Some Lessons in Artificial Regeneration from Southwestern Oregon

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NATURAL REPRODUCTION has often proved undependable for restocking cutovers and burns in the mixed-conifer forest types of southwestern Oregon. These types, covering 6,000 square miles of productive forest land in the five southwestern Oregon counties, are composed of many species—principally Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco; ponderosa pine, *Pinus ponderosa* Laws.; sugar pine, *Pinus lambertiana* Dougl.; incense cedar, *Libocedrus decurrens* Torr.; grand fir, *Abies grandis* (Dougl.) Lindl.; and white fir, *Abies concolor* (Gord. & Glend.) Lindl. Each of these species is commercially important; but three, Douglas fir, ponderosa pine, and sugar pine, may be preferable for specific environments.

By conservative estimate, 60,000 acres of cutover land requiring restocking are created annually in the mixed-conifer types. Much of this acreage is not restocked adequately within a reasonable length of time. Cutovers that were showered with the bumper seed crop of 1949 and the moderate seed crop of 1951 remain unstocked. Some burns 30 to 40 years old have not restocked even though a good seed source has been continuously present. The rapid growth of brush on recent cutovers and the heavy brush on old burns give ample evidence that prompt restocking is needed to keep the land in full forest production. To achieve this goal, artificial reproduction is considered necessary in many places.

Planting has long been the most successful method of artificially reproducing forest stands. However, this method is slow, costly, and limited by nursery capacity. Also, planted trees have often shown poor survival in the mixed-conifer area. Therefore, alternate methods for artificially restocking cutovers are desirable.

Establishing a new tree crop directly from seed has physiological and practical advantages. Seedlings generally root deeper into the soil by early summer than planted trees, and thus are not so susceptible to drouth. Seedling roots are also not subject to disturbance and injury from transplanting. Direct seeding further provides a method that is more flexible in timing and application than planting and one that may prove more economical. However, success in direct seeding hinges upon overcoming additional enemies, especially rodents and certain insects.

Methods

The lessons to be discussed here were learned in three ways—by observation, by analysis of data from nine small-scale studies, and from records of three large-scale direct seedings totaling 175 acres. Most installations were made on either or both of two broad soil types: a fine-textured red clay loam in the South Umpqua drainage, and a coarse-textured pumice on the upper Rogue River. All seed was sown in spots and lightly covered with soil. Stratified seed was used for spring sowing. Ponderosa and sugar pine were the principal species studied, but Douglas fir was also included in several tests.

Observational studies are informal and continuing. Valuable ideas and research leads have been contributed by observant forest administrators. The experience accumulated by the Rogue River, Siskiyou, and Umpqua National Forests in conducting planting and direct seeding projects has yielded lessons directly and also contributed information for the formulation of hypotheses.

The nine small-scale studies were similar in design, but differed in the combination of reproduction methods tested. A typical study consisted of four or more blocks evenly divided between two tracts, often far apart. Blocks within a study contained three to five treatments, randomized and replicated. Each replication consisted of a single row containing five or ten individual seedspots or trees. Methods tested included the planting of nursery stock (as a comparison standard) and the sowing of seed in unprotected seedspots, in seedspots protected with conical screens, and in seedspots within K-screens. Success was measured by the germination, survival, and growth obtained.

The K-screen, designed by Joseph Keyes of the U.S. Fish and Wildlife Service, has been described by Roy and Schubert (1953). A similar device was used by Gemmer, Maki, and Chapman (1940). As used in seven studies in southwest Oregon, the K-screen is a 5-inch-long cylinder, one and one-fourth inches in diameter, made of wire-screen cloth. For study use, the screen was preloaded with soil or other germinating medium. The technique consisted of filling the screen with about two inches of soil, then adding two or three seeds, which were in turn covered with another one-fourth-inch layer of soil. The loaded screen was inserted into the ground deep enough to place the soil level inside the screen equal to or lower than that outside. After the screen was planted, its upper edge was squeezed together to form an eighth- to a fourth-inch opening, small enough to exclude rodents. Though the described method of loading and planting the K-screen is satisfactory for experimental purposes, faster mechanical methods must be developed before the screen will be practical for large-scale use.

An objective, and the first step in each of the three large-scale seedings, was rodent control with sodium fluoroacetate, thallium sulfate, or tetramine (tetramethylene disulpho tetramine). Succeeding steps consisted of seedspotting the area and marking protected and unprotected seedspots for later examination. Rodent censuses, repeated seedling examinations, and quadrat surveys provided the detailed information from which success was evaluated.

Lessons Learned

Protection from Rodents

An outstanding lesson learned from our studies is that direct seeding will not consistently succeed unless the seed and very young seedlings are protected from rodents. Usually the rodents must be excluded, repelled, or eliminated. Sometimes seeds are taken by rodents in a short period of concentrated feeding either immediately after sowing or when germination begins. At other times seed losses are spread over a period of several months. Even after germination, young seedlings are often clipped by rodents.

Trapping studies show that rodent populations vary tremendously in abundance and composition. On one tract, white-footed deer mice (*Peromyscus*) predominated; on another tract, only chipmunks (*Tamias*) were caught. Generally some shrews (*Sorex*), meadow mice (*Microtus*), and red-backed mice (*Clethrionomys*) were also found, but these mammals made up a minor part of the rodent population. On one 20-acre cutover tract, 79 per cent of the rodents caught within the clear-cut area were white-footed mice. Along the timber edge, 76 per cent were chipmunks; near-by, within the dense timber (200 feet from the edge of the clearcutting), 81 per cent were chipmunks, and not a single deer mouse was caught. Rodent populations are generally low on recent clearcuttings and increase in quantity and species complexity as food increases in abundance and variety.

The intensity of rodent feeding after direct seeding is unpredictable. According to studies by Jameson (1952), insects and vegetation are the principal foods of the deer mouse in late spring and early summer, and conifer seeds constitute only a minor percentage. This finding suggested that if stratified seed were sown in late spring, rodents might not disturb the seed. To test this hypothesis, 200 ponderosa-pine seedspots, half unprotected and half protected by conical screens, were put out in early June. Despite a heavy thundershower, which obliterated all evidence of soil disturbance minutes after the seed was sown, 70 per cent of the unprotected and 95 per cent of the protected spots were robbed within five weeks. As more protected than unprotected spots were robbed, it is possible that the screens served as markers that helped the rodents find the seed. Mice dug under the conical screens, whereas chipmunks pushed many of them aside.

An extreme example of the unpredictability of rodent feeding was encountered in a brief test of kerosene as a repellent on sugar-pine seed. In May, 1951, 30 "acceptance spots" baited with treated and 30 baited with untreated sugar-pine seed were placed in a brushy area where chipmunks had completely destroyed small seedspotting plots in just three days in May of the previous year. Although chipmunks were attracted to the fresh disturbances caused in clearing the spots and had dug in several, not a single seed, either treated with kerosene or untreated, was eaten in three days and nights. Present knowledge of rodent feeding habits and food preference is too meager to provide a guide for predicting when rodent-control measures are needed and when they can be safely by-passed.

We have found rodent-feeding pressure to be greatest, and the protection job most difficult, in the spring when the seeds are germinating. In three fall sowings of sugar pine in unprotected seedspots, seed losses were negligible throughout the winter, but losses of seed and seedlings were heavy during the germination period. Spring sowings were heavily attacked immediately after installation.

Protection methods used to date have yielded both failures and successes, but some methods have been more successful than others. A single poisoning of 20- to 50-acre units with sodium fluoroacetate reduced the original rodent population to a very low level in several studies, but infiltration from surrounding areas limited the period of time that control was maintained. Multiple poisoning was tried in one test where sodium fluoroacetate and thallium sulfate were used alternately in fall, winter, and spring applications, the spring application of sodium fluoroacetate being applied in early April when germination began. Total germination was about the same on the treated area as on a near-by untreated one, 74 and 72 per cent, respectively, indicating that little rodent damage occurred during the winter. Subsequent seedling losses due to rodents, however, were 29 per cent of the total on the untreated area compared to only 13 per cent on the treated. This difference was attributed largely to the rodent protection afforded by the spring baiting and indicates that a single poisoning may be useful to protect direct seedings for a short time during the germination period.

Good seed protection was obtained in one test using ponderosa-pine seed soaked for one hour in a 1-per-cent tetramine-acetone solution. This test was complicated by poor germination, only partly attributable to the tetramine treatment, but there was evidence that good protection was provided. Rodents had disturbed only 2 per cent of the staked spots in the treated area compared to 40 per cent in a near-by untreated area within two weeks after sowing. Seedlings occurred in the treated seedspots the next spring, but none were found in the untreated spots.

Though conical screens have failed to give good protection in several studies, properly installed K-screens have consistently given good protection to both seeds and seedlings. Two seedspot studies using conical screens were wiped out by rodents, and two others suffered considerable damage when rodents burrowed underneath them. Roy and Schubert (1953) reported that K-screens were pulled from the ground by large rodents in California. This has not occurred to a single one of 2,565 screens used in six different tests in southwestern Oregon. In a seventh test, 32 of 100 screens apparently were pulled by curious persons, but it is possible that rodents pulled some of the screens. Rodents have dug around screens on rare occasions—once until the screen was tilted at an angle—but the seed within still developed normal seedlings. Large losses of germinating seeds occurred in one test when the screens were left too open at the top. Openings of not more than one-fourth inch are necessary to exclude small rodents.

Germination of Seed

Successful germination of sugar pine has been obtained in both fall and spring seedings. Germination in all studies was measured by the appearance of seedlings above ground. In the case of fall-sown seed, germination occurred in 74 to 100 per cent of seedspots containing two or three sugar-pine seeds. For spring sowings of stratified sugar-pine seed, germination occurred in 85 to 100 per cent of the seedspots. Almost all ponderosa-pine and Douglas-fir seedspots were sown in the spring. The highest germination obtained for these seedspots was 97 per cent for ponderosa pine and 75 per cent for Douglas fir.

Sugar-pine seed can be sown during the summer months if protected from rodents. In one study, K-screens loaded with soil and with vermiculite were planted in August, September, October, November, April, and May; germination in the spring occurred in 92, 89, 92, 93, 91, and 91 per cent of the seedspots for the separate months, respectively.

Vermiculite has proved to be a better material than forest clay-loam soil for loading K-screens because: (1) Vermiculite is light, easy to use in loading screens, and has a high water-holding capacity; (2) it does not compact nor form a hard surface crust that imprisons seedlings; (3) it is a sterile material, free from the harmful fungi found in soils; (4) germination was faster in vermiculite in the one test where vermiculite and soil were compared. Total germination for seedings made in the fall months was about equal for the two media—93 per cent in vermiculite and 90 per cent in soil. Speed of germination, however, differed considerably. Germination was 43 per cent completed in vermiculite compared to only 28 per cent in soil by May 6; by June 11, it was 99 per cent completed in vermiculite, only 88 per cent in soil. The more rapid germination in vermiculite is advantageous in hastening the seedling development necessary for survival during rigorous summer weather.

Germination of Douglas fir was better in a sandy-loam soil than in pumice. For one small experiment, two Douglas-fir seeds were placed in each of 85 seedspots in pumice and in 50 seedspots from which a double handful of the pumice was removed and replaced by sandy-loam soil. Germination was 38 per cent in the sandy loam, but only 18 per cent in the pumice. This difference proved statistically significant and confirmed general observations. The better germination in the fine-textured soil was attributed to more favorable moisture conditions (Hayes, 1952).

Four insecticides had no harmful effect on the germination of sugar-pine, ponderosa-pine, or Douglas-fir seeds when added to sandy-loam soil within K-screens for protection from cutworms. Screens in replicated rows in three blocks on a pumice flat contained untreated soil and soil treated with aldrin, dieldrin, chlordane, and benzene hexachloride.[1] Screens containing aldrin, dieldrin, and chlordane showed no greater germination than the control (Table 1). Those containing benzene hexachloride showed better germination than the

TABLE 1. GERMINATION AND FIRST-YEAR SURVIVAL IN K-SCREENS CONTAINING SANDY-LOAM SOIL TREATED WITH FOUR INSECTICIDES[1]

	Ponderosa pine		Sugar pine		Douglas fir	
Soil Treatment	Germination	Survival	Germination	Survival	Germination	Survival
			Per cent			
Untreated (Control)	93	79	80	17	87	15
Aldrin	100	80	87	0	93	21
Dieldrin	100	73	80	33	73	27
Chlordane	93	93	93	14	80	25
Benzene hexacholride	100	0	100	0	87	0

[1] Basis—15 screens containing two seeds each for each species and treatment combination.

untreated screens, and the difference was significant statistically. Better germination in screens containing benzene hexachloride was believed attributable to fungicidal properties of this insecticide. Unfortunately, this beneficial effect did not continue; all seedlings died later, as discussed under the section on survival.

[1] Concentrations used were recommended by the Department of Entomology, Oregon State College. For each gallon of soil:

Aldrin—10 level teaspoons of 1-per-cent aldrin;
Dieldrin—1 level teaspoon of 15-per-cent active 4-9-7 dieldrin;
Chlordane—3 level teaspoons of 5-per-cent chlordane;
Benzene hexachloride—1½ level teaspoons of 10-per-cent gamma B.H.C.

More seedlings appeared above ground in one test when certain fertilizers were added to the soil in K-screens. In one four-block experiment located on clay-loam soil, bonemeal, superphosphate, superphosphate and potash, or ammonium phosphate was used.[2] The number of ponderosa pine appearing was significantly greater in screens containing each fertilizer than in screens containing none. The number of Douglas fir was significantly less where superphosphate and potash were used in combination compared to no fertilizer, but did not differ significantly for other treatments. The results of this study were not substantiated by another with ponderosa pine on pumice where fertilizer treatments included bonemeal, superphosphate, ammonium phosphate, and Vigoro.[3] In this test with 800 K-screens in eight blocks divided equally into fall and spring planting, no significant differences were found. In a small indoor test, ponderosa pine germinated well in pure bonemeal. As bonemeal has shown some favorable and no unfavorable effects, it is now used as an additive in K-screens whenever it does not interfere with study objectives (Fig. 1).

Germination of ponderosa-pine seed was reduced when sodium fluoroacetate or tetramine was applied as repellent directly on the seed, but germination of sugar pine was unaffected by tetramine. In one study, unpoisoned seed produced nearly twice as many seedlings as seed treated with sodium fluoroacetate in Dowax.[4] Schubert (1953), however, reported no reduction in germination of sugar-pine seed treated with sodium fluoroacetate in Dowax and in asphalt. Germination of ponderosa pine was reduced from 40 to 32 per cent by tetramine applied as a repellent in acetone. The reduction was attributed in part to poor seed quality, and is a greater reduction than has been experienced elsewhere, according to Spencer and Kverno (1952; 1953). The same concentration of tetramine in acetone had no harmful effect on the germination of sugar pine in one field test (75 per cent compared to 74 per cent for control), and laboratory tests with the same seed lot confirmed this finding (Spencer and Kverno, 1953).

Survival

In several tests good seedling survival was obtained in seedspots both with and without K-screens. For one large-scale sugar-pine seeding, 37 per cent of all

[2] Fertilizer added per quart of soil:
Steamed bonemeal, 1 heaping tablespoon.
Superphosphate, 1½ level teaspoon.
Superphosphate and muriate of potash, 1½ level teaspoons of each.
Ammonium phosphate, 1½ level teaspoons.

[3] Fertilizer added per quart of soil (one half as much was used for screens planted in the spring):
Steamed bonemeal, 2 heaping tablespoons.
Superphosphate, 3 level teaspoons.
Ammonium phosphate, 3 level teaspoons.
Vigoro, 3 level teaspoons.

[4] Cold-soaked ponderosa seed was coated with a solution consisting of 5 oz. sodium fluoroacetate to 12 oz. Dowax and 36 oz. water, applied at a rate of 5 oz. sodium fluoroacetate per 100 lbs. of dry seed.

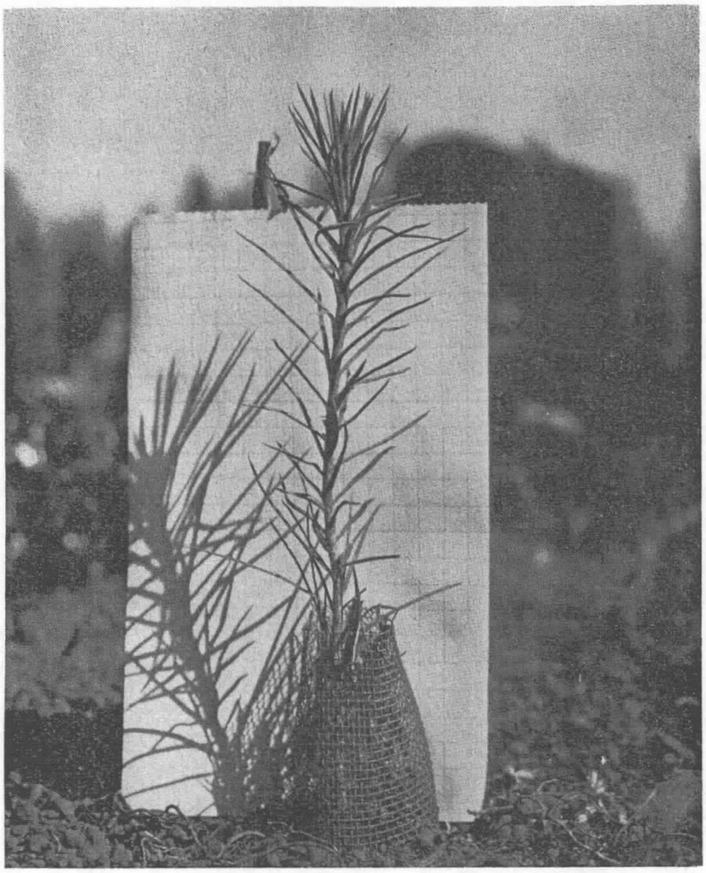

Figure 1. Outstanding growth. A five-month-old sugar-pine seedling, six and one-fourth inches tall, in K-screen containing bonemeal. Studies have shown that bonemeal may have a favorable effect on early seedling growth and survival.

staked seedspots were stocked at the end of the first year; and a fall survey found seedlings on 73 per cent of 4-milacre quadrats. This compared very favorably with planting, and costs were considerably less.

Other survival records are encouraging. For all tests with K-screens, first-year survival has been 66 per cent for ponderosa pine, 61 per cent for sugar pine, and 30 per cent for Douglas fir, based on stocking of screens in which seedlings appeared. Stocking at the end of the first year, based on total number of screens planted, was 49, 59, and 16 per cent, respectively. Better survival can be achieved; these averages are low because they include results from several seedings that were unsuccessful for reasons that can now be avoided.

Ponderosa and sugar pines survived better than Douglas fir, both when planted and when seeded. Both Douglas fir and ponderosa pine have been planted on the national forests of southwestern Oregon, and ponderosa-pine plantings have usually been more successful. Ponderosa-pine survival has generally been above 70 per cent, whereas Douglas fir has averaged less than 50 per cent. Only small acreages of sugar pine have been planted, and survival was better than for Douglas fir. Limited research confirms national forest experience (Table 2).

TABLE 2. SURVIVAL OF NURSERY TREES IN EXPERIMENTAL PLANTINGS

Species	Tests	Trees planted	First-year survival
	Number	*Number*	*Per cent*
Douglas fir	1	50	16
Ponderosa pine	4	550	76
Sugar pine	2	400	60[1]

[1] Foliage was yellow and survival poor for one lot of 200 trees that was packaged too long in transit.

Survival of ponderosa-pine and sugar-pine seedlings has likewise been superior. The primary roots of the two pines grow more rapidly and deeper than Douglas fir (Stein, 1952); consequently, the pines are more drouth-resistant. Their seedling stems are also larger and thicker, which enables them to withstand more surface heat. Results of seedspotting in K-screens substantiate these observations (Table 3).

Rodents, cutworms, and competing vegetation were the principal causes of seed loss and seedling mortality throughout the seeding studies. Occasionally, damping-off of ponderosa pine and heat-killing of Douglas fir were also serious.

TABLE 3. STOCKING IN SEVERAL K-SCREEN TESTS[1]

Species	Tests	Seedspots	Initial stocking	First-year stocking	Decrease (mortality)
	Number	*Number*	*Per cent*	*Per cent*	*Per cent*
Douglas fir	2	160	52	16	70
Ponderosa pine	2	160	74	49	34
Sugar pine	5	820	96	59	39

[1] The Douglas-fir and ponderosa-pine results were obtained from the same two tests. Sugar-pine tests were all different.

Rodents ate both seed and seedlings. In one study, 79 staked sugar-pine seedspots in which no seedlings appeared were examined for seed. Seed loss attributed to rodent activity above ground was 4 per cent; below ground, 30 per cent. The loss below ground was caused mainly through seed displacement by gophers, which also destroy many seedlings by clipping roots or exposing them to air.

A few cutworms were found on freshly logged areas, and their numbers increased rapidly with the re-establishment of vegetation. One study, on a three-year-old clearcutting, was completely destroyed by cutworms (Fig. 2). In another study on an area burned many years before and reburned recently, one third of all seedlings were destroyed by July of the first year. Cutworms clipped seedlings both above and below ground.

Sedge competition has been a major problem on pumice soil. The sedge has so depleted soil moisture to depths of 36-48 inches by midsummer that both seedlings and nursery stock have died, whereas, on large, scalped plots within

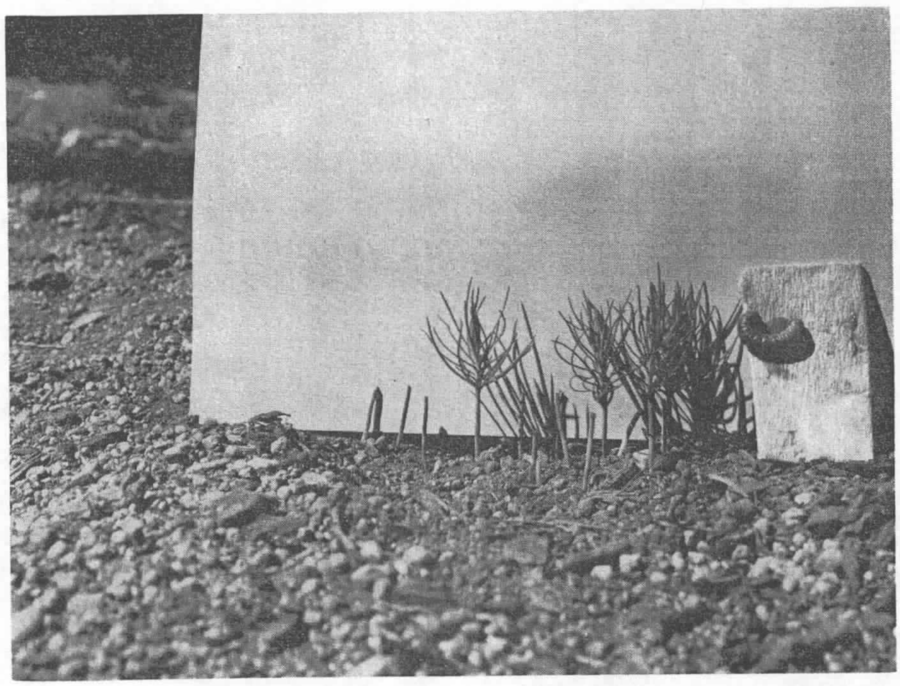

Figure 2. Cutworm damage in a seedspot protected by conical screens. The cutworm shown at the right was found below the surface near seedlings. Cutworms clip tender stems below ground and more woody stems above ground. Clipped tops are often partially pulled into the ground before consumption.

the sedge cover, excellent moisture was found just below the surface, and seedling survival was good.

Properly used, K-screens eliminate losses due to rodents and cutworms, but permit minor losses from other causes, including some that are unique. Soil used in earlier studies formed a hard crust, which sometimes trapped seedlings. In extreme cases, trapped sugar-pine seedlings have broken at the neck of the hypocotyl; sometimes small insect larvae that usually do not harm vigorous seedlings have destroyed trapped ones. Compacted soil in the screens has prevented seedlings from growing downward rapidly enough to keep up with the lowering moisture or has caused the roots to grow out the side where they are girdled by the screen as they grow (Fig. 3). Soil compaction can be avoided by using friable soil or vermiculite. Seedlings generally have emerged readily from the narrow slit at the top of the screen, but a few have become trapped and have grown into a tightly curled mass. Most of these emerged from the screen the second year by growth from the uppermost bud. Frost-heaving, a disadvantage of K-screens reported by Roy and Schubert (1953), has occurred to a limited extent in southwestern Oregon studies, but little mortality resulted. The

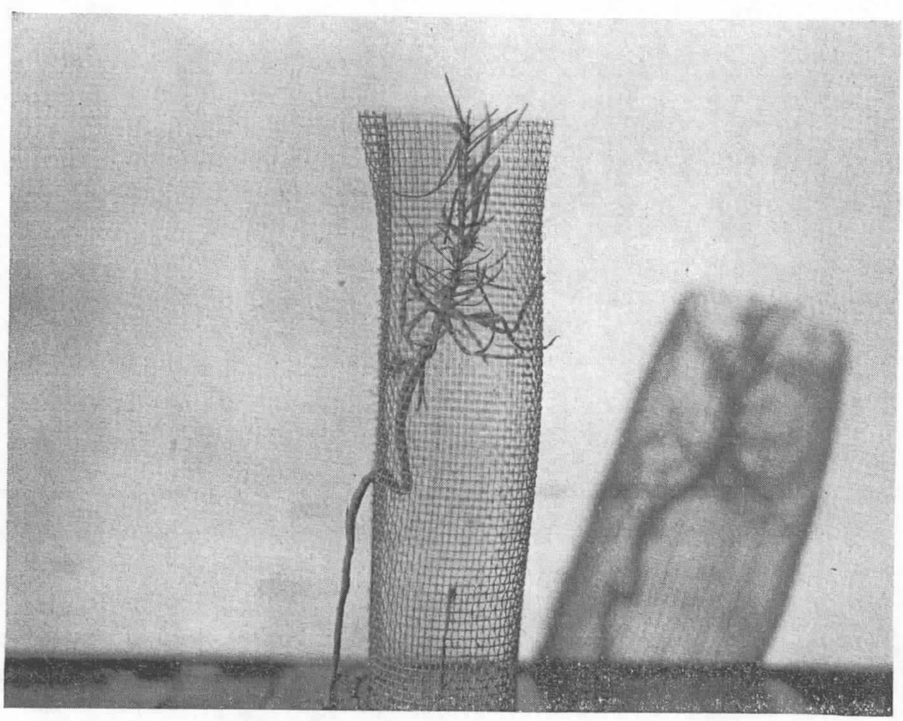

Figure 3. Two-year-old ponderosa-pine root girdled by K-screen. Compacted soil in bottom of screen caused root to grow through the side. Such mortality can be avoided by using friable soil or vermiculite in loading screens.

screens were not pulled completely from the ground, and the seedling roots apparently spanned any underlying soil gap successfully. Trampling by deer or livestock is often fatal to screened seedlings.

Insecticides added to soil in K-screens had no effect on survival with one exception (Table 1). Benzene hexachloride killed all seedlings of all species within a few weeks after germination; the seedling roots were typically short and club-shaped, showing chemical injury. The other insecticides, aldrin, chlordane, and dieldrin, had no effect on survival and early growth.

Fertilizers have shown no consistent effect on survival when used as soil additives in K-screens. In one study, the seedlings receiving bonemeal showed the best survival; but in the other study, no significant differences among treatments were found. The most positive thing learned is that bonemeal has shown no detrimental effects on survival and early growth and appears to be somewhat beneficial.

Conclusions

An objective of research at the Siskiyou-Cascade Research Center has been to find a cheap and effective method of artificial reproduction to supplement planting.

Artificial reproduction of Douglas fir has not been fully satisfactory by any method. On national forest Douglas-fir plantings of several thousand acres, survival has averaged less than 50 per cent. Survival in research installations was only 16 per cent for seedlings in K-screens (two tests) and for nursery stock (one test).

Seeding in unscreened spots has proved promising for reproducing sugar and ponderosa pines. The necessary rodent control has been achieved in several tests with poison or repellent, and control methods are being improved continuously (Shaw, 1953; Spencer and Kverno, 1953). Seedspotting has been about four times as fast as planting trees, and with improved tools can be done even faster. By placing seedspots more densely than trees are usually planted, stocking comparable to planting has been obtained at less cost.

Seedspotting does not promise to be a panacea that eliminates all need for planting in southwestern Oregon. Planting has been consistently better on pumice.

Although successful seedings have been made in other seasons, fall is recommended because (1) stratification or other seed treatment is unnecessary, (2) seed is less difficult to protect from rodents, and (3) seed is in place to start growing when favorable weather arrives. The third reason is particularly important at high elevations where there is only a short time between the melting of snow and the arrival of hot, dry weather. Sugar pine, which requires 90 days of cold stratification, may be seeded even in late summer, when working conditions are most favorable.

K-screens have yielded good results, but they are limited in application until methods for making, loading, and planting them by machine are developed. A practical K-screen would solve the rodent problem and also provide means for solving special regeneration problems through the use of fertilizers, insecticides, and other additives.

The single most important thing forest managers can do to minimize difficulties in obtaining artificial regeneration is to reforest cutover areas promptly. Rodents, cutworms, and competing vegetation are at their lowest concentration immediately after a tract has been logged and burned. Each succeeding year increases the difficulties that must be overcome to obtain adequate stocking of the cutover tract.

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