Survival of Planted Ponderosa Pine in Southern Oregon

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Research Paper 2

June 1965

Forest Management Research
FOREST RESEARCH LABORATORY
OREGON STATE UNIVERSITY
Corvallis

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SUMMARY

Planting techniques, size and age of seedlings, and protection against animals were investigated for their influence on survival of ponderosa pine at two sites in southern Oregon. Caging and mulching with paper were the most effective measures for reducing mortality. Preliminary trials prior to large-scale planting were recommended for determining biotic hazards and severity of climate.

ACKNOWLEDGMENTS

Grateful appreciation is extended for the helpful cooperation of the Bureau of Land Management and personnel of its Medford District for providing the out-planting areas, planting the seedlings, and maintaining the plantations.

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INTRODUCTION

The present study was undertaken to provide a basis for improved planting practices in a portion of the pine region of southern Oregon where plantations have failed with disturbing frequency. Poor survival of planted ponderosa pine has been common there. Efforts to determine the causes have consisted mostly of speculation rather than systematic investigation.

Work on the separate, but related, parts of the study--planting tools and planting depth, size and age of seedlings, and mulching--is described in the single section on procedure, and results are combined in the next succeeding section.

Important contributions to the understanding of factors pertaining to survival of ponderosa pine seedlings have been made in recent years by studies of Stone and his co-workers (12, 13, 15)* in California. Their work has stressed the relationship between physiological condition of seedlings and survival. With RRP (root-regeneration potential) as a criterion, they found that physiological condition of seedlings was affected by origin of seed, location of nursery, and date of lifting. Effect of cold storage on survival of seedlings also was linked to date of lifting (14).

Good physiological condition of seedlings, however, is not sufficient to guarantee satisfactory survival. Biotic and climatic agents can take a heavy toll in plantations regardless of the quality of stock; therefore, good seedlings should be supplemented by measures against adverse environmental factors. Institution of such measures, however, requires knowledge of the relative importance of hazards in the planting area and of methods to eliminate or reduce these hazards.

The investigation was conducted on two burns that lie on a plateau at an elevation of 4000 feet, bordered in the west by the Siskiyou mountains and in the east by the Klamath river gorge.

*Numbers in parentheses refer to references cited.

Forests in this area are composed of ponderosa pine (Pinus ponderosa, Laws.), Douglas-fir (Pseudotsuga menziesii, Mirb., Franco), white fir (Abies concolor, Gord. & Glend., Lindl.), and incense cedar (Libocedrus decurrens Torr.). Pure stands of ponderosa pine are rare, but pine is as a rule the principal species.

Soils are residual, developed on basaltic parent material. They are red-brown, predominantly of clay-loam texture and well-drained.

Annual precipitation ranges from 15 to 20 inches; part of it falls in the form of snow. In the growing season extended periods of dry and hot weather are common; moreover, moisture in the ground is depleted rapidly in spring and seldom replenished before fall. Rains in summer fall as brief showers in the wake of thunderstorms and do not contribute appreciably to the supply of soil moisture.

Soils may freeze to a depth of one foot in winter when snow is not covering the ground. Skies are often clear, resulting in alternate freezing and thawing and danger of frost heaving.

Animals that injure or destroy seedlings in this general area are deer, rabbits, porcupines, and pocket gophers.

Under these circumstances, serious difficulties in regeneration can be expected and appear to arise mainly when a stand is removed completely, either by fire or by clear-cutting. Abundant reproduction must have appeared in most stands that were railroad-logged shortly after 1900. This conclusion is obvious from distribution of age classes and degree of stocking in these "selectively" cut stands. But where the land became entirely denuded, grass and brush, mostly Ceanothus species, replaced trees.

The two locations where this study was made represented an initial stage and an advanced stage of conversion from forest to grasses and brush. The first location, named Dixie and located at the northern end of the Bogus burn, had supported a stand of ponderosa pine from 40 to 50 years old, interspersed with older pine, Douglas-fir, and incense cedar, apparently left after logging the previous stand. All the pole-sized timber, most of the older trees, vegetation on the ground, and litter were destroyed by fire in 1958. Two years later, when this study was initiated, vegetative cover consisted primarily of mullen (Verbascum thapsus), patches of California needle grass (Stipa californica), and cheat grass (Bromus tectorum) (Figure 1). Spot seeding and planting ponderosa pine after scarification in portions of the area in 1959 were unsuccessful.

The second location, Ward road, was near the center of a 30-year-old burn. Judging by the size of stumps, a mature stand of

Figure 1. The planting area at Dixie in 1961. Ground cover consisted of mullen, California needle grass, and cheat grass.

ponderosa pine, Douglas-fir, and incense cedar must have been there at the time of the fire. Although a few trees of each of the three species had survived, natural regeneration was nowhere apparent. Cheat grass and clumps of snow brush (Ceanothus velutinus) had become the principal vegetation. An attempt in 1959 to reforest parts of the burn by planting ponderosa pine following scarification failed completely.

EXPERIMENTAL PROCEDURE

Ten-acre enclosures were constructed for the study at Dixie and Ward road in the fall of 1960. The fences were 8 feet high, with 5 strands of barbed wire, spaced one foot apart, strung above woven wire.

Two measures were taken to eliminate planters as a source of variation. The same crew was used for all plantings and each man planted an equal proportion of seedlings on every plot.

Mortality was tallied biweekly during the first 3 months following planting, and then at monthly intervals during the first growing season. In the second and third year, plots were inspected at the beginning and end of the growing seasons.

Tools and planting depth

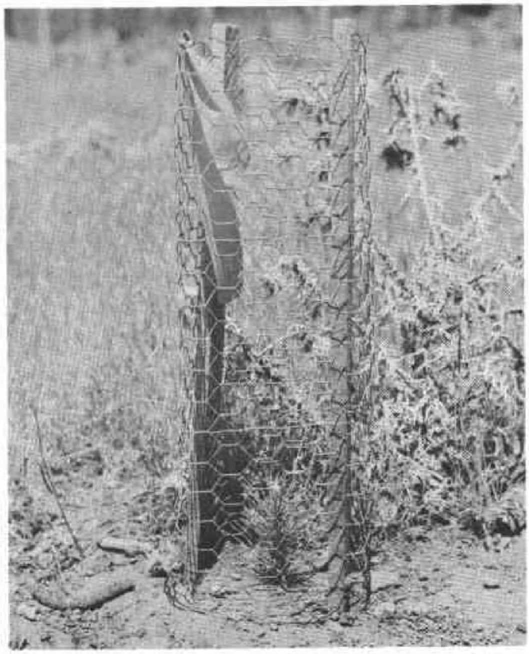
Two thousand ponderosa pine seedlings, 1000 inside and 1000 outside enclosures, were planted in the first week of December 1960 at each locality. Two kinds of tool, hoe and bar, and two planting depths, normal and deep, were used in each of four possible combinations. Seedlings were planted 50 to a plot, replicating each combination of tool and planting depth five times (Table 1). Spacing of trees within plots was 8 by 8 feet. Assignment of treatments in the 20 plots inside and outside of enclosures at each location was random. Seedlings designated as planted to "normal" depth were set into the ground so that the root collar was about one inch below the surface of the soil. Seedlings designated as "deep" had the base of their terminal buds even with the surface of the soil.

Seedlings were 2-0 stock that had been raised in the Oregon State Nursery at Elkton from seed collected at 3800-foot elevation in Klamath County, Oregon. Seedlings had been lifted immediately prior to planting and had been brought directly to the planting area that had about 6 inches of snow lying on the unfrozen ground.

Table 1. Number of Seedlings in Basic Design Followed for Planting in Winter of 1960, and again in Spring of 1961. Seedlings were Planted 50 to a Plot, Resulting in a Total of 40 Plots in Each of the Two Study Areas.

	Depth			
	with bar		with hoe	
Enclosure	Normal	Deep	Normal	Deep
Outside	250	250	250	250
Inside	250	250	250	250

Figure 2. Cage made of poultry netting to protect seedlings against rabbits.



Plants were of uniform size. Crowns were from 10 to 12 inches tall, roots were 8 inches long, and diameters of stems at the root collar varied from 0.20 to 0.25 inch.

Another group of 4,000 seedlings was planted at Dixie and Ward road in the first week of April 1961. Design and procedure were as for the winter's planting. Stock was of the same origin as that in December; the only difference was that seedlings had been lifted in the last week of March 1961.

While the enclosures were considered deer-proof, the question arose whether additional protection was needed against rabbits. To clarify this point, cages made of common poultry wire (Figure 2), 18 inches in height and about 8 inches in diameter, were placed at time of planting around all seedlings on 10 of the plots planted in winter and on 10 of the plots planted in spring.

Size and age of seedlings

Seven groups of ponderosa pines, each group containing 100 seedlings of one of seven different kinds of stock (Table 2), were planted at Dixie and another seven at Ward road in the first week of December 1960. Seedlings were planted 8 by 8 feet apart inside exclosures, 25 to a plot, with plantings of each kind of stock replicated 4 times. Assignment of

Table 2. Origin, Size, and Type of Stock Compared.

Stock	Origin of seed*	Stem diameter**	Elevation	Length of crown
		Inches	Feet	Inches
1-1	Malheur	0.20 - 0.25	4000	8-12
2-0	Deschutes	0.20 - 0.25	4000	8-12
2-1	Malheur	0.20 - 0.30	4500	16-22
3-0	Deschutes	0.22 - 0.28	4000	14-20
2-1-1	Payette	0.30 - 0.40	5000	24-28
2-2	Deschutes	0.30 - 0.40	4000	16-22
3-1	Deschutes	0.35 - 0.42	4500	24-28

*National Forest.

**At root collar.

stock to plots was random. Seedlings were raised at the U. S. Forest Service Nursery at Bend, Oregon, and were lifted the week prior to planting.

Again, 700 seedlings were planted at each of the two study areas in the first week of April 1961. Procedures were the same as in the winter. Stock was identical to that planted in December, except it had been lifted in February and kept 5 weeks in cold storage prior to planting. Planting, both in winter and spring, was done with a bar.

Mulching

One thousand 2-0 ponderosa pine seedlings were planted inside the enclosure at Dixie in early April 1962. Half of the 400 seedlings from Elkton and all 600 seedlings from the Sherwood nursery (near Portland) had been raised from seed collected west of the crest of the Cascades; the other 200 seedlings from Elkton were grown from seed collected east of the crest of the Cascades (Table 3). Stock from the nursery at Elkton was uniform in size, but seedlings from the Sherwood nursery varied considerably in this respect. To eliminate size as an unknown variable, stock from Sherwood was graded into three classes according to size (Table 3). Seedlings had been lifted at Elkton the week prior to planting, while stock from the Sherwood nursery already had been lifted in early March and was kept in cold storage until planting.

Seedlings were planted, with bars, on 40 plots with 25 seedlings of one kind to a plot. Each seedling was protected by a wire cage. Asphalt-interlined paper (Kraft 30-30-30) was placed around 500 seedlings (Figure 3), 100 from each of the 5 groups listed in Table 3, while the other 500 seedlings were left without mulch. Assignment of groups to plots was made randomly. Likewise, plots where mulch was applied were selected at random.

Table 3. Description of 2-0 Ponderosa Pine Stock Studied for Effects of Mulching; 200 Seedlings Were in Each Group.

Code*	Nursery	Seed source**	Elevation	Size of stock	Length of crown	Stem diameter+
			Feet		Inches	Inches
A	Elkton	Klamath	4500	Small	8-10	0.19-0.23
B	Elkton	Douglas	3000	Medium	13-16	0.22-0.26
C	Sherwood	Jackson	3500	Small	5-10	0.16-0.20
D	Sherwood	Jackson	3500	Medium	10-15	0.20-0.25
E	Sherwood	Jackson	3500	Large	15-20	0.23-0.30

*See Figure 12.
**County.
+At root collar.

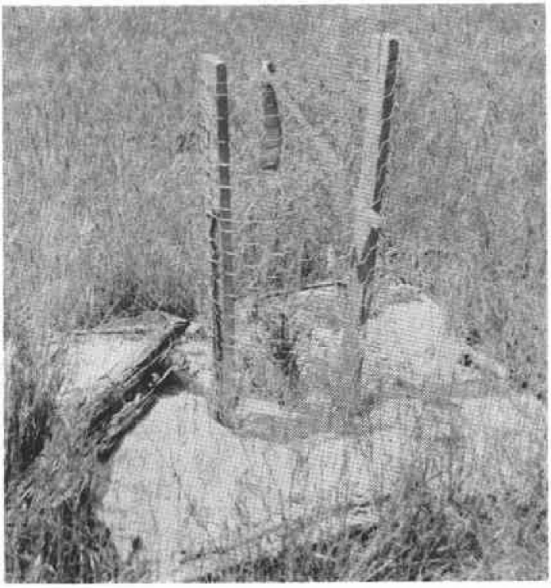


Figure 3. Seedling with paper mulch. Note dense cover of cheat grass.

RESULTS

Although planting techniques, and size and age of seedlings, did influence survival, caging and mulching with paper were the most effective measures for reducing mortality.

Tools and planting depth

Survival of seedlings planted at Dixie was influenced by season of planting and by kind of planting tool, but was not affected by depth to which seedlings were planted. Both inside and outside of the enclosure, winter-planted stock had significantly higher survival than spring-planted stock (Figure 4, Table 4, 5)*. Planting seedlings with bars gave better survival than planting with hoes, except for the spring-planted

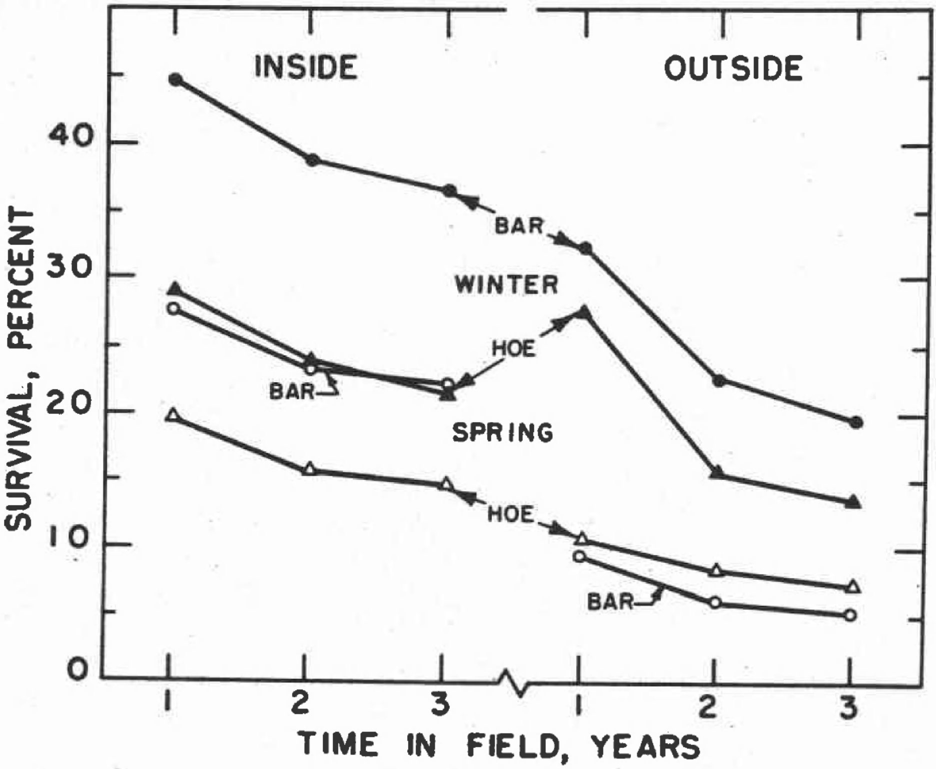


Figure 4. Survival of 2-0 ponderosa pines planted in winter of 1960 and spring of 1961 with two kinds of tools at Dixie. Percentages for each combination of season and tool are based on 500 seedlings planted.

*Tables 4 through 9 contain information on statistical analyses and appear in the APPENDIX.

seedlings outside the enclosure (Figure 4). Survival according to type of tool used in planting differed significantly within the enclosure, but not outside the enclosure (Tables 4, 5).

Inside the enclosure, seedlings that had been caged had higher survival than uncaged trees, regardless of planting season or type of planting tool (Figure 5, Table 4).

No seedling planted at Ward road survived the first growing season. The complete failure at this location resulted from defoliation of all live seedlings by grasshoppers in August 1961. Inspections made prior to the appearance of grasshoppers, however, allowed assessing the effects of other hazards on newly planted trees at Ward road.

Causes of first-year mortality of seedlings planted in winter (Figure 6) indicated that different problems existed in the two areas in regard to damage by animals. From December 1960 to March 1961, deer destroyed almost 70 percent of the seedlings planted outside the enclosure at Ward road, while rabbits clipped few seedlings either inside or outside the enclosure (Figure 6). At Dixie, deer did little damage, and rabbits were the major hazard. Direct killing by rabbits was low, but many seedlings were injured by rabbits so severely that they did not recover. Seedlings listed as killed by injury from animals combined with drought were mostly trees partially cut by rabbits.

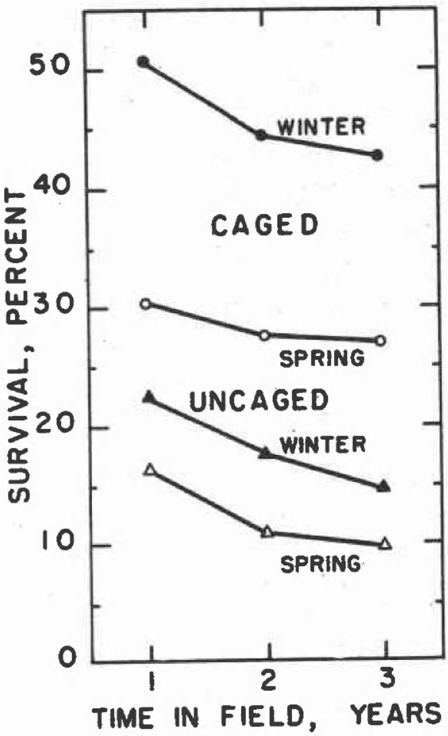


Figure 5. Survival of caged and uncaged seedlings within the enclosure at Dixie. Percentages for each combination of season of planting and presence or absence of cages are based on 500 seedlings planted.

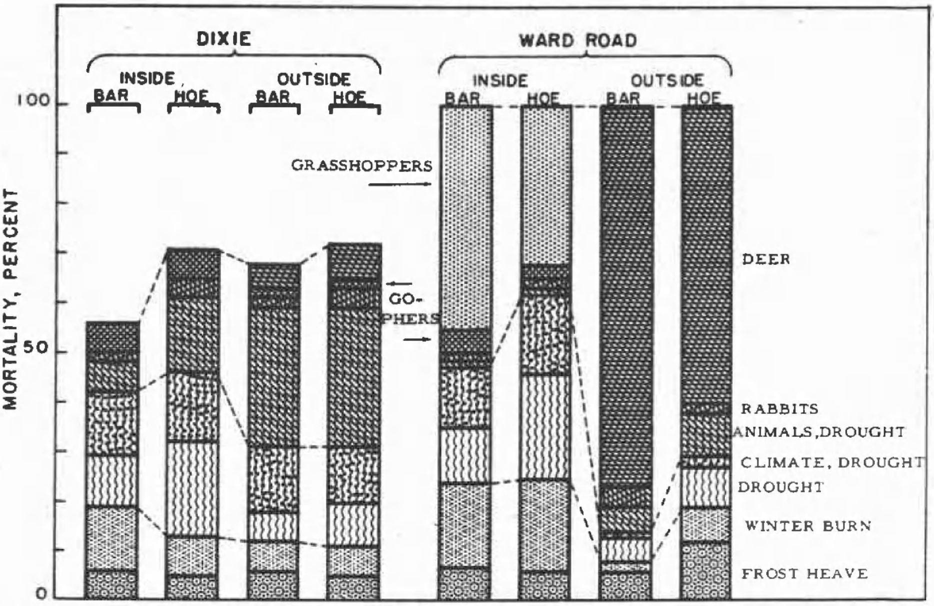


Figure 6. Causes of first-year mortality of 2-0 ponderosa pines planted in December 1960. Percentages for each bar are based on 500 seedlings planted.

Probably because of damage by animals, differences in climatic hazards between the two locations were not distinct. Except for more frequent occurrence of winter-burn (death resulting from inability to balance transpirational losses on clear days through uptake of moisture from frozen ground) inside the enclosure at Ward road, losses attributable to climatic factors were about the same for both areas.

The only major difficulty in identifying causes of mortality arose with seedlings that had been injured either by animals or by frost in winter of 1960-61 and died the following summer. Since neither injury nor drought could be fixed as the sole reason for death, cause of death was listed as a combination of both for seedlings that died later than April. /

Many seedlings failed to burst buds and turned brown from 4 to 8 weeks after planting. Failure to burst buds was significantly higher in seedlings planted by bar than in seedlings planted by hoe (Figure 7). The adverse effect of planting by bar on bursting of buds was, however, without consequence for total mortality, because mortality, by drought, of seedlings planted with a hoe became correspondingly greater later in the season. For seedlings planted in spring, drought was the most frequent cause of death at both localities (Figure 7).

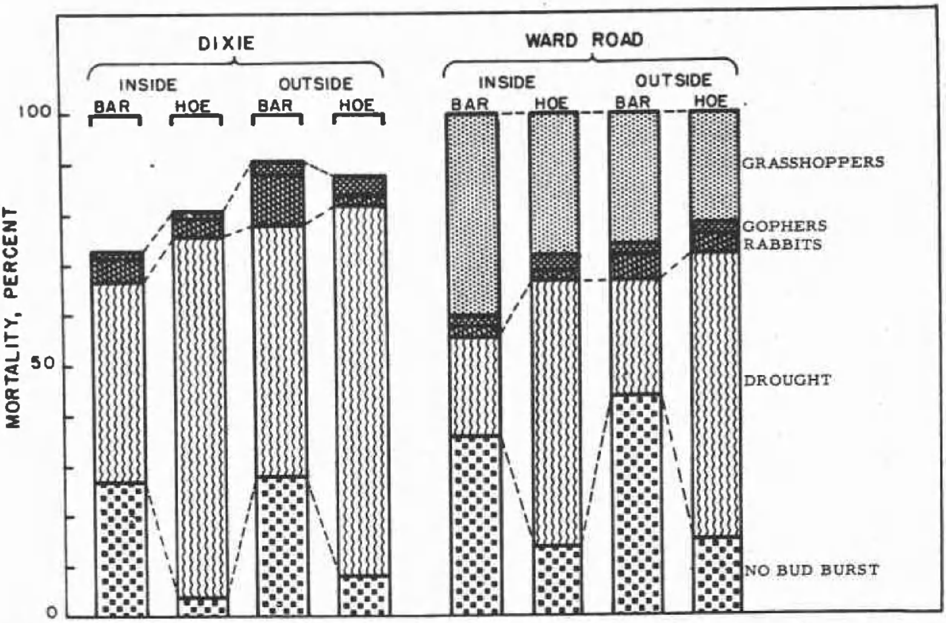


Figure 7. Causes of first-year mortality of 2-0 ponderosa pines planted in April 1961. Percentages for each bar are based on 500 seedlings planted.

Mortality in the second and third year at Dixie was slight compared to the heavy losses in the first year. Frost-heaving, drought, gophers, and deer (outside the enclosure) were principal causes of mortality in the second year. Losses the third year were caused primarily by gophers.

Value of protection against animals was manifested not only by increased survival, but also by differences in development of surviving seedlings. Trees in cages had reached an average height of 2.5 feet at the end of the third growing season (Figure 8). Completely unprotected seedlings outside the enclosure had been injured repeatedly; few had tops larger than 2 or 3 inches (Figure 8).

Size and age of seedlings

Survival of seedlings at Dixie was influenced both by season of planting and by age of stock. Effect of season of planting on survival varied, however, with different kinds of stock (Figure 9). Groups of 2-0, 3-0, and 2-2 stock had higher survival when planted in winter rather than in spring, while the converse was true for the other kinds of stock. Differences in survival according to season of planting and kind of stock, as well as interactions between kind of stock and season of planting, were highly significant (Table 6).

Figure 8. Protected (left) and unprotected (right) seedlings 3 years after planting.

At Ward road, trees still alive in August were defoliated completely by grasshoppers; none survived. Initial losses because of winter-burn, frost-heaving, and the combined effects of injury by frost and drought of winter-planted seedlings (Figure 10), and mortality by drought of spring-planted trees (Figure 11) were far more severe at Ward road than at Dixie.

With the exception of 2-1 stock, outright kill by winter-burn was infrequent at Dixie. Many seedlings, however, had been so injured by winter-burn as to become unable to withstand severe stress of moisture and died early in summer. This dual effect of injury by winter-burn and drought was the most frequent source of mortality for winter-planted stock at Dixie, although mortality from this cause varied significantly among different kinds of stock (Table 7). Determination of the least significant difference (Table 8, column 1) indicated that the combined effect of winter-burn and drought led to higher losses of 2-1 and 1-1 stock compared to other stock, except for 2-1 seedlings. Total mortality at the end of the first growing season was higher for 2-1 and lower for 2-2 stock than for other stock (Table 8, column 2). High mortality of 2-1 seedlings reflected a high incidence of direct and indirect effects of frost; low mortality of 2-2 seedlings was a consequence of less occurrence of injury from frost and of small losses from drought and animals.

Spring-planted seedlings at Dixie showed differences among types of stock in regard to failure of buds to burst following planting. The percentage of trees that did not burst buds and were dead soon after planting was larger for 3-0 and 2-2 seedlings than for other seedlings (Table 8, column 4). The major cause of losses in spring-planted seedlings was, however, drought. Differences in the amount of mortality from all causes at the end of the first growing season were significant among the various kinds of stock. Determination of the least significant difference showed that 3-0 seedlings had mortality higher than that of any other kind of stock (Table 8, column 5). Seedlings of 3-0 stock suffered heavy losses because of drought, in addition to their high rate of failure to burst buds. Drought killed even more 2-0 than 3-0 seedlings, and mortality of 2-0 stock was significantly higher than that of any of the transplants, with the exception of 2-2 seedlings. Drought killed few 2-2 seedlings, but their total mortality was boosted substantially by the many seedlings that failed to burst buds.

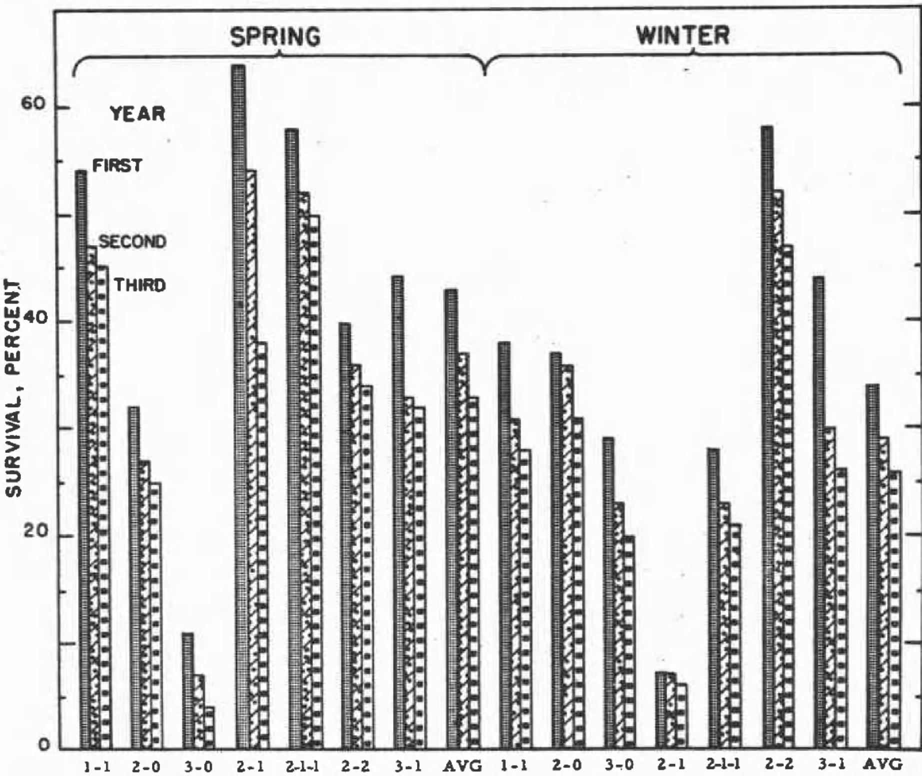


Figure 9. Survival of spring- and winter-planted transplants at Dixie. Percentages are based on 100 seedlings of each type of stock.

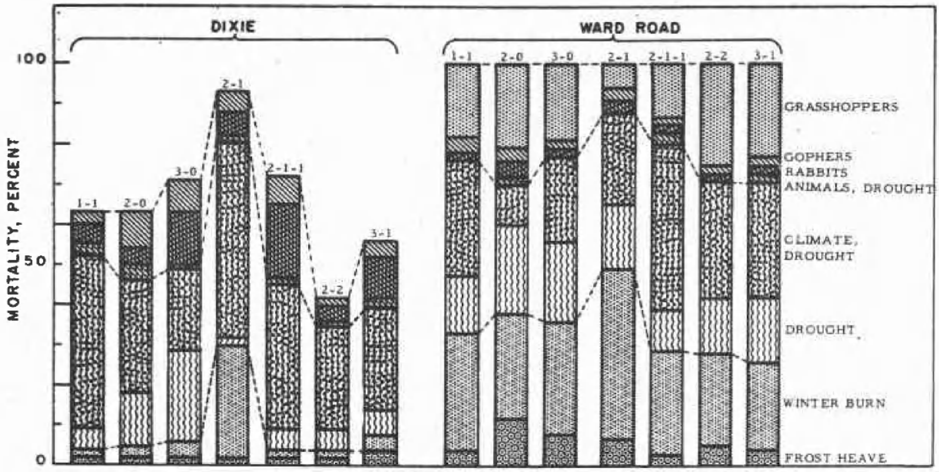


Figure 10. Causes of first-year mortality for stock of various sizes or ages planted in winter. Percentages for each of the 14 bars are based on 100 seedlings.

Mortality of both winter- and spring-planted seedlings was moderate in the second and third year, except for winter-planted 3-1 stock and spring-planted 2-1 stock (Table 8, columns 3, 6). Gophers were responsible for substantial losses of seedlings of these two kinds of stock.

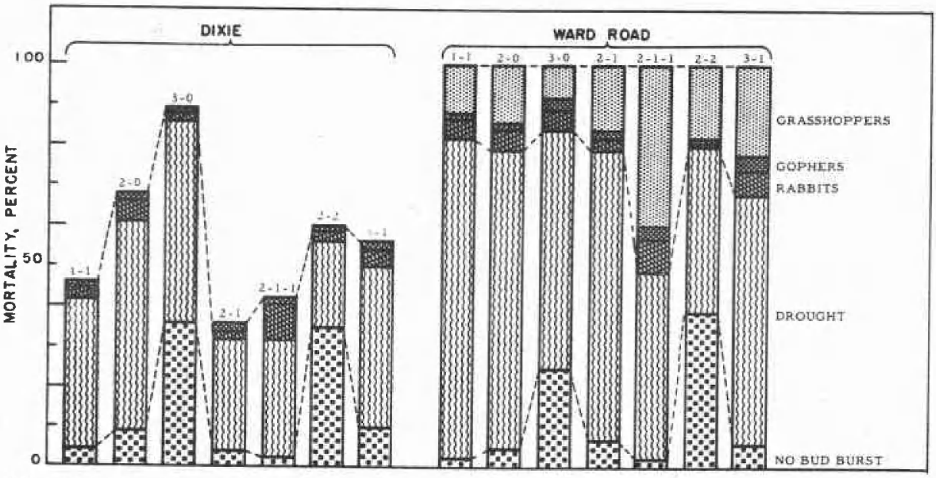


Figure 11. Causes of first-year mortality for stock of various sizes or ages planted in spring. Percentages for each of the 14 bars are based on 100 seedlings.

Second-year mortality of other stock resulted from frost-heaving, drought, and gophers. Losses in the third year were caused mainly by gophers.

Mulching

Application of mulching paper had a highly beneficial effect on survival of 2-0 ponderosa pines planted in spring of 1962 at Dixie. Survival of seedlings with mulch was almost twice as high as for seedlings without mulch (Figure 12). Size of seedlings, source of seeds, and location of nursery where seedlings had been raised were of no consequence to survival in this trial. Mulch was the only variable of significance (Table 10).

In the first year, drought was the principal factor in mortality of seedlings without mulch. Gophers and failure to burst buds following planting were responsible for most of the mortality of mulched seed-

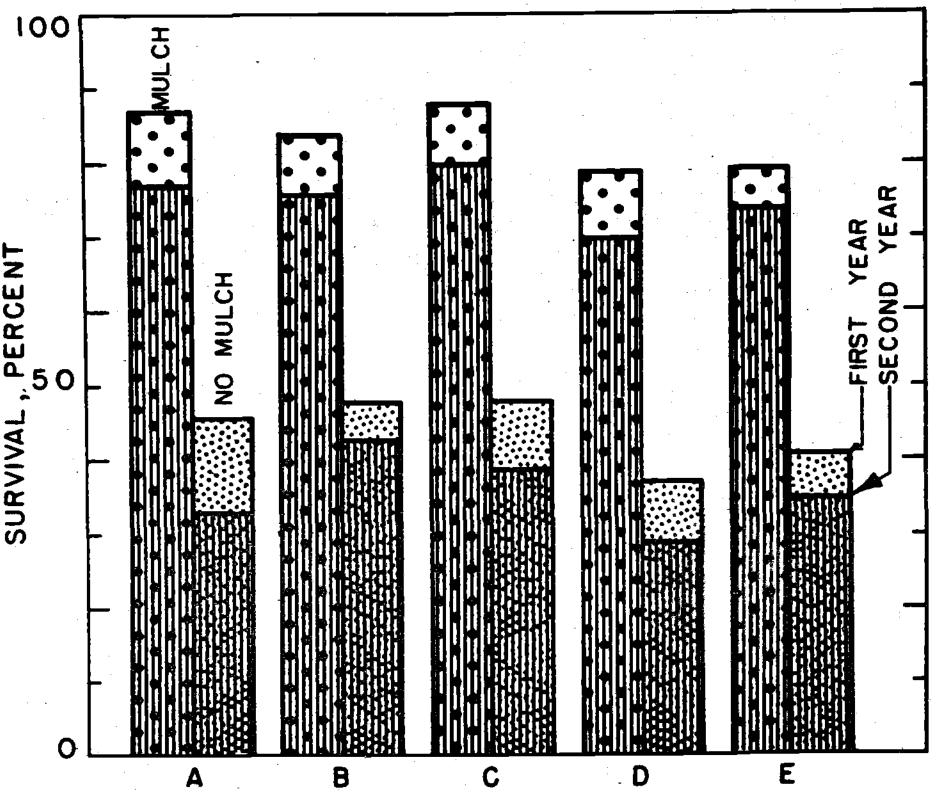


Figure 12. Survival of seedlings with and without paper mulch. Percentages for each bar are based on 100 seedlings. Letters under each column refer to groups described in Table 3.

lings. Determination of seasonal course of moisture at from 10- to 14-inch depth in the soil showed greater depletion of moisture in the absence than in the presence of mulch (Figure 13).

Mortality in the second year was moderate and did not differ significantly among seedlings with and without mulch. Gophers and drought were responsible for the major share of losses. Frost-heaving killed some unmulched seedlings.

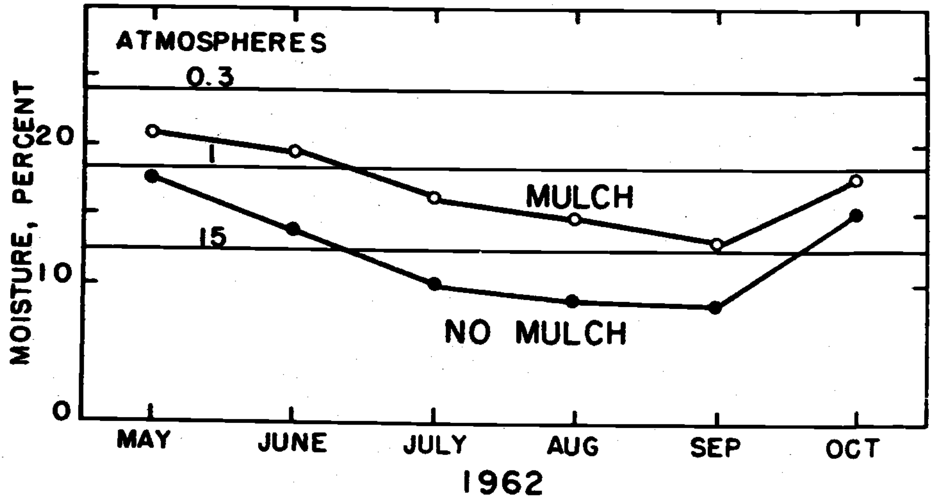


Figure 13. Seasonal course of soil moisture at one-foot depth under 2-0 ponderosa pines with and without paper mulch. Each point represents the mean of two gravimetric samples. Moisture percentages at tensions of 0.3, 1, and 15 atmospheres were determined on pressure-membrane equipment.

DISCUSSION OF RESULTS

The current study is essentially a case history of the initial stage in establishing small plantations on two severe sites in the pine region of southern Oregon. While results apply directly to these particular areas only, they are, nevertheless, indicative of the problems encountered throughout most of the region and may serve as a starting point for discussion of these problems and of possible means to their solution.

<u>Season</u> <u>of</u> <u>planting</u>

Whether planting in spring is preferable to planting in fall or winter is a purely speculative question as far as some parts of the pine region of southern Oregon are concerned. Soils are too dry for planting in fall, and heavy rains or snow render the terrain inaccessible in winter. Under these conditions, spring is the reasonable choice for planting. The situation is different in regard to those sites that remain accessible through part, or all, of the wet season. Here, planting in late fall or winter is feasible and can relieve foresters from the necessity of doing all their planting during a few weeks in spring.

Observations made in this investigation suggest that neither spring nor winter can be considered the more favorable season for planting. Each season presents particular problems to the establishment of plantations. When planting in late fall or winter, there is the risk of frost-heaving, winter-burn, and direct killing by frost. Another aspect of fall and winter planting is the increased chance of damage by animals. Deer, rabbits, and gophers are more likely to feed on seedlings in winter than in spring when other sources of food become available. Effects of frost and animals become far less serious in spring, but rapid dessication of the soil may endanger survival of seedlings planted at this time.

To what extent disadvantages of each season of planting will become effective also may depend on physiological condition, origin of seedlings, or both. Results obtained at Dixie indicated such an effect. The 2-0 seedlings planted in December 1960 had survival significantly higher than that of 2-0 seedlings planted in early April of 1961, regardless of treatments (Figure 4). Losses of winter-planted 2-0 seedlings because of animals and frost were considerably less than drought-caused mortality of spring-planted trees. The various kinds of transplants did not, however, show such a consistent pattern of survival in regard to season of planting. For some, planting in winter resulted in higher survival than planting in spring, while for others the converse was true (Figure 9). Important differences in microenvironmental conditions over the planting area would have been brought out by significant differences among replications. Since differences were not found, environmental variations probably were not decisive factors. Size of seedlings appears to have been of little consequence to survival. Increase, or decrease, in survival of trees according to season of planting could not be correlated with size of stock. Seedlings raised at the nursery at Elkton from a single source of seed gave consistent results, and those raised at the nursery at Bend from different sources did not; this fact pointed to differences either in physiological condition or in origin among seedlings. Unfortunately, extent of effects of nursery and source of seed, and their relationship to season of planting, could not be determined, since the study was not designed to permit an analysis of these variables and their interaction.

Seasonal variation in the ability of ponderosa pine to initiate new roots is relevant to this discussion. Stone and Schubert (13) demonstrated that production of new roots was low among 2-0 ponderosa pines lifted in September and October, increased sharply in seedlings lifted from November to March, and declined markedly again in trees lifted after April. Stone and Benseler (14) pointed out in a later publication that stock lifted and placed in cold storage late in fall, during the winter, or early in spring before buds break, maintains a high potential for regenerating roots and can be stored until needed. These authors concluded, nevertheless, that planting in late fall or winter entailed unnecessary risks; an opinion Stone defended repeatedly in the ensuing controversy regarding the most desirable season for planting in the pine region of California (10, 17, 18, 19).

Stone argued that even if the root-regenerating potential of a seedling is high, new roots will not be formed unless average temperatures in the top foot of soil are not much below 60 F. Secondly, movement of water in cold soil is slowed to such an extent that seedlings cannot replace transpirational losses of moisture quickly enough, and dessication of tissues becomes a real danger.

Both arguments are open to question. Stone based his contention on numbers of new roots formed 4 weeks after planting in a greenhouse. A seedling lifted in November, planted in cold soil, and examined in December may have few new roots. This situation would not necessarily imply that activity of roots will not increase 2 or 3 months hence when the soil begins to warm. Lavender (6) in his work with Douglas-fir observed essentially the same pattern of seasonal variation. He did not, however, find evidence of impairment in production of new roots in spring when seedlings lifted in, or after, November were outplanted in winter. In Oregon, average temperatures in the uppermost foot of soil barely reach 60 F even in the middle of the growing season, and remain substantially below that temperature during most of the year.

The danger of dessication of seedlings in cold soil seems to be vastly overrated. Imbalance between loss and uptake of water by seedlings ordinarily is not a problem in soils saturated with moisture (as most soils are in winter) as long as they are not actually frozen. If low temperatures in soil were such a problem, seedlings probably could not be held in nursery beds through winter.

Seedlings in this study were lifted in December, February, and March. Those lifted in the latter two months were stored 5 and 2 weeks, respectively. In the light of current knowledge, neither lifting at any of these dates nor short storage should have affected adversely the physiological condition of seedlings. Planting in winter apparently resulted in growth and elongation of roots early enough to remain ahead of the zone of dessication when the soil started to dry in spring. Only where this advantage was eliminated by substantial losses of seedlings because of direct and indirect effects of frost, did planting in spring give higher survival than planting in winter.

Survival on droughty sites

Rapid dessication of soils with onset of the dry season is characteristic of many sites in the pine region of southern Oregon; it jeopardizes first-year survival of seedlings planted in spring unless measures are taken to insure adequate supply of soil moisture.

Deep-planting of seedlings has been advocated as an economic means of improving survival on droughty soils. However, tests of this method yielded mostly disappointing results. In a trial in Arizona (3), 2-0 ponderosa pines set into the ground to the base of the terminal bud had even lower survival than seedlings planted at standard depth. Reviewing similar experiments with southern pines, McGee and Hatcher (9) cited only two instances where deep-planting increased survival. In other trials, survival was equal to, or less than, survival after planting at normal depth. Deep-planting did not provide any benefits in the present study through reducing mortality caused by winter-burn or drought.

Another technique employed in the present study, mulching with paper, gave excellent results; it preserved soil moisture effectively and nearly doubled survival of seedlings. Paper mulch, introduced a few years ago, was successful on severe sites in southern Oregon (4). Experience with the method indicated some limitations: Sheets slip easily on slopes and bury seedlings. On areas subject to grazing, paper is torn quickly and ripped by trampling of livestock. Proper timing of application is difficult and costs are high; depending on terrain and effectiveness of crew, placing 100 sheets requires from 1.5 to 5 man-hours if trees are spaced 8 by 8 feet.

On sites with a heavy cover of grass and other herbaceous vegetation, spraying with chemicals such as atrazine promises to be a far cheaper and more efficient way of eliminating competing vegetation to provide enough moisture for survival of seedlings (11). Paper mulch, however, is preferable to chemicals on sites where frost-heaving is an additional problem. Here, mulch fulfills a dual purpose--preserving moisture and keeping seedlings in the ground.

Removing all existing vegetative cover offers another possibility for controlling loss of soil moisture, but it is an expensive operation and frequently ineffective when ground is covered primarily with grasses. In such instances, grasses re-invade the land and may lead to complete failure of plantations, as happened at Dixie prior to the present study.

The findings did not confirm the commonly held belief that transplants will assure better survival on droughty sites than will ordinary 2-0 stock. Transplants cost too much to produce and out-plant, and success is too questionable to advocate their use in reforesting droughty areas.

Planting tools

Bar and hoe are still the most common tools for planting in southern Oregon. Although numerous minor variations exist in modes of use, all represent basically two techniques described as the "bar-slit method" and the "side-hole method" (2).

Comparison of the two methods of planting indicated different results among seedlings planted during winter only within the enclosure at Dixie (Figure 4). Damage by animals and insects probably obscured effects of planting tools at Ward road.

Effect of planting tools on mortality of trees planted in winter did not show until summer, when drought killed far more seedlings planted by hoe than planted by bar. This phenomenon apparently was a consequence of rapid drying of the soil caused by extensive loosening of the ground with the hoe.

Results of the planting in spring showed again the same unfavorable effect of the hoe. Seedlings planted with that tool had a rate of mortality by drought significantly higher than that of those planted with the bar. Improper handling of the bar, however, led also to considerable losses of seedlings. Working the bar back and forth created holes with convex sides. The lowest part of such holes often remained partly open, which led to quick dessication of the root system and failure to commence growth. High incidence of failure to burst buds among seedlings planted by bar, both at Dixie and Ward road (Figure 7), indicated how frequently a faulty technique had been employed. Although use of the bar requires skill and care to make proper planting holes, it appears to be preferable to use of the hoe in medium- and light-textured soils subject to rapid drying in spring. Loosening the soil when planting with the hoe seems to accelerate dessication in ground around the tree and thus increases chances of seedlings being killed by drought.

The choice between bar and hoe probably will be of lessened concern in the future. Growing use of planting machines and back-packed, power-driven augers for preparing planting holes soon may make bar and hoe obsolete.

Protection against animals

Risk of severe damage to newly established plantations is high in southern Oregon unless seedlings are protected against animals. Use of protective measures, however, poses problems.

Costs of labor and materials for each enclosure in the present study were slightly above $2,000. Expenditures for a cage were 12.2 cents; 5 cents went for materials, and 7.2 cents for labor required for manufacturing, transporting, and placing.

Even if enclosures can be constructed for less money, costs must be considered prohibitive and also unjustifiable because of lack of protection against rabbits. Cages, by contrast, may be regarded as an effective and economically feasible means of protection if trees are spaced more widely than customary. Based on costs cited above, going from 8- by 8-foot to 16- by 16-foot spacing would reduce expenses for caging from $83 an acre to $20 an acre. Cages have the further advantage of being reusable if they should become unnecessary at the original location.

Effectiveness of cages against deer could not be evaluated in the present investigation, since cages were placed inside enclosures. Experience elsewhere (1, 9), however, indicated that cages offered dual protection against rabbits and deer for several seasons after planting. Deer, and even elk, seldom disturbed cages. Barbed-wire fences were needed in grazing areas because cattle would overturn and trample cages.

Coating seedlings with TMTD (tetramethyl thiuram disulphide) or ZAC (zinc dimethyldithiocarbamate cyclohexylamine complex) offers an alternative to caging. Both chemicals are effective as repellents against wildlife. The period of protection is limited, however, and under heavy feeding pressure, their repellent action breaks down, and animals will feed on treated seedlings (7).

CONCLUSIONS AND RECOMMENDATIONS

Successful establishment of plantations in the pine region of southern Oregon requires protective measures against adverse environmental factors. Good physiological condition of seedlings and careful planting do not by themselves assure satisfactory results.

Drought and frost are major climatic hazards that may be avoided to some extent by proper timing of planting operations. Since snow and heavy rains frequently render prospective planting areas inaccessible in early spring, the frost-free period during which the ground holds enough moisture for planting is usually too short for the execution of large programs of reforestation. Planting schedules have to be staggered according to elevation, with planting begun as soon as low elevations are open. Early planting involves risk of damage by winter-burn and frost-heaving, but chance of large losses of trees is far less than if planting is delayed to late spring.

Control of competing vegetation, especially when seedlings are planted in spring, is essential to insure adequate supply of soil moisture. Paper mulch is advisable for areas subject to both drought and frost-heaving. When applied correctly, it preserves moisture and keeps seedlings from being heaved out of the ground. On many sites, chemical spraying will be the cheapest and most effective way to eliminate competition for moisture. Scarification is too expensive and frequently ineffective because of rapid and heavy reinvasion of grasses.

Planting deeply does not reduce mortality and should not be substituted for other measures of preventing dessication. Use of transplants is unreliable and costly in improving survival on droughty sites.

Risk of partial or complete loss of plantations in the first growing season and loss of increment in subsequent years because of injury to surviving trees by browsing and clipping is high without protection against deer and rabbits. Cages of narrow-mesh wire placed around seedlings are excellent means for making trees inaccessible to these animals for several years. An alternative is to coat seedlings with TMTD or other repellents. Such treatment is cheaper than cages, but offers less reliable and shorter lasting protection. Enclosures seldom will be justifiable, since costs of construction are high and only deer are excluded. Addition of a narrow-mesh wire netting to exclude rabbits is usually ineffective because rabbits can burrow underneath.

Partial or complete failure of large plantations is a costly way to discover that severe climatic or biotic hazards exist on a site. Establishing small plantations should be considered as an approach to determine beforehand the nature of problems on prospective planting areas.

Results of preliminary trials will be useful in deciding on necessary steps to protect the investment represented by large plantations.

Protective measures should be applied where need for them has been demonstrated. Refusal to do so, on grounds that costs of protection are prohibitive, may be false economy. The expense of losing plantations often equals, or exceeds, the costs of measures required for protection. If protective measures are needed and the necessary funds are not available, deferment of planting may be the best alternative.

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APPENDIX

Analyses of variance for planting techniques, size and age of seedlings, and mulching are presented here.

Table 4. Analysis of Variance of Third-year Survival of 2-0 Ponderosa Pine Planted Inside the Exclosure at Dixie with Eight Combinations of Season, Tool, and Depth of Planting, Adjusted for Use of Cages. (This adjustment had to be made because cages were put by mistake on alternate plots instead of dividing them equally among plots of each combination of planting tool and depth of planting).

Source of variation	Survival			Survival adjusted for caging		
	Degrees freedom	Mean square	F	Degrees freedom	Mean square	F
Season	1	429.03	6.19*	1	429.03	9.05**
Tool	1	342.23	4.93*	1	235.45	4.96*
Depth	1	9.03	0.13	1	0.00	0.00
Season x tool	1	30.62	0.44	1	6.04	0.13
Season x depth	1	15.62	0.23	1	48.56	1.02
Tool x depth	1	42.02	0.61	1	42.02	0.89
Season x tool x depth	1	245.03	3.53	1	9.72	0.20
Error	32	69.35	--	31	47.43	--
Regression on caging				1	748.84	15.79**

*Significant at 5 percent level of probability.
**Significant at 1 percent level of probability.

Table 5. Analysis of Variance of Third-year Survival of 2-0 Ponderosa Pine Planted Outside the Exclosure at Dixie with Eight Combinations of Season, Tool, and Depth of Planting.

Source of variation	Degrees of freedom	Mean square
Season	1	960.4**
Tool	1	2.5
Depth	1	19.6
Season x tool	1	32.4
Season x depth	1	28.9
Tool x depth	1	67.6
Season x tool x depth	1	8.1
Error	32	22.2

**Significant at the 1 percent level of probability.

Table 6. Analysis of Variance of Third-year Survival of Seven Kinds of Stock Planted in Winter and Spring at Dixie.

Source of variance	Degrees of freedom	Mean square
Season	1	42.87**
Replications in season	6	2.64
Stocks	6	47.48**
Stocks x seasons	6	48.08**
Error	36	4.19

**Significant at 1 percent level of probability.

Table 7. Analysis of Variance of Mortality Resulting from Combined Effects of Frost and Drought in Seven Kinds of Winter-Planted Stock at Dixie.

Source of variation	Degrees of freedom	Mean square
Replications	3	2.99
Stocks	6	22.57**
Error	18	2.57

**Significant at 1 percent level of probability.

Table 8. Mortality of Seven Sizes or Ages of Ponderosa Pine Stock Planted in Winter and Spring at Dixie; Percent, Based on 100 Seedlings for Each Stock and Season.

Stock	Planted in winter			Planted in spring		
	Winter burn, drought	Years in field* 1	Years in field* 3	No bud-burst	Years in field* 1	Years in field* 3
1-1	44	63	72	5	46	55
2-0	29	63	69	9	68	75
3-0	22	71	80	36	89	96
2-1	48	93	94	4	36	62
2-1-1	36	72	79	2	42	50
2-2	29	42	53	35	60	66
3-1	27	56	74	10	56	68
Least significant difference at 5 percent level:						
	9.5	12.0	12.0	7.5	11.7	12.4
Least significant difference at 1 percent level:						
	13.0	16.3	16.3	10.3	16.0	17.0

*Mortality from all causes.

Table 9. Analysis of Variance of Second-year Survival of Five Kinds of Spring-Planted 2-0 Ponderosa Pines with and without Paper Mulch.

Source of variation	Degrees of freedom	Mean square
Total	39	--
Replications	3	17.00
Stocks	4	8.50
Replications x stock	12	5.75
Mulch	1	1000.00**
Stocks x mulch	4	2.00
Replications x mulch	3	0.67
Replications x mulch x stocks	12	7.33

**Significant at 1 percent level of probability.

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The Forest Research Laboratory, Oregon State University, is part of the Forest Research Division of the Agricultural Experiment Station. The industry-supported program of the Laboratory is aimed at improving and expanding values from timberlands of the State.

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The current report stems from studies of forest management.

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Develop the full potential of Oregon's timber resource by:

increasing productiveness of forest lands with improved practices.

improving timber quality through intensified management and selection of superior trees.

reducing losses from fire, insects, and diseases--thus saving timber for products and jobs.

Keep development of the forest resource in harmony with development of other Oregon resources.

PROGRAM . . .

REGENERATION through studies of producing, collecting, extracting, cleaning, storing, and germinating seed, and growing, establishing, and protecting seedlings for new forests.

YOUNG-GROWTH MANAGEMENT through studies of growth and development of trees, quality of growth, relationship of soils to growth, methods of thinning, and ways of harvesting to grow improved trees.

FOREST PROTECTION through studies of weather and forest fire behavior to prevent fires, of diseases and insects to save trees, and of animals to control damage to regrowth.

TREE IMPROVEMENT through studies of variation, selection, inheritance, and breeding.

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