AN ABSTRACT OF THE THESIS OF

DENIS MERLE WILLIAMSON for the degree of MASTER OF SCIENCE

in FOREST ECOLOGY presented on September 8, 1977

Title: EVALUATION OF FACTORS ASSOCIATED WITH REFORESTATION PROBLEMS ON SEVERE SITES IN THE DEAD INDIAN AREA OF SOUTHWESTERN OREGON

Abstract approved: Redacted for privacy
Don Minore

Reforestation of certain areas of southwestern Oregon has become a serious problem. Reforestation failures are evident in numerous clear-cut stands, but failures are also noted in various partially-cut stands. The Dead Indian Plateau, approximately twenty miles east of Ashland, Oregon, has many areas where this is evident.

This study investigated rodents, drought, cattle, and differences between clear-cut and canopied areas as factors associated with poor seedling survival.

Four plantations were established on the plateau in the spring of 1975, and data were obtained through two growing seasons. Three species, Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco.), white fir (Abies concolor (Cord. and Glend. (Lindl.)), and ponderosa pine

(*Pinus ponderosa* Dougl. ex Loud.) were planted on each plantation in a split-split plot experimental design. Both containerized and bare-root stock of each species were used.

Survival and growth were tallied throughout the study, then subjected to analyses of variance. There were several significant differences. Canopied areas had better survival than open areas. Bare-root stock survived better than container-grown stock. Ponderosa pine had much better survival than Douglas-fir or white fir in the clear-cut areas. Caging effectively protected seedlings from rodent damage, as there were significant caged vs. uncaged survival differences in clear-cut areas. There also were significant species-fencing and species-caging interactions.

Growth data for all species and all plantations were analysed for canopied areas only. (Excessive mortality precluded several clear-cut growth analyses.) Plantation #2 had significantly better growth than the other plantations. Caged seedlings grew much better than uncaged. Container-grown Douglas-fir and white fir grew significantly better than bare-root stock.

With this many significant interactions, it is apparent that no single factor was associated with seedling survival and growth on the Dead Indian plantations. The most apparent survival difference was between open and canopied plots. Absence of overstory canopy cover was related to seedling mortality. This was largely due to a combination of growing season frosts and gophers. Damage from these factors was limited under a canopy cover. For satisfactory survival, seedlings should be planted under a forest cover. Later, after seedlings are large enough to withstand severe frosts, the canopy can be removed.

The superior growth of containerized Douglas-fir and white fir under overstory canopies indicates that these stock types may be under-planted on severe sites in the Dead Indian area where shelterwood harvesting is practiced. Further study should be conducted to substantiate this conclusion. Superior survival of bare-root ponderosa pine in the open indicates that it may be preferred for planting on clear-cut sites in the study area. Other frost hardy and drought resistant species should also be investigated for suitability in clear-cut areas. This includes Douglas-fir stock with induced frost hardiness.

Evaluation of Factors Associated with Reforestation Problems on Severe Sites in the Dead Indian Area of Southwestern Oregon

by

Denis Merle Williamson

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed September 8, 1977
Commencement June 1978

APPROVED:

Redacted for privacy

Assistant Professor of Forestry
in charge of major

Redacted for privacy

Head of Department of Forest Science

Redacted for privacy

Dean of Graduate School

Date thesis is presented September 8, 1977

Typed by A & S Bookkeeping/Typing for Denis Merle Williamson

ACKNOWLEDGEMENTS

I am grateful to Dr. Don Minore for his encouragement, understanding, and most of all friendship, which lasted and grew in the production of this thesis.

My special thanks to friends, too numerous to mention, who, at various critical times during this thesis gave me much needed support.

I am also grateful to the U.S.F.S. Pacific Northwest Forest and Range Experiment Station in providing financial support, equipment, and technical assistance for this study. The Medford District Bureau of Land Management and Mr. Carl Wimberly provided the sites on which the plantations were established.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

EVALUATION OF FACTORS ASSOCIATED WITH REFORESTATION PROBLEMS ON SEVERE SITES IN THE DEAD INDIAN AREA OF SOUTHWESTERN OREGON

INTRODUCTION

Certain areas of southwestern Oregon are noted for their reforestation problems. The Dead Indian Plateau, 20 miles east of Ashland, Oregon, is a good example of one of these problem areas. Both planted and naturally established seedlings have high mortalities in some locations, while in others mortality is low. Satisfactory regeneration is usually confined to forest stands which have been partially cut, but on certain sites regeneration is as poor in partial cuts as in adjacent clear-cuts. Some of the land controlled by private companies continues to be clear-cut, but the Bureau of Land Management considers the problem so extreme they have eliminated clear-cutting on the plateau as a means of timber harvest. However, some areas are cut numerous times resulting in a few residual trees.

A basic objective of timber management is reforestation of lands after timber harvest. The need for reforestation becomes more and more important as use of wood products increases and demand exceeds supply (Mayo, 1969). "The successful reforestation of cut-over lands becomes the first and the most important step in intensive land management. Without a new stand on every harvested acre we will be faced with a diminished timber supply in the future" (Cleary and Graves, 1974). In addition to these considerations, Oregon State law requires harvested land to be reforested. The need for reforestation is becoming increasingly serious as more and more cutover land is added to unstocked or poorly stocked acreage.

Reforestation research on the plateau has not solved several difficult problems. The question still exists: Why are the forests on the Dead Indian Plateau not reproducing well stocked stands? This study concerns itself with answering this question. Reconnaissance of the plateau and personal interviews with people familiar with the areas' reforestation problems revealed a wide range of possible reasons for poor reforestation. The following factors seemed to be the most probable causes of poor conifer regeneration: damage from pocket gophers (*Thomomys* sp.), drought, cattle, and differences between clear-cut and canopied areas due to factors such as frost and varying light intensities.

Numerous studies have confirmed the presence of a dense population of pocket gophers on the Dead Indian Plateau (Hermann and Thomas, 1963; Hooven, 1971; Canutt, 1969). The Bureau of Land Management has identified this area as one in which pocket gophers conflict with forest practices. Drs. Black and Hooven of the Oregon State University Forest Research Lab are currently studying pocket gophers on the plateau. Large populations of these rodents can be a significant cause of seedling mortality. Gophers seem to be non-selective in their choice of tree species. Feeding has been reported on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), ponderosa pine (Pinus ponderosa Dougl. ex Loud.), lodgepole pine (Pinus contorta Dougl. ex Loud.), Englemann spruce (Picea engelmannii Parry ex Engelm.), and Shasta red fir (Abies magnifica Murr. var. shastensis Lemm.) (Lawrence et al., 1961; Moor 1940, 1943; Ronco, 1967 and Stein, 1954). Losses result from root pruning, girdling and clipping of stems, exposure of roots and seedling burial due to burrowing activity (Hermann and Thomas, 1963; Trevis, 1965; and personal observance). Hansen and Reid (1973), found that young trees on the plateau are often debarked from three to five feet above the ground while they are covered with snow. This was observed in certain areas of the study. Black (1969) states that practically all above-ground damage by pocket gophers is done under the snow. However, I observed much above-ground clipping during snow-free summer months. Gopher mounds were almost always present when clipping was noticed.

The Dead Indian Plateau is noted for its strong summer winds and severe climate. Minore (1973) stated that moisture and temperature seem to be the limiting environmental factors that most influence stand composition andforest succession in southwestern Oregon, with moisture being particularly important. DeMoulin et al. (1973) blamed the dry continental winds that influence the area during the growing season for making southwestern Oregon generally a low timber-producing region. They also stated that soils in the rooting zone are drier than the wilting point for grass for more than 45 consecutive days a year on many southwestern Oregon sites. Hallin (1968) found soil surface temperatures to be higher in southwestern Oregon than in other areas. Another factor seemed worthy of investigation--the relationship of cattle grazing to seedling survival. No grazing damage data were available, but certain areas of the plateau appear to be heavily grazed. One last factor investigated was the difference between clearcut and canopied areas on conifer seedling survival. This factor affects numerous environmental components such as light intensities, heat fluxes, frost, and moisture regimes.

STUDY AREA

The Dead Indian Plateau, located in southwestern Oregon, occupies approximately 92,160 square acres. It is generally within Township 38 S., R. 3 E.; Township 38 S., Range 4 E.; Township 39 S., R. 3 E.; and Township 39 S., R. 4 E. Franklin and Dyrness (1973) place the plateau in the High Cascades province on their physiographic map of Oregon. This high plateau ranges in elevation from 1,220 m to 1,830 m (4,000 feet to 6,000 feet). In general, winters are cold and moist and summers cool and dry. However, summer temperatures in the high 90's are not uncommon.

Mean annual air temperatures range from 5-8° C (43-47° F). The mean January temperature is -1° C (30° F), and the mean July temperature is 14° C (58° F). For the Dead Indian Plateau as a whole, January minimums average -6° C (21° F) and July maximums average 30°C (86° F) (deMoulin et al., 1975). On the experimental plots described here, July maximum temperatures during the summers of 1975 and 1976 averaged only 24° C (75° F).

The average annual precipitation ranges from 40 to 60 inches, with much of this falling as snow during winter months. Summer rainfall is generally accompanied by thunderstorm activity.

Geology

As the geology of the Dead Indian Plateau has not yet been thoroughly mapped or investigated, much of the information which follows was obtained from general geological maps and studies and histories of adjacent areas (Wells, 1955, 1961; Franklin and Dyrness, 1973; U.S.G.S. 1971; State of Oregon, 1971; Purdom 1970). The oldest rocks found on the plateau are probably of the Eocene, Oligocene, and Miocene epochs. During this time span temperate forests may have been replaced by redwood forest. However, the oldest rocks near the surface seem to be of the Pleistocene epoch. Mt. McLoughlin, which lies 12 miles to the northeast of the plateau, was formed during this epoch. Volcanic deposition from this mountain probably covered and obscured most of the older rocks from earlier epochs. Therefore, the plateau surface is geologically young. Porphyritic flows of massive dark-grey andesite, grey olivine basalt, basaltic andesite, olivine-bearing andesite and breccias are among these surface deposits. The area is also interbedded with pyroclastic rocks. Modern day forests began covering the plateau during the Pleistocene epoch.

Soils

Soils of the Dead Indian Plateau were formed from basic volcanic colluvium. These unnamed soils are classified as 809 and 810 series by the Bureau of Land Management. Although some variation occurs within the area, the soils tend to be moderately deep (50-100 cm), loamy, very cobbly, and well drained. Cool dry climatic conditions, which slow the decomposition of plant residue, have resulted in organic matter accumulation in surface horizons. Soils of the 809 and 810 series have relative thick, dark colored surface horizons that are high in organic matter and exchangeable bases (mollic horizons). Both series have subsoil horizons which are notably weak-structured from lack of clay (cambic horizons). Productivity Site Index for Douglas-fir on 809 soils in 115 - 120 and PSI for Douglas-fir on 810 soils is 120-125 (BLM, 1968). BLM classifies the regeneration hazard for these soils as severe to moderate. Soil variation does occur on the plateau, but the main variations are coarse fragment content and depth to bedrock. A typical profile description of these gravelly loams includes: a very friable and slightly acidic surface soil (0-55 cm), a friable and moderately acidic subsoil (43-125 cm), and a fractured volcanic rock substratum (83+ cm). This underlying substratum consists of andesite and basalt. Coarse fragment content of the soils ranges from 35-75%. Surface soil textures are either very cobbly loam, very cobbly light clay loam, or very gravelly loam. Many areas are stony on the surface.

The productivity of these soils is low--apparently because of cool temperatures and a short growing season. High frost-heave potential also is a factor. Dead Indian soils support mixed conifer stands of white fir (*Abies concolor* (Cord. and Glend.) Lindl.), Douglas-fir, ponderosa pine, incense-cedar (*Libocedrus decurrens* Torr.), and sugar pine (*Pinus lambertiana* Dougl.). At higher elevations Shasta red fir and western white pine (*Pinus monticola* Dougl. ex D. Don) become more abundant, but for the most part are found only near the eastern boundary of the Plateau (deMoulin *et al.*, 1975).

Vegetation

The Dead Indian Plateau occupies the "Mixed-Conifer Zone" defined by Franklin and Dyrness (1973). Major tree species in the Mixed-Conifer Zone are white fir, Douglas-fir, ponderosa pine, sugar pine, and incense cedar. There is little underbrush on the Dead Indian Plateau. *Ribes* sp., *Amelanchier* sp., *Symphoricarpus albus* (l.) Blake, *Rosa* sp., and *Pachistima myrsinites* (Pursh) Raf. are commonly present, but seldom abundant under the forest canopy. *Sambucus glauca* (Nutt.) often occurs in clear-cut areas.

Measurements in 54 partially-cut stands indicate that 60 percent of the overstory basal area is white fir, 20 percent Douglas-fir. Incense-cedar and sugar pine account for 5 to 10 percent of the overstory basal area. Ponderosa pine contributes less than 5 percent (Minore, Carkin, and Hollins, 1975--unpublished data).

Common herbaceous species include the following: Smilacena stellata (L.) Desf., Vicia americana Muhl. ex Willd., Fragaria sp., Cryptantha affinis (Gray) Greene, Stellaria jamesiana Torr, Phacelia heterophylla Pursh, Collomi grandiflora Dougl. ex Lindl., Festuca occidentalis Hook., Vancouvaria hexandra (Hook.) Morr. and Dec., Campanula scouleri Hook., Lathyrus palustris (L.), Linnaea borealis L., Trientalis latifolia Hook., Synthris reniformis (Dougl.) Benth., Galium aparine L., Osmorhiza chilensis H. & A., Anemone deltoidea Hook., Arenaria macrophylla Hook., Viola sp. Collinsia parviflora Lindl., Chimaphila umbellata (L.) Bart., and Hieracium albiflorum Hook. No detailed plant community analyses have been published for the Dead Indian Plateau. However, the following associations have been tentatively identified (Minore, Carkin and Williamson, unpublished data):

Abies concolor-Pseudotsuga/Castanopsis/Chimaphila umbellata,

Abies concolor-Pseudotsuga/Amelanchier/Campanula scouleri,

Abies concolor-Pseudotsuga/Pachystima/Linnaea,

Abies concolor-Psuedotsuga/Arctostaphylos nevadensis/Trientalis,

Abies magnifica var shastensis/Pachystima/Chimaphila umbellata.

Timber

The Dead Indian Plateau furnishes a large timber supply for wood industries in the region. The Bureau of Land Management administers a large portion of the plateau. The U. S. Forest Service, private lumber companies and small woodland owners control the rest. Most of the timber in this area goes to the Medford-Ashland valley, but some is taken to the Klamath Falls area.

During post WW-II years high grade selective logging often was used in the mixed conifer forests of the Dead Indian Plateau. Douglas-fir and ponderosa pine were favored in these logging operations, increasing the proportion of white fir in the residual stands.

Grazing

Large natural meadows and numerous grass-covered clearcuts provide pasture for many animals in this area. Cattle brought up to the plateau after spring thaws are allowed to roam free, but usually are kept within certain areas with watering holes and salt licks. Most of the plateau has open grazing, but some areas are fenced for control. Cattle are taken off the plateau in late fall before winter storms arrive.

Recreation

The Dead Indian Plateau is an important source of water for surrounding areas. Two man-made reservoirs, built to conserve and distribute this water, account for the majority of the area's recreational use. Fishing, skiing, sailboating, camping, hunting, and snowmobiling are popular during the appropriate seasons. Howard Prairie Reservoir is reportedly one of the better sailing lakes in the state due to frequent high winds during the summer months. Gravelly, cobbly soils which become dusty when dry, poor soil conditions for sewage disposal systems and sanitary landfills, and the limited number of springs for domestic use constitute major limitations to recreational development.

MATERIALS AND METHODS

In the spring of 1975, four experimental plantations were established on the Dead Indian Plateau. Each plantation consisted of two 100 by 200 foot (30.5 by 61 m) plots, one located under a canopy, the other located in an adjacent open area which had previously been forested. Crown densities and basal areas of the stands overtopping the canopied plots were determined with a spherical densiometer and a wedge prism (Table 1). Plots in the open were placed to minimize edge effect. Thus, each plantation was divided into two plots--plots with different light and temperature conditions. Each of these plots was then further divided into two 100 by 100 foot (30.5 by 30.5 m) sub-plots. This second plot division resulted in four distinct sub-plots on each plot site. One sub-plot from both the canopy and open area was randomly chosen and fenced for cattle protection.

Table 1. Crown Densities and Basal Areas on Canopied Plots.

Plantation Number	Basal Area (ft^2/acre)	Crown Density (percent)
1	111	57
2	156	69
3	164	60
4	155	61

Plantation number 1, near the Shale City Road, is located in Township 38 S., R. 2 E., Sec. 12 and 13 (Figure 1). The site has a 15% slope and 340° aspect. It is at an elevation of 1,555 m (5,100 feet). Canopy cover is 57% and overstory basal area is 111 ft^2/acre in the partially cut portion of this plantation. This portion was logged in 1966, when 5,000 board feet per acre were removed. History of the clear-cut portion of plantation number 1 is unknown, but stump decomposition indicates that it was logged many years ago. The soil is lightly cobbled, with only a few stones showing on the surface.

The second plantation, near Keno Road, is located in Township 38 S., R. 3 E., Sec. 13 (Figure 2). It has a 5% slope with a 320° aspect. It is at an elevation of 1,402 m (4,600 feet). The partially-cut portion of plantation number 2 has been cut twice, once in 1971 and once in 1969, leaving a canopy cover of 69% and overstory basal area of 156 ft^2/acre. The clear-cut portion of plantation number 2 was logged in 1960 when 50,000 board feet were removed. Coarse fragments are uncommon in the soil, and there are no surface stones.

The third plantation is near Moon Prairie Road on the border between Sections 17 and 20 in Township 39 S., R. 4 E (Figure 3). This plantation has a 5% slope and 270° aspect. It is at an elevation of 1,463 m (4,800 feet). The clear-cut here resulted from five separate cuts. In the first, diameter-limit cut (1948-1950), all

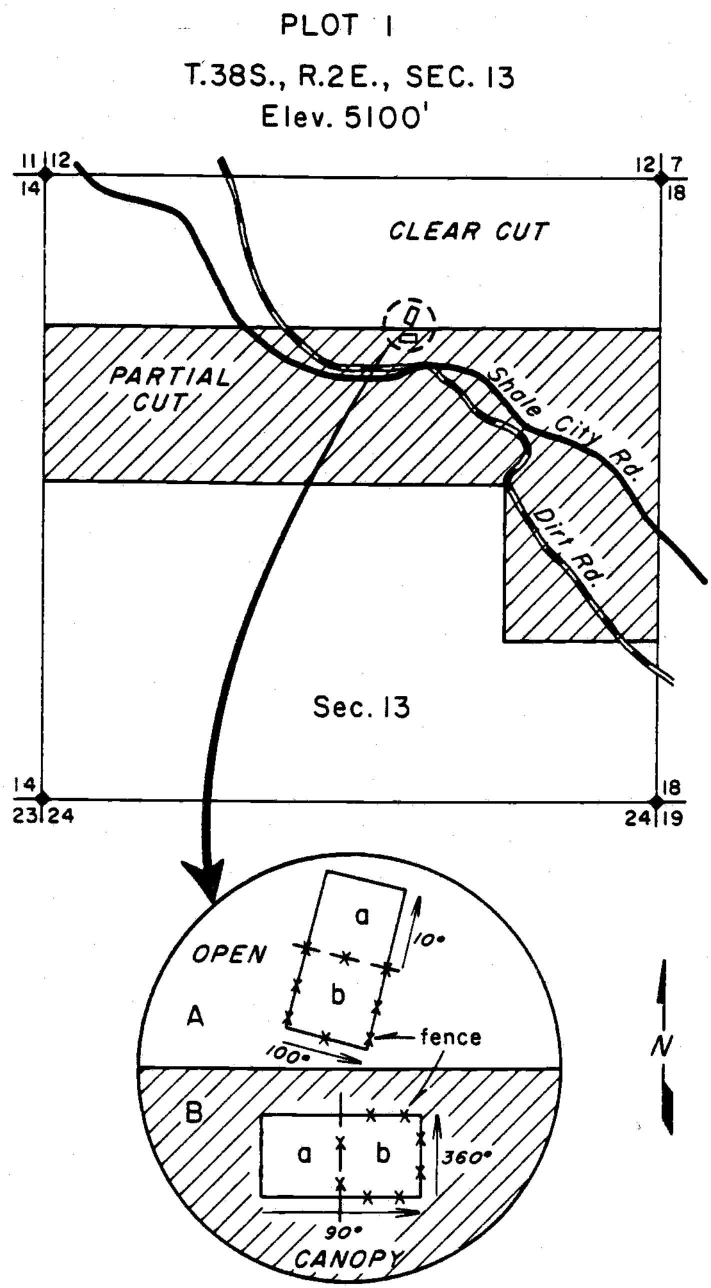

Figure 1. Location and plot orientation of plantation #1.

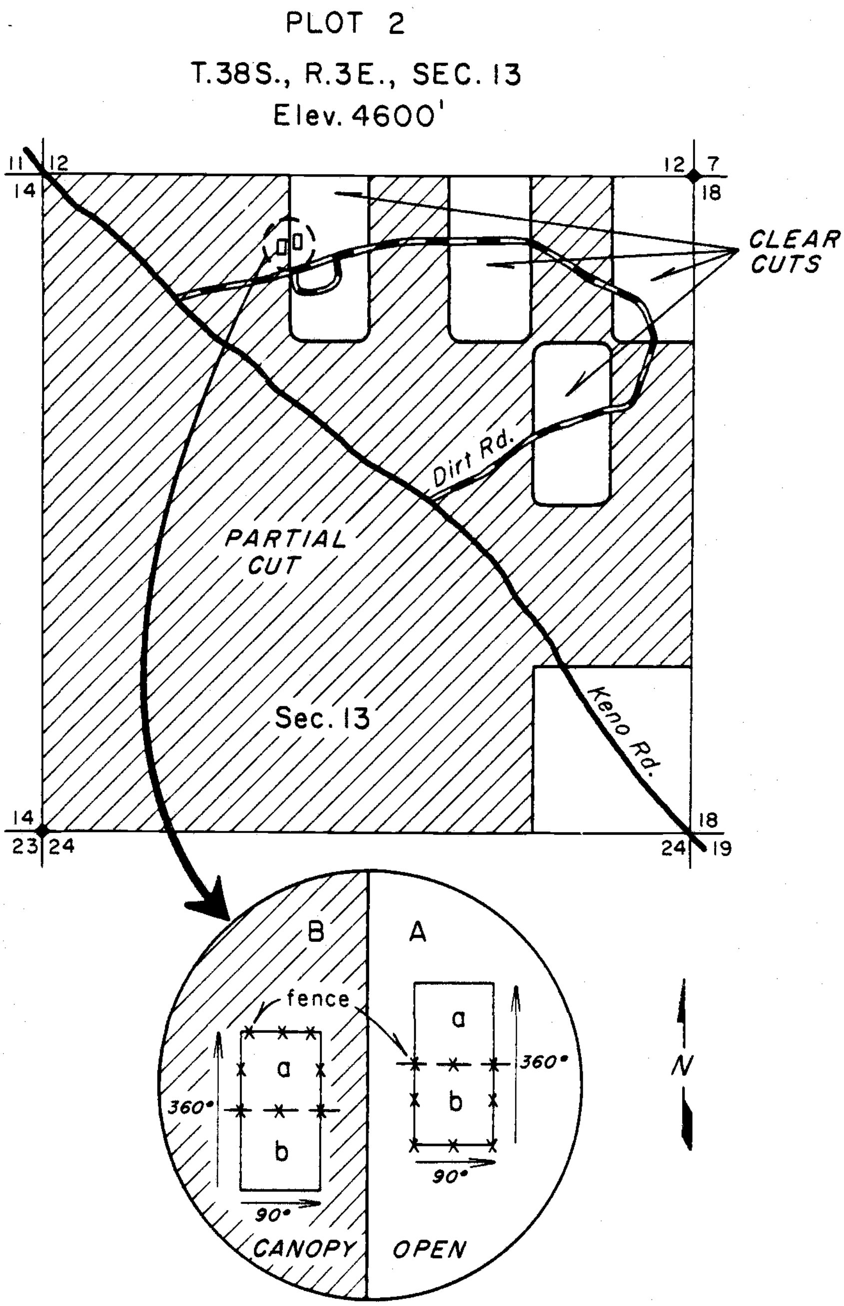

Figure 2. Location and plot orientation of plantation #2.

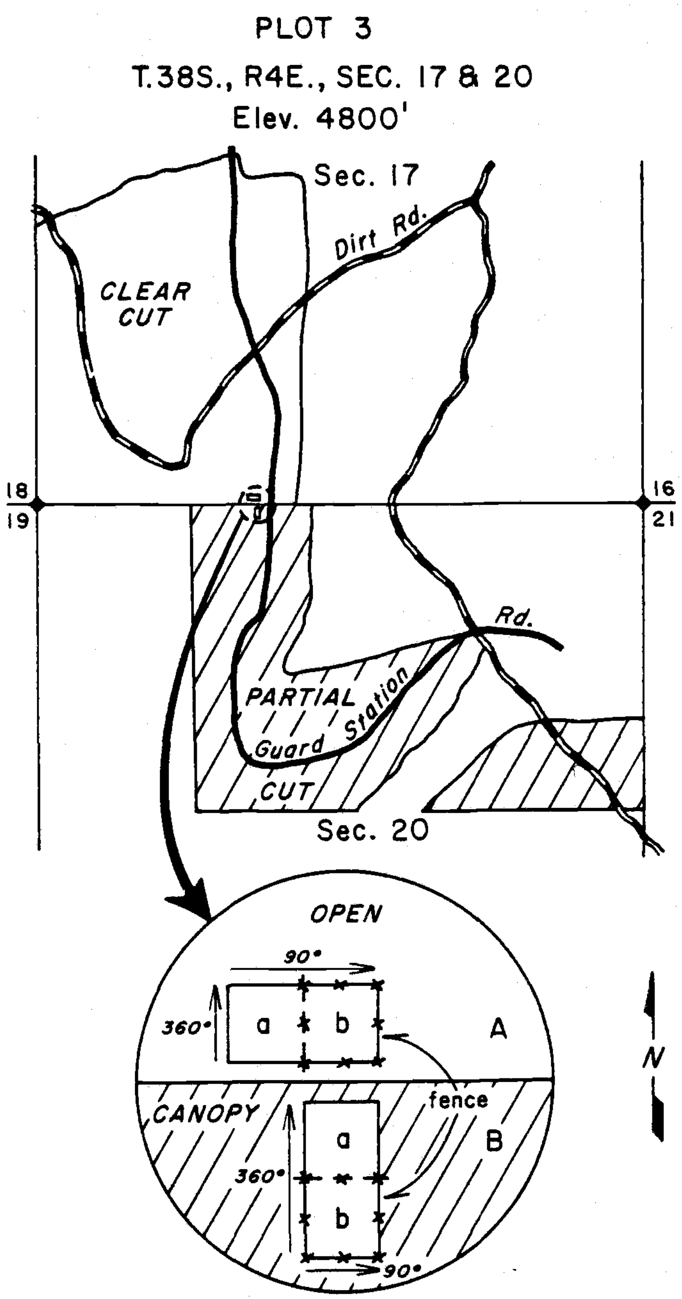

Figure 3. Location and plot orientation of plantation #3.

Douglas-fir over 30 inches and all white fir over 22 inches D. B. H. were removed. The next cut (1951-1953) was a salvage cut, as was the following (1958), which was termed a seed tree cut. Another salvage cut occurred in 1960. Finally, in 1968, all remaining overstory was removed to leave an unstocked clearcut. The partially-cut portion of plantation number 3 was logged twice--in 1961 and 1968, leaving a canopy cover of 60% and overstory basal area of 164 ft^2/acre. Ponderosa pine and sugar pine were the tree species harvested. The soil is very cobbly, with stones showing on the surface.

The fourth plantation, southwest of Hyatt Reservoir, is located in Sec. 21 of Township 39 S., R. 3 E (Figure 4). It is level, at an elevation of 1,524 m (5,000 feet). The "clear-cut" area here is actually one of several large, open pockets in an area partially-cut very heavily in 1941 and 1958. In 1941, 2,000 board feet per acre of Douglas-fir and white fir were removed from the sale area. In the 1958 cut, 12,000 board feet per acre of the same species were removed. A light partial-cut was applied to the canopied area of this plantation in 1941, leaving a residual stand with canopy density of 61% and overstory basal area of 155 ft^2/acre. Many stones show on the surface of a very cobbly soil in this plantation.

Douglas-fir, white fir and ponderosa pine seedlings were grown from seed obtained by the Bureau of Land Management from the study

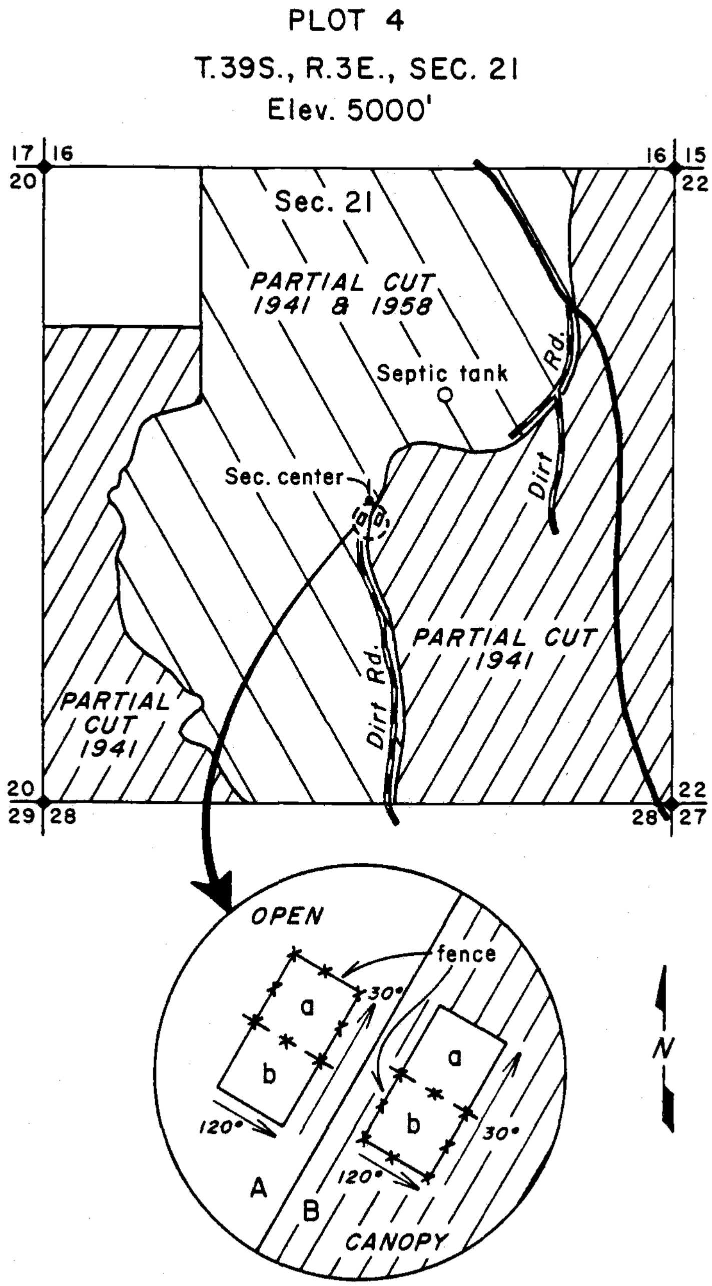

Figure 4. Location and plot orientation of plantation #4.

area. A total of 2,304 seedlings (768 seedlings of each species) were used for the study. Half were bare-root, 2-0 stock and half were one year old containerized seedlings. The following treatment contrasts were applied to each species on all four sub-plots in each plantation:

1) container vs. bare-root stock

2) watering vs. no watering

3) caging vs. no caging.

Container-stock was grown in 4 cu. inch plug-mold Styroblock containers for one year at Corvallis, Oregon. Seedlings were fertilized with 4 oz. per 100 sq. feet of 9-45-15 fertilizer every two weeks and watered weekly. On March 12, 1975, containerized seedlings were bundled in groups of 25, put into plastic bags and placed into cold storage. Temperature in the cold storage room was maintained at 1° C.

All of the bare-root seedlings were 2-0 stock. Douglas-fir and white fir seedlings were grown at Wind River Nursery in Washington, and the ponderosa pines were grown at the U.S.F.S. nursery in Bend, Oregon. Seedlings at Wind River were shovel-lifted on March 7, 1975, while still dormant. After lifting the seedlings were heavily culled to ensure the best possible stock, bundled in groups of 50, put in coolers with ice, and transported to Corvallis. At Corvallis they were placed in plastic bags and put into cold storage with the containerized seedlings. Using the same methods, the ponderosa pine seedlings were lifted at Bend on March 10th and immediately placed in cold storage with the other stock. Measurements of 10 random samples from each species for bare-root stock are summarized in Appendix Table 1.

In the open areas, three foot diameter planting spots were scalped prior to planting. Flagged wires were then marked and placed on each spot to denote the species, stock type, and treatment to be applied in all areas--both open and canopied.

Planting started on May 19, 1974. This was the earliest date the study areas were accessible. Even then it snowed 1-1/2 inches on the first planting day. Seedlings were kept in iced coolers until needed, then wrapped in wet burlap and removed for planting.

Seedlings randomly assigned predetermined treatments were planted at 8 by 8 foot spacings for each of the four sub-plots on each of the four plantations. Each species-stock-treatment combination was replicated six times, making 144 seedlings in each sub-plot. Random number tables were used to determine planting designs which are available on request (Figure 5).

Half of the seedlings were caged for protection from rodents. One-half inch mesh hardware cloth was used for construction of these

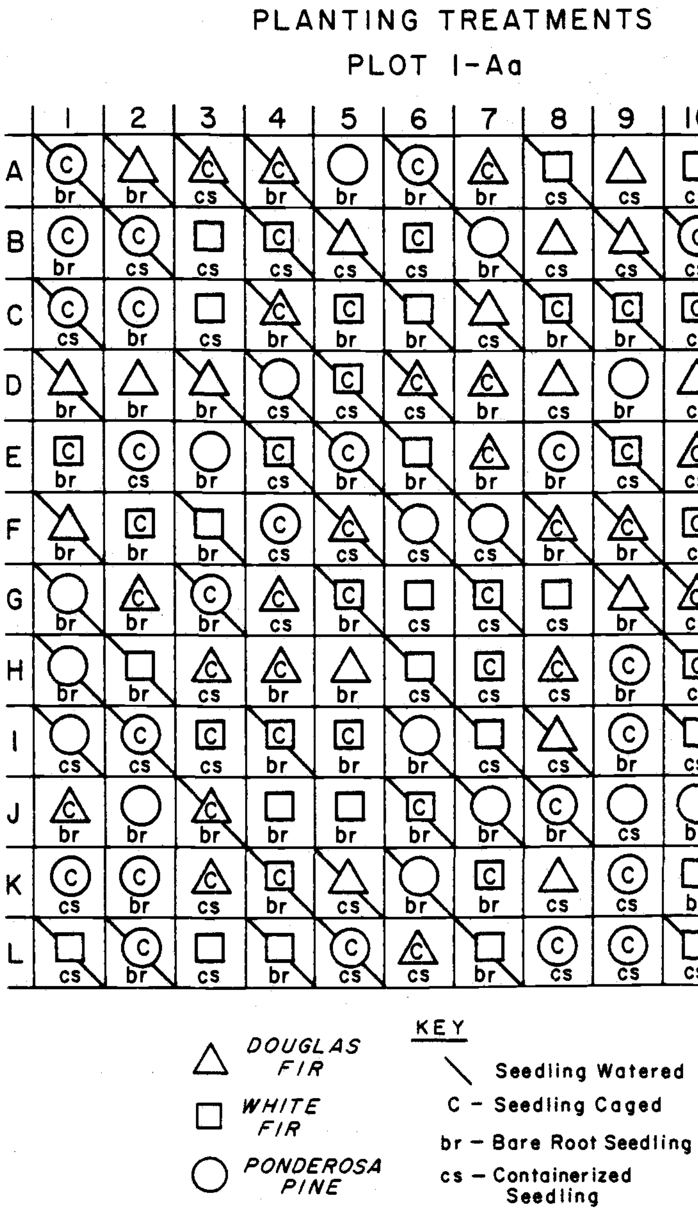

Figure 5. Randomization of species, stock types, caging, and watering in the unfenced sub-plot in the open at plantation #1. (Randomization of other sub-plots and plantations is available on request.)

cages. They consisted of two sections, each 5 inches in diameter and 1 foot in length, with one closed end. One section was placed underground and the seedlings' roots placed inside at time of planting (Figure 6), while the other section was placed over the seedlings in late fall and attached to the bottom half (Figure 7). This section was to eliminate possible damage from rodents tunneling through snow during winter.

Planting was accomplished by seven workers. Each progressed along an assigned row, planting the species, stock types, and caging treatments as they occurred. Shovels were used for all planting. Planting was completed on June 5, 1975. Soil surface to terminal bud heights of all seedlings were measured soon after planting was completed.

Immediately after planting, fences were built around the subplots to be protected from cattle (Figure 8). These three wire fences complied with BLM standards. Weather stations were set up after completion of fencing.

Partlow RFH 11 temperature recorders were used to record temperatures at 20 and 137 cm. All probes were shielded in premade shelters. Every study area had two recorders; one located under the canopy and one in the open. Soil temperatures were measured with Weston 8 inch dial thermometers. (Average soil

Figure 6. Containerized Douglas-fir seedling being planted in a rodent protection cage.

Figure 7. Complete rodent-protection cage just before removal of the upper portion on May 14, 1976. (Only the sub-surface portion remained in place during growing seasons.)

Figure 8. Cattle fencing on the open portion of plantation number two in August, 1976. Note the difference in vegetation outside (right) and inside (left) of the fence.

temperatures for each canopied and open area were derived by measuring numerous points within each area.) In addition, two unshielded Taylor Min-max thermometers were used in each open and canopied area. These were monitored regularly to record subfreezing temperatures on unshielded surfaces. However, temperatures measured with dial and Min-max thermometers were so variable the measurements were not used for this study. Precipitation was measured using plastic wedge rain gauges.

One gallon of water per month was applied by hand to half of the seedlings during the summers of 1975 and 1976. A seven-gallon backpack was used to facilitate this treatment. The first watering commensed on June 12, 1975. It was repeated monthly for two growing seasons, with the last watering occurring on September 18, 1976. The upper halves of the rodent cages were wired to the lower portions the end of September, 1975. The weather instruments also were taken down and put in storage at this time. On May 14, 1976, the upper portions of the rodent protection cages were removed, and seedling survival was counted. Weather stations were replaced on June 14th. Heights of all surviving seedlings again were measured at the end of September, 1976.

Seedling condition was observed each month during the growing seasons, May through September, 1975 and 1976. During these counts attempts were made to determine the nature, degree, and amount of seedling damage. Lawrence and Hartwell (1961) was used as a reference in determining wildlife damage.

Survival was recorded one year after planting and again after the second growing season. Growth was measured after the second season. Both survival and growth then were subjected to split-split plot analyses of variance.

RESULTS AND DISCUSSION

Most seedling damage occurred when they were either killed or injured by clipping, trampling, barking, burial, breakage, uprooting, freezing, or drying. Deer, cattle, gophers, aphids, snow, frost, and drought were responsible.

Deer damage was limited and consisted mainly of browsing terminal branches. A few instances of trampling were observed with damage limited to containerized seedlings. Most deer damage was found in the spring during periods of rapid growth, when the foliage was most succulent. Its main effect was a reduction in seedling growth.

Cattle damage usually resulted from trampling during periods when the soil was moist or saturated (Figure 9). Seedlings trampled into wet soil remained flat when their branches were covered with mud. Some instances of complete burial were noticed, including an incident of burial by cattle waste. There also were a few cases of cattle browsing, which probably resulted from the seedling being in or near a clump of grass, the initial browse species.

Most gopher damage occurred by clipping seedlings at ground level, but there were a few instances of pulling the seedlings underground, feeding on roots, burial under gopher mounds, and exposing

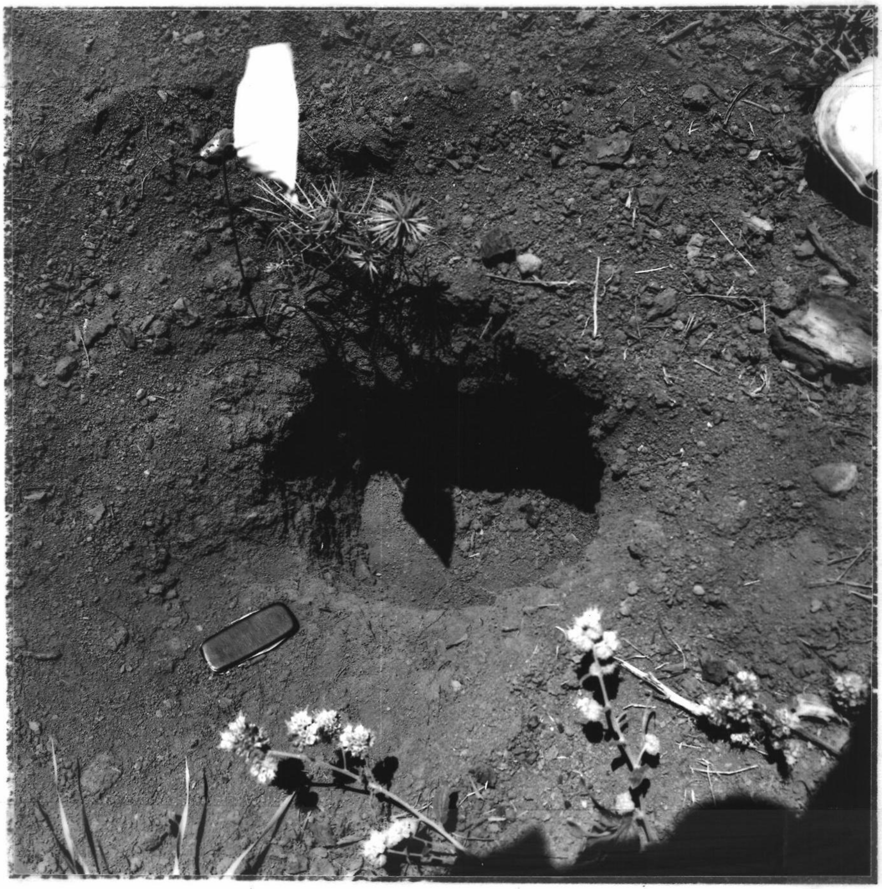

Figure 9. Cattle-damaged seedling with hoof print.

roots by burrowing. Gopher damage usually resulted in seedling mortality.

Frost damage occurred almost exclusively in clear-cuts (Table 2). This damage was first observed in August, 1975 on Douglas-fir and white fir--first on containerized stock, then on bare-root stock. Areas receiving the most frost sustained the highest mortality. As much as 80% more frost days per month were observed in open areas. Weather data for clear-cuts during August, 1975 showed one plantation (number three) had 21 days when temperatures in the clear-cut went below 0^{o} C (32^{o} F), with a low recording of -8^{o} C (18^{0} F). During the same period, the canopied area of this plantation had only three days when temperature went below 0^{o} C (32^{o} F), with a low of -3^{o} C (27^{o} F). The temperature differences between open and canopied areas on the plantations averaged 5^{o} C (9^{o} F). When temperatures were near -2^{o} C in the canopies, temperatures in the open areas were near -8^{o} C. Apparently, this was a significant difference. Clear-cuts on the Dead Indian Plateau seem to accentuate cold air accumulations. This seems especially true for level or concave ground. The clear-cut on plantation one (15% slope) had only one day during August, 1975 when temperature reached below 0^{o} C (32^{o} F) while plantations two and three (less than 5% slopes), had 21 and 19 days with below freezing temperatures.

Table 2. Percent of Temperatures Below 0° C (32° F) for Four Plantations, by Month and Year.[a/]

Plantation	Forest Cover	June 15-June 30	July	August	Sept.
		1975			
1	Open		0	3	3
	Canopy		0	0	0
2	Open		7	61	83
	Canopy		0	26	--[b/]
3	Open		18	68	83
	Canopy		4	10	3
4	Open		7	35	27
	Canopy		0	3	0
		1976			
1	Open	66	0	3	7
	Canopy	13	6	0	0
2	Open	80	6	10	23
	Canopy	6	--[b/]	--[b/]	27
3	Open	--[b/]	--[b/]	13	47
	Canopy	87	42	3	3
4	Open	33	3	3	16
	Canopy	40	3	13	7

[a/] Temperatures were recorded at 20 cm above the soil surface.

[b/] Data missing because of thermograph malfunction.

Drought damage was not evident. The unusually wet summers negated most of the effects of watering the seedlings. Over 4 inches (10 cm) of rain fell from June through September in 1975 and over 6 inches (15 cm) fell for the same period in 1976. This precipitation usually occurred during one or two major storms which tended to happen on a monthly basis, often coinciding with my watering schedule. These summer downpours had a negative effect on containerized seedlings. They often washed the surface soil away from these seedlings, exposing the tops of containerized plugs (Figure 10). In clear-cut areas this usually initiated a wicking effect, drying out the plugs and resulting in mortality. Drought probably was responsible for secondary damage and death. It usually affected seedlings after they had already been damaged by some other factor, such as rains washing soil away from the tops of the containerized plugs or animal clipping.

Aphids were found only under the canopy, usually on white fir (Figure 11). Injury resulted in unthrifty condition and decreased growth of seedlings. The effects of aphids on seedlings probably were minimal due to numbers and localized areas of aphid populations.

Snow damage resulted from debris on ground holding seedlings down after they had been bent by snow. Trees which had been bent but not kept on the ground resumed their normal stance after a few

Figure 10. Top of container plug exposed by surface erosion. This ponderosa pine seedling is in poor condition, but it survived. Most container seedlings died when plug tops were exposed.

Figure 11. Aphids on a white fir seedling growing under the canopy at plantation number 2. Growth was reduced.

weeks with no apparent negative effects. Trees which remained bent survived but had reduced general health and suppressed growth. These seedlings, aided by wind and rain, usually righted themselves by the end of summer.

Overall survival data were tallied for two periods; approximately one year from outplanting (May 14, 1976) and at the end of the second growing season (September 25, 1976). The tallies will be referred to here as spring and fall counts. The final fall count showed some striking differences in seedling mortality (Appendix Tables 2-5). However, differences between plantations were not statistically significant.

Survival was better ($P < .05$)[1/] under the canopied areas than in the open for both spring and fall seedling counts (Table 3). Species survival also differed ($P < .01$) in both counts (Table 4). Most of this difference can be attributed to better ponderosa pine survival in the clear-cuts. Bare-root stock also survived better ($P < .01$) than container-grown stock in both spring and fall counts (Table 5).

Seedlings which were caged had better survival than non-caged seedlings in both spring and fall (spring $P < .06$, fall $P < .01$) (Table 6). Cages effectively protected treated seedlings (Figure 12).

[1/] Probability figures in parenthesis refer to levels of statistical significance.

Table 3. Percent Survival in Canopied and Open Areas (P < .05).

	Survival %	
	Canopy	Open
Spring 1976	92.5	50.4
Fall 1976	88.8	36.4

Table 4. Species Survival (P < .01).

	Survival %		
	Douglas-fir	White fir	Ponderosa Pine
Spring 1976	65.5	66.9	82.0
Fall 1976	54.7	59.2	73.8

Table 5. Stock Type Survival (P < .01).

	Survival %	
	Container grown	Bare-root
Spring 1976	68.4	74.6
Fall 1976	59.9	65.3

Table 6. Caging Survival.

	Survival %		
	Not caged	Caged	
Spring 1976	69.4	73.6	(P < .05)
Fall 1976	58.7	66.5	(P < .01)

Figure 12. Evidence of caging success. A gopher approached this seedling from the left rear (surface trench made under snow), then burrowed completely around the cage perimeter (mounds surrounding bottom of cage). The seedling was not injured.

The caged vs. uncaged difference in the fall was almost double that tallied in the spring. Rodent damage therefore would seem to be most significant during the growing season in this study. This contradicts previous studies which find seedling damage from gophers greater during winter months. This result may be explained in part by the atypical winter which occurred on the Dead Indian Plateau during 1976. Snow depth during winter months is usually 3-5 feet on the plateau. Although weather data (Environmental Data Service 1975 and 1976) for the plateau show that it snowed over 10 feet during the 1975-1976 winter, local residents on the plateau observed accumulated snow depths that never exceeded one foot. Many clear-cut areas were bare for the greater part of the winter.

Watering and fencing did not significantly affect seedling survival. Unusually wet summers during the study period probably negated the watering treatment.

In clear-cut areas, species had high survival differences ($P < .01$) in both spring and fall (Table 7). All three species had similar survival counts (less than 1% difference) under the canopy, but ponderosa pine had almost twice as good survival in the open areas as the other species.

There was a species-fencing interaction ($P < .05$) in the fall, but not in the spring (Table 8). This seems to be the result of poor

Table 7. Canopy x Species Interactions (P< .01).

	Survival %	
	Spring 1976	Fall 1976
Open--Douglas fir	38.0	21.1
Canopy--Douglas fir	93.0	88.3
Open--White fir	41.4	29.4
Canopy--White fir	92.4	89.1
Open--Ponderosa pine	71.9	58.6
Canopy--Ponderosa pine	92.2	89.1

Table 8. Species x Fencing Interactions for Fall, 1976 (P < .05).

	Survival %		
	Douglas-fir	White fir	Ponderosa Pine
Fenced	52.3	62.8	77.1
Not fenced	57.0	55.7	70.6

Table 9. Caging x Canopy Interactions.

	Survival %			
	Not caged-open	Not caged-canopy	Caged-open	Caged-Canopy
Spring 1976 (P < .05)	46.0	92.7	54.9	92.4
Fall 1976 (P < .01)	29.3	88.0	43.4	89.6

Douglas-fir survival inside the fenced sub-plots. Why this occurred is uncertain.

There were significant caging-canopy interactions in both spring ($P < .05$) and fall ($P < .01$, Table 9). Caging improved survival only in the open areas. Either this is where the gophers were concentrated, or if they also were in the canopy, they preferred other species for food.

There also was a significant ($P < .05$) species-caging interaction in the fall (Table 10), but not in the spring. The data showed ponderosa pine to be more affected by caging than white fir or Douglas-fir. This might be a species preference, but it may also reflect the fact that most surviving seedlings in the open were ponderosa pines during the second growing season. All other interactions were insignificant.

Table 10. Species x Caging Interactions for Fall 1976 ($P < .05$).

	Survival %		
	Douglas-fir	White fir	Ponderosa pine
Caged	55.5	62.5	81.5
Not caged	53.9	56.0	66.1

Growth data for all species and all areas were analyzed for the canopied areas only. (Excessive mortality in the open made statistical analyses of growth in the clear-cuts impractical.) When all species and treatments under the canopy were combined, average growth on the four plantations were significantly different ($P < .05$). Average growth on plantation number one was 6.3 cm, on plantation number two 11.2 cm, on plantation number three 6.0 cm, and on plantation number four 5.9 cm. Plantation number two had almost double the growth on other plantations (Figure 13). It also had the highest crown density (Table 1). Although Strothmann (1972) found height growth to be inversely proportional to amount of shade received, as did Emmingham and Waring (1973), my findings show that a slight increase in crown density was not associated with a decrease in growth.

When all species were combined, containerized stock grew better ($P < .01$) than bare-root stock. Containerized stock averaged 8.2 cm growth compared to 6.6 cm for bare-root stock. Caged seedlings grew better ($P < .05$ than uncaged seedlings (7.7 cm vs. 7.1 cm growth). Caging may have influenced growth through factors other than protection from gophers...it protected seedlings from snow damage, debris dropped by overstory trees, deer, etc. There also was a species-stock type interaction ($P < .05$, Table 11). Container grown Douglas-fir and white fir seedlings grew better than bare root stock. Ponderosa pine seedlings did not. There were no significant growth differences for fencing, species, or watering. No other interactions were significant. If summers had been more typical (drier) during this study, growth differences probably would have been greater. Douglas-fir has been found to need 3.5 times

Figure 13. A white fir seedling growing vigorously under the canopy in plantation number two.

more light to grow when moisture is limiting, and ponderosa pine needs 18 times more light (Atzet, Thomas and Waring, 1970).

Table 11. Species x Container Interactions Under Canopy ($P < .05$).

	Growth in cm.		
	Douglas-fir	White fir	Ponderosa pine
Container	8.5	8.5	7.6
Bare-root	6.7	6.0	7.1

Ponderosa pine height growth was analyzed for all treatments. Because of excessive mortality in the open for the other species, it was the only species which could be examined in this way. The only factor associated with a significant ($P < .05$) growth difference was caging. Caged ponderosa pine seedlings grew an average 7.3 cm while uncaged seedlings averaged 6.8 cm.

Height growth was analyzed for all species and all treatments on plantations number one and number four. (Excessive mortality prevented complete growth analyses of the other two plantations.) On plantations number one and number four, white fir grew better ($P < .05$) than Douglas-fir or ponderosa pine. White fir grew an average 7.4 cm, Douglas-fir grew 6.7 cm, and ponderosa pine grew 6.5 cm. Containerized stock also grew better ($P < .01$) than bare-root stock. Containerized stock of all three species grew an average 7.6 cm, bare-root growth averaged 6.2 cm. Caging affected growth significantly ($P < .01$). Caged seedlings grew an average 7.3 cm, uncaged averaged 6.4 cm. The only significant interactions were species-stock types, species-canopy, and species-fencing (Table 12).

Table 12. Species Growth by Stock Type, Canopy, and Fencing Treatments on Plantations One and Four at End of Two Growing Seasons.[a]

	Growth in cm					
	Stock Type (P< .01)		Canopy (P< .01)		Fencing (P< .05)	
Species	Containerized	Bare root	Open	Canopy	Fenced	Unfenced
Douglas-fir	7.9	5.7	6.8	6.8	7.7	5.6
White fir	8.6	6.2	9.9	6.1	7.2	7.6
Ponderosa pine	6.4	6.6	8.1	5.4	6.9	6.1

[a] Growth data in open areas on plantations two and three were not analyzed because of excessive seedling mortality.

CONCLUSIONS

When all treatments are considered, it is evident that multiple factors are associated with reforestation problems on these severe Dead Indian Plateau sites. Deer, cattle, aphids, and snow had limited effects on seedling mortality. In localized areas these effects can be serious. However, these factors probably are not of great concern for the Dead Indian Plateau as a whole.

Large survival differences between open and canopied plots indicate that the absence of overstory canopy cover is important. The following major factors seem to be involved: frost, pocket gophers, and drought. Frost was a severe limitation to seedling survival in open areas. Temperature data (Table 2) show that growing season frosts occurred more often in the open than under a canopy cover. Differences of up to 80% more frost days per month in open areas were observed. Gopher damage was also significant in open areas. This damage usually resulted in seedling mortality and must be considered in reforestation planning. Drought may have been responsible for secondary damage.

In clear-cut areas, bare root ponderosa pine had superior survival among the three species studied. Other frost hardy and drought resistant species such as lodgepole pine (<u>Pinus contorta</u>

Dougl.) should be investigated in clear-cut areas. Douglas-fir stock with nursery induced frost hardiness should also be tried. In localized areas where drought is more limiting than frost, such as on south slopes, shading may be beneficial. Although not tested on the experimental plantations, this has been observed elsewhere on the plateau where shade was used as a microsite criterion for evaluating planting spots (Minore, 1971).

As satisfactory survival occurs under a protective canopy cover, seedlings should be planted under canopied areas and overstory cutting delayed until after seedlings are fully established and large enough to withstand severe frosts. The degree of overstory required for satisfactory survival should be investigated and incorporated into management practices.

Containerized Douglas-fir and white fir seedlings had statistically superior growth over other planting stock under overstory canopies. This indicates that these species may be underplanted successfully as containerized stock. However, further study should be conducted. Seedling response after canopy removal needs to be better understood before widespread use of this or any other underplanting technique.

BIBLIOGRAPHY

Atzet, Thomas and R. H. Waring. 1970. Selective filtering of light by coniferous forests and minimum light energy requirements for regeneration. Can. J. Bot. 48(12):2163-2167.

Black, H. C., E. J. Dimock II, W. E. Dodge, and W. H. Lawrence. 1969. Survey of animal damage on forest plantations in Oregon and Washington. Trans-North American Wildlife and Natural Resources Conference 34:388-407.

Bureau of Land Management. 1968. Field Instructions for Integrated Forest Survey and Timber Management. Inventories in Western Oregon. Portland, Oregon.

Canutt, Paul. 1969. Relative Damage by Small Mammals to Reforestation in Washington and Oregon. IN: Wildlife and Reforestation in the Pacific Northwest--Symposium. Oregon State University. Corvallis, Oregon.

Cleary, Dr. Brian and Robert Greaves. 1974. Loggers Handbook, Vol. XXXIV Pacific Logging Congress.

deMoulin, LeRoy A., James A. Pomerening, and Byron R. Thomas. 1975. Soil Inventory of the Medford District, Bureau of Land Management.

Emmingham, W. H. and R. H. Waring. 1973. Conifer Growth under Different Light Environments in the Siskiyou Mountains of Southwestern Oregon, Northwest Science, Vol. 47, No. 2.

Environmental Data Service, 1975-1976. Climatological Data for Oregon, Environmental Science Services Administration, Vol. 81 #1, Asheville, N. C.

Hallin, William. 1968. Soil Surface Temperatures on Cutovers in Southwestern Oregon. USDA For. Serv. PNW Research Note #78, Pac. Northwest For. and Range Exp. Sta. Portland, Oregon.

Hanson, Richard M. and Vincent H. Reid. 1973. Distribution and Adaptations of Pocket Gophers. IN: Pocket Gophers and Colorado Mountain Rangeland. Colorado State University Exp. Sta., Fort Collins, Colorado.

Hermann, Richard K. and Harold A. Thomas. 1963. Observations on the Occurrence of Pocket Gophers in Southern Oregon Pine Plantations. J. For. 61(7).

Hooven, Edward F. 1971. Pocket Gopher Damage on Ponderosa Pine Plantations in Southwestern Oregon. J. of Wildlife Manage. 35(2):346-353.

Lawrence, W. H. and Harry D. Hartwell. 1961. Guide to Wildlife Feeding Injuries on Conifers in the Pacific Northwest. Western Forestry and Conservation Assoc., Portland, Oregon.

Mayo, Robert P. 1969. Mayo Report, Findings and Recommendations of the Working Party, Task Force on Softwood Timber and Plywood.

Minore, Don. 1971. Shade Benefits Douglas-fir in Southwestern Oregon Cutover Area. U.S.D.A. For. Serv. Tree Plant. Notes 22(1):22-23.

Minore, Don. 1973. Silvicultural Systems for the Major Forest Types of the United States. U.S.D.A. For. Serv., Agric. Handbook No. 445, 114 p.

Moore, A. W. 1940. Wild Animal Damage to Seed and Seedlings on Cutover Douglas-fir Lands of Oregon and Washington. U.S.D.A. For. Serv. Tech. Bull. 706.

Ronco, Frank. 1975. Diagnosis: "Sunburned" Trees. J. For. January 1975.

Stein, W. I. 1954. Natural Reproduction of Shasta Red Fir From a Single Good Cone Crop. USDA For. Serv. Res. Note #100, Pac. Northwest For. and Range Exp. Sta., Portland, Oreg.

Strothmann, Rudolph O. 1972. Douglas-fir in Northern California: Effects of Shade on Germination, Survival and Growth. USDA For. Serv. Res. Pap. PSW-84, Pac. Southwest For. and Range Exp. Sta. 10 p., illus. Berkeley, California.

Trevis, L. Jr. 1956. Pocket Gophers and Seedlings of Red Fir. Ecology 37:379-381.

APPENDIX

APPENDIX

Appendix Table 1. Bare-Root Planting Stock Characteristics.

Species	Average diameter at root collar (mm)	Average shoot length (cm)	Average oven-dry shoot wt. (g)	Average oven-dry root wt. (g)
Douglas-fir	2.37	20.0	1.49	1.02
White fir	3.11	13.78	1.58	1.06
Ponderosa pine	4.9	14.6	5.2	2.16

Appendix Table 2. Seedling mortality on plantation number one as tallied in September, 1976. As there were six replications per treatment, "6" represents complete mortality, and "0" represents complete survival.

TREATMENT MORTALITIES
PLOT I

	Species	Stock	CANOPY, WATERED, Non-Caged	CANOPY, WATERED, Caged	CANOPY, NON-WATERED, Non-Caged	CANOPY, NON-WATERED, Caged	CLEAR-CUT, WATERED, Non-Caged	CLEAR-CUT, WATERED, Caged	CLEAR-CUT, NON-WATERED, Non-Caged	CLEAR-CUT, NON-WATERED, Caged
FENCED	DOUGLAS FIR	Containerized	2	0	1	1	6	6	5	5
FENCED	DOUGLAS FIR	Bare root	0	0	1	0	6	2	4	5
FENCED	WHITE FIR	Containerized	1	1	1	0	2	2	6	2
FENCED	WHITE FIR	Bare root	0	2	1	0	6	4	3	3
FENCED	PONDEROSA PINE	Containerized	3	0	1	0	6	3	5	3
FENCED	PONDEROSA PINE	Bare root	0	0	0	0	6	2	6	2
NON-FENCED	DOUGLAS FIR	Containerized	2	1	0	1	5	6	4	5
NON-FENCED	DOUGLAS FIR	Bare root	0	1	0	0	5	3	4	5
NON-FENCED	WHITE FIR	Containerized	2	2	0	0	3	5	5	4
NON-FENCED	WHITE FIR	Bare root	1	1	1	0	5	3	5	5
NON-FENCED	PONDEROSA PINE	Containerized	1	2	2	1	5	5	4	3
NON-FENCED	PONDEROSA PINE	Bare root	0	0	0	0	4	2	5	3

Numbers indicate dead seedlings after 2 growing seasons

Appendix Table 3. Seedling mortality on plantation number two as tallied in September, 1976.

TREATMENT MORTALITIES
PLOT 2

			Canopy				Clear-cut			
			Watered		Non-watered		Watered		Non-watered	
			Non-Caged	Caged	Non-Caged	Caged	Non-Caged	Caged	Non-Caged	Caged
Fenced	Douglas Fir	Contoinerized	1	1	0	0	5	6	6	5
Fenced	Douglas Fir	Bore root	0	0	0	0	6	4	6	5
Fenced	White Fir	Contoinerized	0	0	0	0	6	6	6	5
Fenced	White Fir	Bore root	0	0	0	0	6	2	5	6
Fenced	Ponderosa Pine	Contoinerized	0	0	1	0	1	3	6	1
Fenced	Ponderosa Pine	Bore root	0	0	0	0	2	0	4	0
Non-Fenced	Douglas Fir	Containerized	1	1	1	0	6	6	6	6
Non-Fenced	Douglas Fir	Bore root	1	1	1	0	6	6	4	5
Non-Fenced	White Fir	Contoinerized	1	1	1	0	6	6	6	6
Non-Fenced	White Fir	Bore root	0	3	1	0	6	6	6	6
Non-Fenced	Ponderosa Pine	Contoinerized	0	1	0	0	5	4	4	5
Non-Fenced	Ponderosa Pine	Bore root	0	1	0	0	1	2	1	0

Numbers indicote deod seedlings offer 2 growing seosons

Appendix Table 4. Seedling mortality on plantation number three as tallied in September, 1976.

TREATMENT MORTALITIES

PLOT 3

			Canopy: Watered: Non-Caged	Canopy: Watered: Caged	Canopy: Non-Watered: Non-Caged	Canopy: Non-Watered: Caged	Clear-cut: Watered: Non-Caged	Clear-cut: Watered: Caged	Clear-cut: Non-Watered: Non-Caged	Clear-cut: Non-Watered: Caged
FENCED	DOUGLAS FIR	Containerized	1	2	1	2	6	6	6	6
		Bare root	0	1	0	0	5	6	6	6
	WHITE FIR	Containerized	1	0	0	0	5	5	4	6
		Bare root	2	1	1	1	5	4	4	3
	PONDEROSA PINE	Containerized	0	1	0	0	3	0	1	0
		Bare root	0	0	0	1	3	1	2	1
NON-FENCED	DOUGLAS FIR	Containerized	1	1	1	2	6	6	6	6
		Bare root	0	1	0	2	6	4	6	5
	WHITE FIR	Containerized	0	0	3	0	6	6	6	6
		Bare root	0	1	0	1	6	5	5	6
	PONDEROSA PINE	Containerized	0	1	1	0	5	0	5	1
		Bare root	0	0	1	2	4	0	2	0

Numbers indicate dead seedlings after 2 growing seasons

Appendix Table 5. Seedling mortality on plantation number four as tallied in September, 1976.

TREATMENT MORTALITIES

PLOT 4

			CANOPY				CLEAR-CUT			
			WATERED		NON-WATERED		WATERED		NON-WATERED	
			Non-Caged	Caged	Non-Caged	Caged	Non-Caged	Caged	Non-Caged	Caged
FENCED	DOUGLAS FIR	Contoinerized	1	0	2	0	4	5	4	2
		Bore root	1	1	2	0	3	4	2	3
	WHITE FIR	Contoinerized	0	1	1	1	2	3	2	1
		Bore root	1	0	1	0	3	3	2	1
	PONDEROSA PINE	Contoinerized	3	2	2	0	2	0	0	1
		Bore root	1	1	2	1	1	0	2	1
NON-FENCED	DOUGLAS FIR	Contoinerized	0	0	0	0	2	2	2	1
		Bore root	1	1	0	0	3	2	4	2
	WHITE FIR	Contoinerized	1	0	0	0	4	1	4	1
		Bore root	0	0	1	0	3	3	2	1
	PONDEROSA PINE	Contoinerized	1	1	3	0	1	1	2	0
		Bore root	0	1	1	3	2	2	3	2

Numbers indicote deod seedlings
ofter 2 growing seosons