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AND RANGE SCIENCES

Root Development and Survival of Planted Ponderosa Pine Seedlings as Influenced by Competing Vegetation

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Forest, Wildlife and Range
Experiment Station
Moscow, Idaho

Station Paper No. 5

December, 1968

SUMMARY

Radioisotope tracer technique was employed in an experiment involving root development and survival of out-planted ponderosa pine seedlings. Native vegetation was either not distrubed or else removed within circles of 12-, 36-, and 60-inch diameters around the young trees. Phosphorus^{32} was injected into the soil and periodic determinations were made of radioactivity levels in the foliage of seedlings and competing plants in order to ascertain the presence of roots in the isotope injection zone and the amount of absorptive activity occurring.

On undisturbed microsites, survival of seedlings was only 48 percent after the first growing season, compared to 77 to 85 percent 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 first 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.

The seedlings obtained most of their foliar p^{32} from the injection placement zones located at 3- and 8-inch soil depths, one inch from the root collar. Considerable uptake also occurred in the zones also located 1 inch in a lateral direction from the plant, but at 16 and 24 inch soil depths. 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 grasses, forbs, and shrubs established considerable distances from the seedlings. Some such plants which definitely showed 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 both the specific type of competing vegetation expected and the rooting pattern of the tree seedlings should be considered when planning site preparation and assessing results of planting programs.

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INTRODUCTION

There are approximately 52 million acres of unstocked commercial forest land in the United States (U. S. Dept. of Agr., 1958), and this represents 11 percent of the total commercial forest area. Attempts to restock land in the western mountain region are hampered by a lack of knowledge concerning the behavior of the various factors involved in seedling establishment. Development of root systems, in particular, is poorly understood. Conventional root observation techniques generally involve excavation of specimens, and 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 replications. The lack of a less time-consuming method has hampered investigations of root systems in the past.

Radioisotope technique provides a way to examine roots *in situ* without disturbing the plant. Most studies using radioisotopes to trace root systems have involved agricultural crops (Hall, *et al* 1953; Hammes and Bartz, 1963; Mathis, Jaynes, and Thomas, 1965). There have been few attempts to utilize the method in forestry. Karpov (1962) used phosphorus^{32} to study the amount of competition between roots of dense-standing birch (*Betula verrucosa*) and seedlings of Norway spruce (*Picea abies* (L.) Karst). Seedlings planted with a 40-cm trench excavated around them would, within 14 days, absorb 5 times more p^{32} than those without adjacent trenches. Smaller root systems on the trees without trenches were as active per unit surface area as the larger systems. He concluded that the size of root systems, rather than phosphorous removal by competition, was the limiting factor.

Rates of uptake and translocation were studied by Moreland (1950) Loblolly pine (*Pinus taeda*, L) translocated p^{32} at rates up to 1.2 meters per hour; lateral roots moved the isotope more rapidly than stems.

Much of the phosphorus added to soil, whether it is radioactive or not, quickly reverts to an unavailable form. However, even a relatively large uptake of p^{32} will not injure plant tissue. Stanton and Sinclair (1953) indicate that single buds from plum trees were not damaged, although they contained up to 3 mc of the isotope. This quantity involves over 100,000 disintegrations per second, but as few as 5 or 10 disintegrations per minute can be detected with a well-shielded gas-flow Geiger Counter. Thus an extremely small amount of isotope in a leaf is sufficient to verify the location of a root, and the actual amount of translocation to

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[1] Published with the approval of the Director, Forest, Range and Wildlife experiment Station, University of Idaho, Moscow.

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the leaf need not be nearly as great when using a radioisotope than when using something more difficult to detect. In addition, because such low quantities of radiotracers can be accurately recorded, only minimal amounts of the material need be added to the soil.

The investigation detailed in this paper was designed to ascertain the effects of various levels of competition on rooting and survival of planted two-year-old ponderosa pine (*Pinus ponderosa* Douglas). A radiotracer, p^{32}, was used to reveal patterns of root development.

PROCEDURE

During May of 1965, a plot was established on the University-of-Idaho Forest (Big Meadow Creek Unit) 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, (Kuntz)
   Barberry (*Berberis repens* Lindl.)

b. Forbs
   Aster (*Aster conspicuous* Lindl.)
   Yarrow (*Achillea lanulosa* Nutt.)
   Dogbane (*Apocynum pumilum* Gray, Greene)

c. Grasses
   Pinegrass (*Calamagrostis rebescens* Buckl.)
   Idaho fescue (*Festuca idahoensis* Elmer.)
   Bluebunch wheatgrass (*Agropyron spicatum* Pursch, Schribn. and Smith)
   Sedges (*Carex* spp.)

The site was located on a 5 per cent west-facing slope. The soil was classified in the Santa series, transitional between the western brown forest and brown podzolic great soil groups. It had a prominantly-leached A_2 horizon, a nearly impermeable fragipan at a 24-inch depth, and a high percentage of silt-sized volcanic ash. Texture of the soil above the fragipan was silt loam, 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, one 2-0 ponderosa pine seedling (root-pruned to 9 inches and graded at the nursery for uniformity) being planted in the center of each microsite.

Initial injections of carrier-free p^{32} were made to the soil around the individual trees in late June. Three probes, of the type described by Loewenstein (1965), were employed to carry out this operation. These were constructed of stainless steel tubing, 1/4 inch in diameter and about 30 inches long. Outlet ports for discharge were located slightly above the tips, and glass syringes set to deliver 5 ml of solution (concentration 15 uc/ml) per injection were attached to the tops. These syringes were connected to 500-ml plastic reservoir bottles supported by a shelf attached to the upper part of the probe sheath.

Injections were made in a circular pattern around individual trees according to the treatment scheme outlined in Table 1. In each block, one tree of each age class received a particular treatment. Injections were spaced around the circle so as to give 20 percent coverage of a "tube" of soil at the particular depth indicated by treatment. This degree of coverage has been used in agricultural tracer experiments and was the maximum deemed possible because of isotope cost considerations.

Table 1. Outline of treatments involved in experiment. Soil injections of p^{32} were made in a circular pattern at the indicated distances from root collars of 2-0 ponderosa pine seedlings.

Treatment number	Distance from seedling root-collar (inches)	
	Lateral radius	Depth
1	1	3
2	1	8
3	1	16
4	1	24
5	6	3
6	6	8
7	6	16
8	6	24
9	12	8
10	12	16
11	12	24

To facilitate proper placement, wire hoops of the radii desired were fabricated. These were marked at equal distance around the circumference; 2 marks for 1-inch radius circles, 10 for 6-inch, 20 for 12-inch.

In practice, the hoops were placed on the ground, with the tree at the exact center-point. Injections were then made in soil adjacent to each mark on the hoop with the probe inserted to the required depth. Utilizing three probes, it was possible to complete the entire injection procedure in one day.

One week after injection, and at weekly intervals throughout the 1965 growing season, needle samples were collected from the trees. To help ascertain the degree of competition to the seedlings from other plants outside the scalped zones, weekly collections were made of leaves from several species located 2 and 3 feet from the trees planted on 11 of the 36-inch diameter scalps. Each of these microsites had received a different one of the 11 isotope injection treatments. Presence and level of radioactivity in all samples were determined through use of a Nuclear-Chicago automatic gas-flow counting system. Rates of activity were recorded in counts-per-minute per 10 mg of oven-dry tissue so that all data were comparable.

Radiotracer data were used for two purposes:

1. As an indication of the part of the seedling root zone where maximum absorption of p^{32} (and thus presumably other compounds) were taking place. The *Relative Activity* of needle tissue was obtained at each sampling time by dividing the radioactivity found for each seedling by the total activity found for all seedlings and multiplying by 100. The figures obtained in this way were interpreted in the following manner: A plant with high relative radioactivity in its needles was judged to have had either many roots, or at least very actively-absorbing roots, in the zone of isotope placement. Foliage of low relative radioactivity would indicate that the plant had few roots, or at least very inactively-absorbing roots, in the isotope placement zone involved.
2. As an indication of the degree of competition to seedlings exerted by plants located outside the scalped zones. Presence of radioactivity in foliage of grasses, forbs, and shrubs would indicate that their roots extended into the zone of isotope placement.

Tree survival was recorded weekly; leader growth was measured at the end of the first growing season. These determinations were repeated in the fall of 1966 (after the second growing season).

Soil moisture levels on all four kinds of microsites were monitored by weekly resistance readings of gypsum blocks. These blocks were inserted in depth-lateral zones corresponding to each p^{32} placement. A calibration curve was used to convert resistance to percent moisture.

RESULTS

Because of the fragipan located 24 inches below the surface, the soil at Meadow Creek is limited in its total water-holding capacity. Any water in excess of the field capacity of the soil above this layer is lost through runoff and lateral percelation. A soil monolith taken near the plot in late May of 1965, when soil moisture was at a maximum, showed no living roots and very little water below the dense fragipan.

Some rain fell during nearly every week of the growing season (Figure 1.) This frequent precipitation was undoubtedly in part responsible for maintaining good soil-moisture supplies where trees were planted on microsites scalped of competing vegetation. Results of a study on a similar site, made in a very dry year, showed that even 36-inch scalps failed to enhance survival of Douglas-fir seedlings (Loewenstein and Pitkin, *unpublished*). In the current experiment, a high percentage of the planted seedlings survived on scalped microsites (Figure 2.) Where no scalp was constructed, only 48 percent of the trees were alive by November 15. Scalps of 12, 36, and 60 inches all proved beneficial, with survival ranging from 77 to 85 percent at the end of the first growing season.

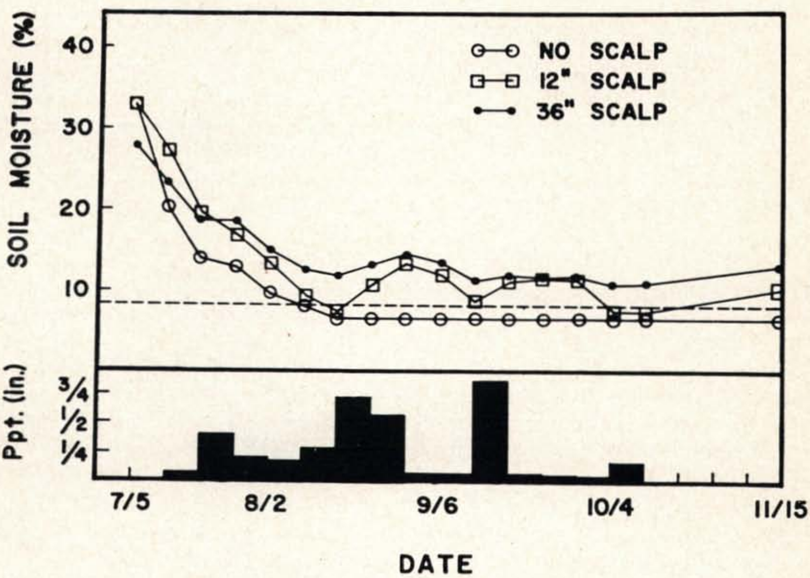

Figure 1. Precipitation and soil moisture percentages (at the 8-inch depth) on the Big Meadow Creek plot during 1965.

Soil moisture was rapidly depleted on the control microsites, and from August 16 until November 15 it was below the wilting point (8 percent) at the 8-inch depth (Figure 1). Because of space limitations, data concerning moisture trends at other depths have not been plotted. By October 11, the entire soil profiles of control and 12-inch scalped microsites were depleted of all available moisture. Profiles of the larger scalped areas retained available moisture at all depths through the whole growing season.

In 1965, leader growth of the seedlings was only to a minor degree affected by the removal of competing vegetation. By fall, the leader length of seedlings growing on large 36- and 60-inch scalps averaged just 0.2 inch more than that of seedlings growing on control and 12-inch scalp microsites.

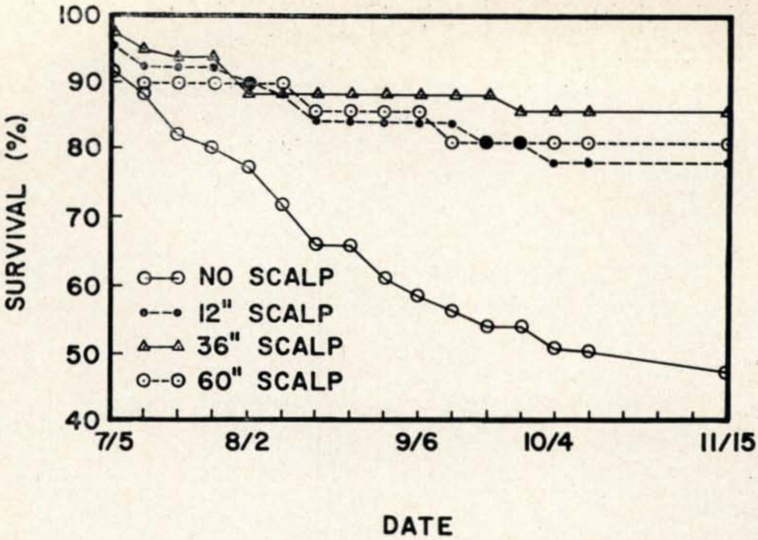

Figure 2. Effects of scalping upon ponderosa pine seedling survival at Big Meadow Creek, 1965. The presence of scalps, regardless of size, was very beneficial.

Table 2 shows the amount of radioactivity (corrected for decay and mortality) present in foliage of trees growing on the four competition level microsites as determined on November 15. The values are the summation of data for 44 samples (10 mg each), or 440 mg of tissue. Control trees contained no detectable radioactivity at this time, but these on 60-inch scalps had retained some 14,596 cpm/440 mg tissue. If these findings are a valid indication of root activity, the latter seedlings possess superior rooting systems. This factor should be reflected in su-perior survival and growth in subsequent years. Measurements taken after the second growing season (fall, 1966) shows that this superiority is indeed being manifest. No further mortality was experienced on the 60-inch diameter scalps, but survival on control microsites decreased from the 48 percent recorded at the end of the first growing season to 27 percent at the end of the second. Differences in leader growth were much

Table 2. Total radioactivity present in tissue of ponderosa pine seedlings at Big Meadow Creek on November 15, 1965. Data represent cpm/440 mg tissue for each of the 3 scalp sizes and control. Corrections were made for mortality and isotope decay.

Scalp size	Total radioactivity
Control	0
12 inches	3211
36 "	11348
60 "	14596

more marked in 1966 than in 1965. For example, seedlings from 60-inch diameter scalped zones bore leaders averaging 4.7 inches after the second growing season, compared to an average of but 2.1 inches for seedlings from unscalped microsites.

Highest foliar p^{32} content was found in seedlings growing on soil injected 1 inch from the stems. On October 11, for example, the greatest activity occurred in the 1x8-inch injection treatment, followed by the 1x3, 1x16, and 1x24-inch treatments in that order (Table 3). The trees from 1x8 and 1x3-inch injection sites absorbed considerably more than those from sites having deeper isotope placement. However, even the seedlings from the 1x24-inch treatment had foliage higher in radioactivity than the plants growing on sites injected at shallower depth but greater lateral distance from the stem. Trends evidenced on this date were similar to those found during other weeks. These results in total indicate that the pine seedlings in the first growing season after planting tended to develop relatively deep but narrow root systems.

Rates of p^{32} absorption by seedlings on the Big Meadow Creek plot indicated the occurrence of considerable competition between the young trees and other vegetation. A higher rate of p^{32} absorption was found throughout the summer in trees on scalped sites, as compared to trees on unscalped microsites (Figure 3). At least two factors could have contributed to these results. Competition for moisture by other vegetation on unscalped sites may have adversely affected the root proliferation and activity of seedlings, thus affecting uptake of p^{32}. Also,

Table 3. Radioactivity recorded from foliage sampled at each of 11 treatment locations at Big Meadow Creek on October 11, 1965.* The value for each treatment is the sum of the radioactivity per 10 mg of needle tissue for all live trees. This value has been corrected for missing (dead) trees and for isotopic decay.

Treatment	Radioactivity (cpm)
1x8	19411
1x3	12470
1x16	5059
1x24	3529
6x3	2588
12x8	2353
6x8	1765
12x16	1294
6x16	1059
6x24	118
12x24	0

*The highest seasonal level of radioactivity was recorded from samples taken on this date.

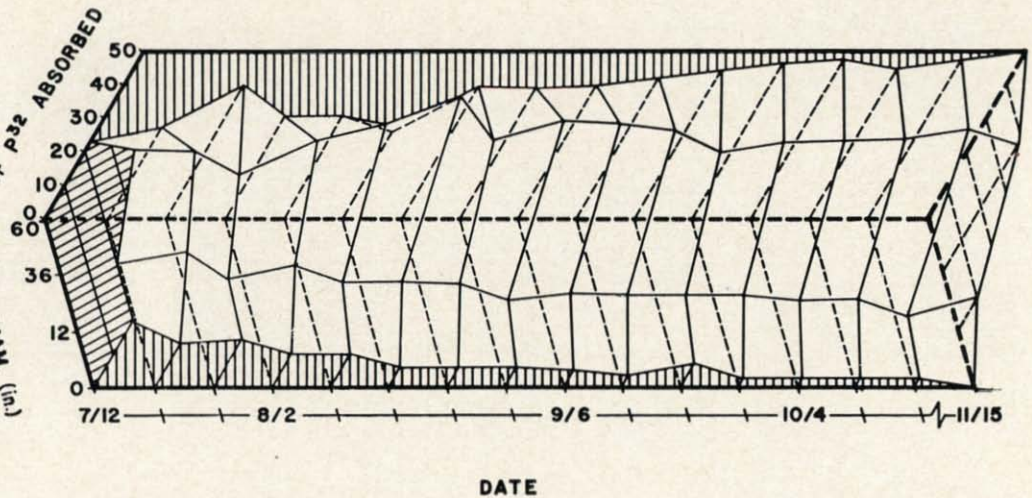

Figure 3. Relative radioactivity in foliage of 2-0 ponderosa pine seedlings growing on microsites providing 4 levels of competition; control (no scalp) 12-, 36-, and 60-inch scalps at Big Meadow Creek, 1965. Weekly data indicate the percent of the total radioactivity which was found in the seedlings growing on each particular type of microsite.

the competing plants may have absorbed the isotope, making a lesser quantity available for uptake by the tree seedlings. The data presented below show that even plants growing some distance from the treated areas were extending roots into the zone of isotope placement. This being true, competition by vegetation growing in close proximity to the seedlings must have been especially strong.

Foliar samples from vegetation surrounding the seedlings growing on 36-inch scalps were periodically analyzed for presence and level of radioactivity. The data indicated rooting habits of the grasses, forbs, and shrubs on the plot and the magnitude of competition from such plants located a considerable distance from the tree seedlings. Shrubs absorbed 87.8 percent of the total p^{32} found in all competing plants. Forbs and grasses obtained only 7 percent and 5.2 percent respectively.

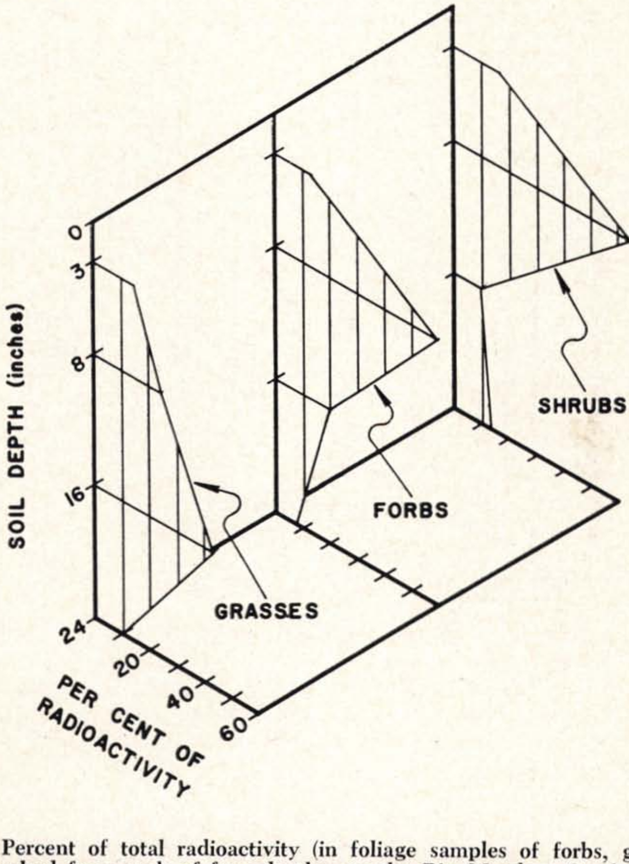

Figure 4. Percent of total radioactivity (in foliage samples of forbs, grasses, and shrubs) absorbed from each of four depths, on the Big Meadow Creek plot, 1965. Note that grasses obtained a greater amount of p^{32} from the 16-inch depth than did the other 2 groups of plants.

The three kinds of vegetation exhibited somewhat dissimilar rooting patterns. Shrubs and forbs obtained the most p^{32} (indicating the most root activity) at the 8-inch depth. Grasses and sedges, surprisingly, absorbed the greatest amount of p^{32} from the 16-inch depth, as diagrammed in Figure 4. Values are based on percent of the total radioactivity found in foliage of all plants of a particular vegetation type. The uptake pattern also indicated that lateral root extension of grasses was less than that of shrubs or forbs (Figure 5). The grasses obtained only 3 percent of their total recorded radioactivity 24 inches from the injection site, compared to 14 per cent for forbs and 10 percent for shrubs.

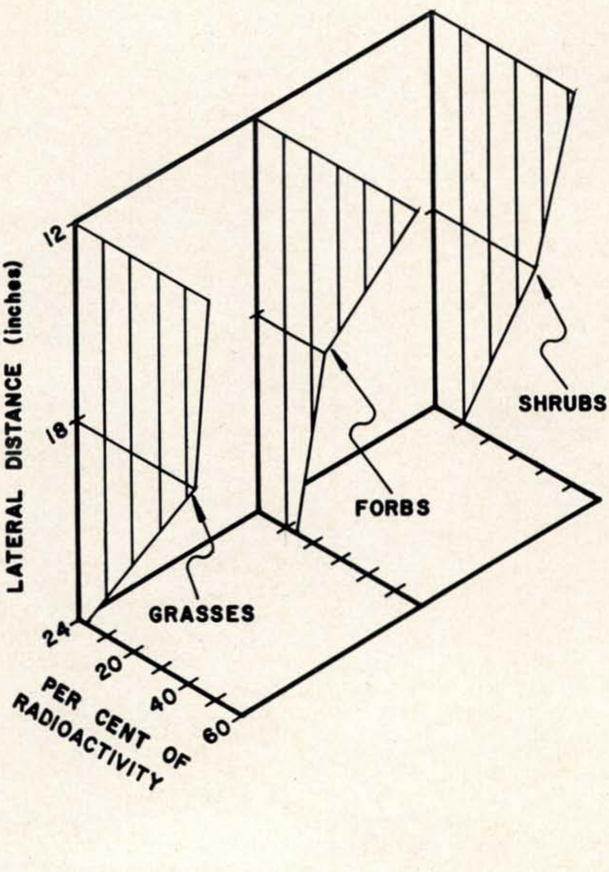

Figure 5. Percent of total radioactivity (in foliage samples of forbs, grasses, and shrubs) absorbed from each of three lateral distances on the Big Meadow Creek plot, 1965. The grasses absorbed considerably less p^{32} from the 24-inch distance than did the other 2 groups of plants.

These data concerning competing plants are of particular interest when reviewing the problems concerning seedling survival, especially in growing seasons of average or below average precipitation.

It is often thought that removing vegetation from a small zone around the seedlings will greatly lessen the chance of mortality. This concept frequently proves false, however, and reasons given for planting failures the numerous. Often overlooked in such reasoning is the possibility of marked competition with seedlings from plants outside the scalped zones. Information presented here clearly indicates that such competition exists, and that tree seedlings and plants growing at least 2 feet, and possibly more, from them are exploiting the same rooting zone. The dominant type of competing vegetation on a site and the rooting pattern of the planted seedlings are also factors of considerable significance. This study indicates, for example, that most root activity of ponderosa pine seedlings during the first growing season after outplanting occurs in the upper 8 inches or so of soil. Especially in a dry year, then, competition on scalped areas from forbs and shrubs should be greater than from grasses, which exploited the 16-inch depth zone to the greatest extent.

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