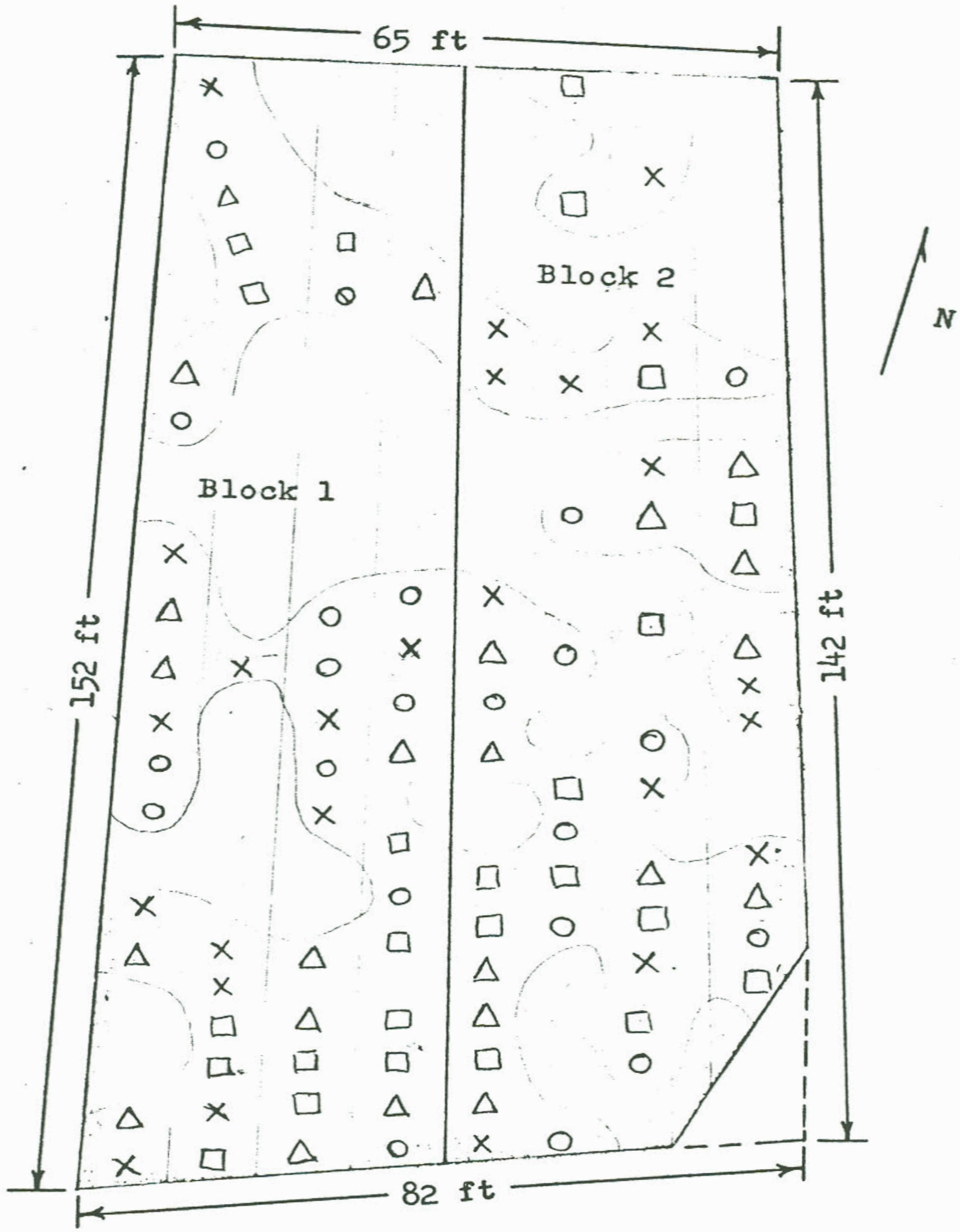

Figure 5. Blocks One and Two of the Meadow Creek Plot. Delineated unused areas indicate sites too brushy for use in the experiment. Rows are numbered one to eight from left to right. Blocks Three and Four are south of those shown on this figure. X indicates seedlings without scalps; O indicates those with 12-inch diameter scalps; Δ indicates 36-inch scalps; and □ indicates 60-inch scalps.

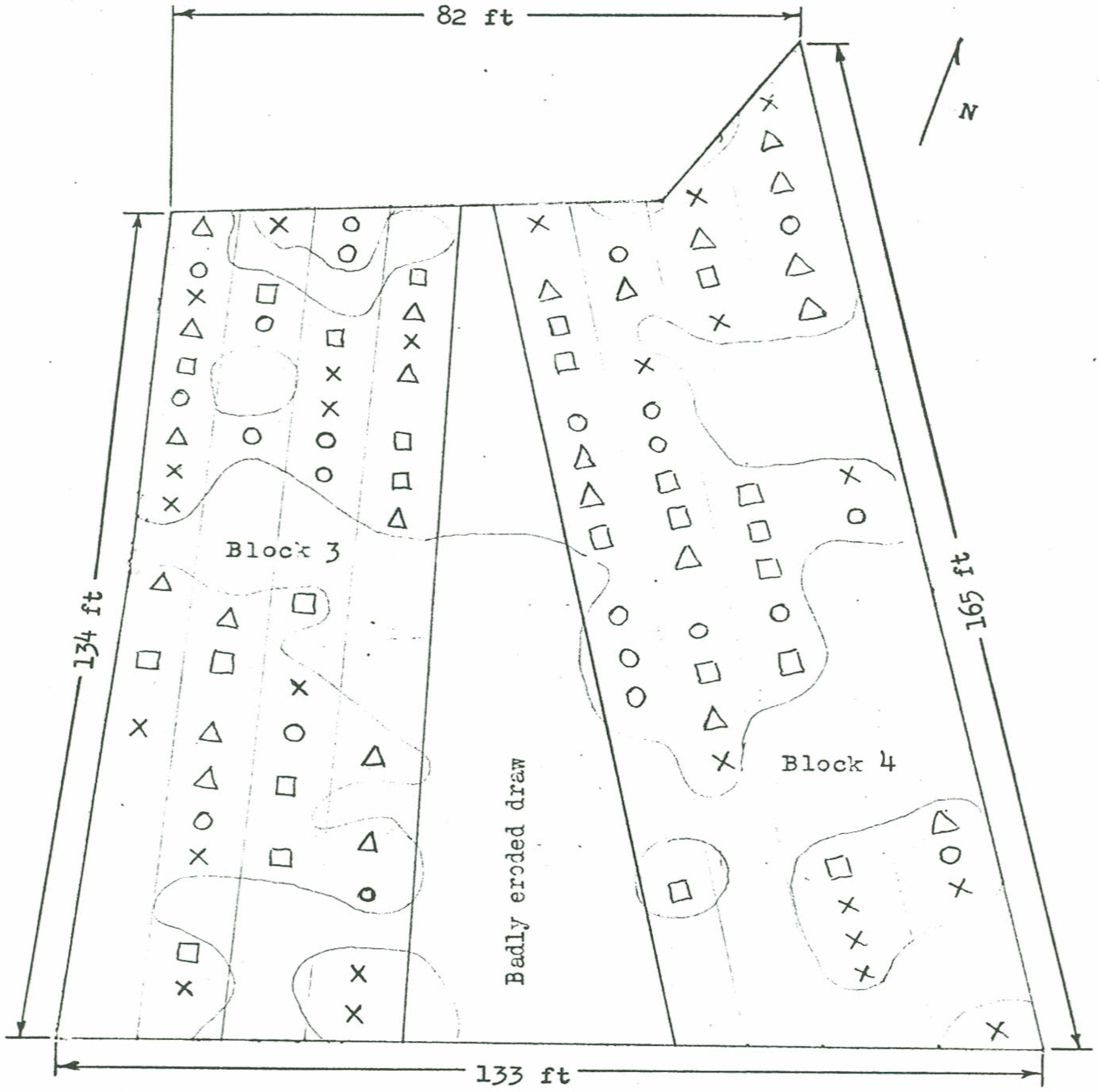

Figure 6. Blocks Three and Four of the Meadow Creek Plot. Rows are numbered 9 through 16 from left to right. Blocks One and Two are north of the area shown in this figure. X indicates seedlings without scalps; O indicates those with 12-inch scalps; Δ indicates those with 36-inch scalps; and □ indicates 60-inch scalps.

able to absorb the isotope. This would indicate that they were also able to compete with the seedlings for moisture. Thus, leaf samples were taken for analysis weekly from several species located 2 and 3 feet from trees planted on eleven 36-inch scalps on Block 3. Each of the microsites had received a different one of the 11 isotope injection treatments.

Greenhouse Experiment

A greenhouse study was conducted during the winter of 1964-65, the main purpose of which was evaluation of techniques. Of particular concern was the possibility of a considerable time-lag between uptake of the P^{32} by the root and its appearance in detectable amounts in sampled needles.

During late fall of 1964, the author constructed 24 glass-fronted root boxes (Figure 7) similar to those built by Lavin (1961), except that these were made of wood and were only half as wide as Lavin's. The root boxes were 2 inches thick, 10 inches wide, and 30 inches deep. Drainage holes were provided at the bottom of each box. The boxes were housed in a wooden frame structure covered with plastic to exclude light from the roots. Supports within the housing allowed the individual root boxes to be angled forward so that more roots would tend to grow against the glass, thus aiding observation of roots.

SUMMARY

Radioisotope tracer technique was employed in a series of experiments involving root development of conifer seedlings and the competition afforded the young plants by other vegetation. Phosphorus^{32} was injected into the soil, and radioactivity levels in the foliage were sampled to indicate the presence of roots in the isotope injection zone and the amount of absorptive activity occurring. Results may be summarized as follows.

Greenhouse Experiment

Glass-front root observation boxes were utilized both to evaluate technique and to compare isotope uptake patterns of three tree species. The radioisotope was injected into the soil at various distances below the pruned root tips of seedlings. Elongation of roots into the radioactive zone was followed visually, and periodic determinations of radioactivity in foliage were made.

On the average, roots of ponderosa pine seedlings reached the deepest placement zone more rapidly than Douglas-fir and Engelmann spruce. Most new root growth originated above the pruned root tips on all three species. Considerable variation in seedling-root elongation rates was noted among specimens within species. This observed variation probably occurred because only those roots growing against the glass could be seen.

Roots were observed to grow sporadically. A single root may have grown 2 inches during one week and virtually stopped elongating during the next week.

Radioactivity was generally detected in foliage within a week before or after a visible root was seen to enter the isotope-placement zone. Although in certain instances relationships were not this good, the results in total indicated that the detection of radioactivity in foliage is a reliable technique for tracing the location of roots.

Ponderosa pine seedlings absorbed the largest percentage of P^{32} from the placement zone 6 inches below the original pruned root tips. In contrast, both Engelmann spruce and Douglas-fir absorbed more P^{32} from the zone only 2 inches below the pruned tips. Seedlings of all 3 species absorbed relatively little P^{32} from the 10-inch placement zone. Total phosphorus levels in stem and needle samples taken at the end of the experiment were lowest in ponderosa pine, with Douglas-fir containing over twice as much per unit weight. Engelmann spruce contained an intermediate amount of phosphorus.

Autoradiograms indicated that radioactivity was very high in roots and in meristematic areas. Older needles and stems contained considerably less P^{32}.

Nursery Experiment

Rooting patterns of 2-0 and 2-1 Douglas-fir seedlings, as indicated by foliar P^{32} content, were investigated during the 1964 and 1965 growing seasons. The radioisotope was placed in the soil at various depths and lateral distances from individual seedlings.

Roots of 2-1 trees normally penetrated to more distant placement zones 1 or 2 weeks sooner than 2-0 trees. In 1964, foliar P^{32} content was highest in 2-1 seedlings growing in soil injected at the 8-inch depth, but 2-0 specimens absorbed the greatest amount from the placement zones only 3 inches below the soil surface. During the second year of the nursery study, both age groups absorbed higher amounts of P^{32} from the 24-inch depth zones than from the 16-inch. The shallower placement treatments were not used in 1965.

Roots of both aged seedlings extended 12 inches laterally during 1964, but by far the most absorptive activity occurred within 1 inch of the plant stems. By the end of 1965, the 2-1 seedlings were obtaining most of the isotope from lateral zones 6 inches away. The absorptive activity of 2-0 plants was highest 1 inch away from stems. Although some roots were detected to have extended 18 inches laterally in 1965, relatively little absorption occurred in this zone.

The greater amount of P^{32} per unit weight of foliar tissue was found in 2-1 seedlings throughout both summers. This finding suggests either more roots per unit of shoot weight or more active roots in the 2-1 trees than in the 2-0 seedlings.

The 2-0 seedlings attained a more rapid rate of leader and needle growth than did the 2-1 plants. This may indicate a higher shoot-to-root ratio and less drouth tolerance. Abnormally wet conditions during both years of the experiment, however, insured excellent survival of the seedlings in both age groups.

Examination of excavated root systems of seedlings from both groups at the conclusion of the experiment showed that the tracer method data had satisfactorily indicated the true patterns of root growth. The excavations also showed that the direction of new root growth was not greatly influenced by the slit formed when trees were planted with a planting bar.

Meadow Creek Experiment

In 1965 a plot was established on an already vegetated area of the College Forest in order to study some effects of competition on tree seedling growth and survival. Ponderosa pine seedlings (2-0) were used, with P^{32} injected into the soil around them as in the nursery experiment. Native vegetation was either not disturbed or else was removed within circles of 12-, 36-, and 60-inch diameter around the planted seedlings. On the undisturbed microsites, survival of seedlings was only 48%, compared to 77 to 85% on scalped sites. Unusually beneficial weather conditions probably prevented the particular size of the scalped area from exerting much influence on survival or on leader growth.

Higher rates of P^{32} absorption were found on scalped areas. On undisturbed sites the low values found could have been caused both by poor root growth resulting from severe competition and by removal of P^{32} from the soil reservoir by the other vegetation. Radioactivity in foliage indicated that roots of seedlings reached a depth of at least 24 inches during the growing season. Maximum lateral extension was only 6 inches at the 24-inch depth, but at least 12 inches at 8- and 16-inch depths.

Ponderosa pine seedlings obtained most of their foliar P^{32} from the 3- and 8-inch depths, 1-inch lateral placement injection sites. Considerable uptake was also noted from the zones located 1 inch from the plant, but 16 and 24 inches deep. A deep, narrow system of most-active roots was indicated by this pattern of recovery.

Analysis of foliage samples from the native vegetation provided information regarding magnitude of competition from plants considerable distances from the seedling root zones. Some such plants definitely showing radioactivity were growing at least 24 inches from the isotope placement sites. Grasses absorbed more P^{32} from deeper placements than did forbs and shrubs; forbs and shrubs were more effective in absorption at greater lateral distances. These results indicate that the specific type of expected competing vegetation and the rooting pattern of the tree seedlings should both be considered when planning site preparation and assessing results of planting programs.

Location of Complete Research:

Author & Title: McConnell, Lee Porter
Root Development of Conifer Seedlings as Measured by a Radiophosphorus Tracer

University of Idaho Library:

Call Number- SD597.C7M23

College of Natural Resources:

Department- Forest Resources-
Major in Forest Soils

Other Sources: