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Direct Seeding Ponderosa Pine on Recent Burns in Arizona

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The significant factors determining success of direct seeding are those affecting seedling survival, particularly moisture stress and frost heaving. Because there is little or no control of these factors, the results of direct seeding are extremely variable, even on the most favorable sites. Direct seeding recent burns, even by spot seeding, is of limited usefulness in the Southwest because of high cost and variability of results. The method should be reserved as a flexible tool to promptly regenerate only the best sites when planting stock is unavailable.

Keywords: Forest regeneration, direct seeding, frost heaving, ponderosa pine.

Research has demonstrated that planting forest trees is the most positive way to start new stands when and where needed, but planting is expensive. Direct seeding has the potential of being more economical and flexible than planting, but is less reliable.

The best time to plant or seed is immediately after disturbance. Regeneration problems become more difficult as reforestation is delayed. Recently burned areas present the fewest obstacles to direct seeding, and constitute an excellent test situation to determine the success potential of direct seeding in the Southwest.

Habitat conditions for seedeating rodents and birds are least desirable immediately following a fire. A hot burn also destroys most of the herbaceous seeds, so new pine seedlings compete with fewer grass and weed seedlings of their own age. This study examined the problems and prospects of direct seeding on recent burns.

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Literature Review

Lavin (1955) found that fresh burns in northern Arizona, on which the vegetation was largely destroyed and the soil surface covered with a layer of loose ash, were good sites for seeding grasses. The practice of seeding grasses after fires has been curtailed in recent years, however, because the grasses compete strongly with tree seedlings in later ponderosa pine regeneration programs. Larson and Schubert (1969b) found that competition for soil moisture was the main factor in competition between grasses and ponderosa pine seedlings. Pine seedlings survived and grew best on plots completely cleared of other vegetation. Grasses start root growth earlier, grow faster, deplete soil moisture rapidly to lower levels, and are capable of enduring more drought than the pines. Although partial shade from grass and weeds favors germination of pine seeds, the later effects of competition are detrimental (Pearson 1950).

Water stress during germination and initial development of ponderosa pine seedlings is one of the main reasons for poor success with direct seeding (Larson and Schubert 1969a). A slightly negative (-3 bars) water potential stimulated germination, but potentials below -7 bars greatly depressed germination. Seeds alternately wetted and dried several times germinated as well as unwetted seeds, and significantly better than seeds soaked for 24 hours without aeration. Root penetration, root dry weight, and cotyledon length decreased with decreased water potential of the soil solutions. Another significant finding was that seedlings that germinated under stress conditions grew poorly even if they subsequently were well watered.

Low soil water potential is usually the result of the precipitation pattern, competition of herbaceous vegetation, or a combination of the two (Pearson 1942, 1950; Heidmann 1969; Larson and Schubert 1969b; Schubert et al. 1970). Even in the absence of competing vegetation, there is no control over the precipitation pattern, and direct-seeded pine seedlings are more susceptible than planted seedlings to temporary drought.

Study Areas and Methods

The study was established on two spring burns that occurred in successive years on the Coconino National Forest, Arizona. The Kelly Burn consumed 3,550 acres in April 1971, and the Rattle Burn consumed 714 acres in May 1972. Although only two burns were available, contrasting soil and site conditions are representative of those found on the Coconino Plateau in northern Arizona. On the Kelly Burn experimental plot, site index was 65 (Minor 1964) at 7,470 feet elevation; soils were Kelly sandy loam derived from basalt and cinders. On the Rattle Burn plot, site index was 98, and elevation was 6,760 feet; soil was Soldier sandy loam derived from limestone and sandstone parent materials.

Kelly Burn Experiment

Direct seeding methods tested on the Kelly Burn were broadcast, broadcast and rake, and seed spot. Viable seeds of local origin were sown at rates of 2, 4, and 8 pounds per acre by each seeding method. There were four replications of the nine treatments; one replication consisted of four circular 1-milacre subplots treated alike. The broadcast treatment involved spreading seeds evenly over the soil surface with no attempt to cover them. In the broadcast-and-rake treatment, seeds were worked into the soil with a garden rake. Seed spots were shallow depressions made with a hoe in which the seeds were covered uniformly with 0.5 inch of soil and compressed. Four seeds were placed in each spot; the number of seed spots per milacre increased with the seeding rate. The Kelly Burn was seeded on July 14, 1971, 2 days before summer showers began. Schubert (1974) recommends that direct seeding in the Southwest be done in late June or early July, just before the beginning of summer rains, to minimize the period seeds are susceptible to rodent and bird depredation.

Rattle Burn Experiment

Because of lessons learned from the Kelly Burn experiment in 1971, only seed-spot and broadcast-and-rake treatments at rates of 4 and 8 pounds of seed per acre were tested on the Rattle Burn in 1972. In addition, three frost-heaving "retardants"—gypsum (calcium sulfate), sodium tetraphosphate, and coarse sand—were tested for their capacity to reduce frost heaving of seedlings, and for their interaction with seeding method. Coarse sand was applied as a 0.5-inch layer over the seed spots only; it was impractical to cover an entire broadcast-and-rake subplot. There were 8 replications of the 14 treatments, each represented by 1 rectangular milacre subplot.

On designated subplots, either gypsum or sodium tetraphosphate were added to the surface 1 inch of soil at rates of 1 percent and 0.5 percent, respectively. Seeds of local origin, but from a different seed lot than that used in the Kelly Burn experiment, were sown by the prescribed methods and rates on July 6, 1972. Summer rainfall began 10 days later.

The measures used to retard frost heaving and application rates employed were those found to be most promising and nontoxic in concurrent studies by Heidmann and Thorud (1976). Gypsum lowers the freezing point of soil water, while sodium tetraphosphate disperses the colloidal fraction of the soil. Coarse sand is thought to disrupt the migration of water to the soil surface to form the ice lenses responsible for heaving.

General

All plots were examined for emerging and dead seedlings at weekly intervals during the germination period, and for dead seedlings at intervals of approximately 1 month during 2 growing seasons. Causes of mortality were noted when possible.

The rate and completeness of germination were incorporated in "speed of emergence," a parameter adapted from Maguire's (1962) "speed of germination." Here speed of emergence (SE) is defined as: SE $= \Sigma$ number new emerging seedlings/number days from beginning of rainfall. Speed of emergence was calculated for each inventory and summed over the germination period. A higher value reflects earlier emergence of a large number of seedlings. Percent stocking was also calculated; milacre subplots supporting at least one live seedling were considered stocked. On the Rattle Burn experiment, emerging seedlings on three plots were marked with color-coded nails in an attempt to link the date of emergence and fate of individual seedlings.

Results and Discussion

Kelly Burn Experiment

Germination.—Spot seeding resulted in earlier and more complete germination, expressed as speed of emergence and number of seedlings per acre, than either the broadcast-and-rake or broadcast treatments (fig. 1). Emerging seedlings were first noted in seed spots on August 5, 20 days after the beginning of the summer rains. By August 8, germination in seed spots (3,800 seedlings/acre) was considerably more advanced than on broadcast-and-rake subplots (1,350), which in turn was far better than the broadcast treatment (300).

Differences in speed of emergence among the three seeding methods were highly significant. Differences in number of seedlings per acre between the seed-spot and broadcast-and-rake methods were not significant beyond September of the first growing season, however. The broadcast-and-rake and seed-spot methods were similar in terms of percent stocking (fig. 2), but the broadcast method still showed a very low success level.

The differences in speed of emergence and number of seedlings per acre among the three seeding rates were highly significant and linear. The abundance of seedlings germinating early and number of seedlings per acre increased directly with seeding rate. However, the 2-lb/acre rate resulted in an unacceptably small seedling population, even with spot seeding.

The initial success of the seed-spot method, as evidenced by the more rapid and complete germination on the Kelly Burn, can be attributed to the uniform covering and the compaction of soil over the seeds to facilitate transfer of moisture. The slight depression of the seed spot also served to trap rain water. In contrast, seeds broadcast and raked into the soil are covered to variable depths, often too deep or too shallow, and are surrounded by loose soil which limits the transfer of water from soil to seed. Broadcast seeds, which depend on soil washing to cover them sufficiently for germination to occur, may be inadequately covered or washed away. For example, heavy showers in late July 1971, caused some sheet erosion which probably carried away some seed from the broadcast-and-rake and broadcast-seeded subplots.

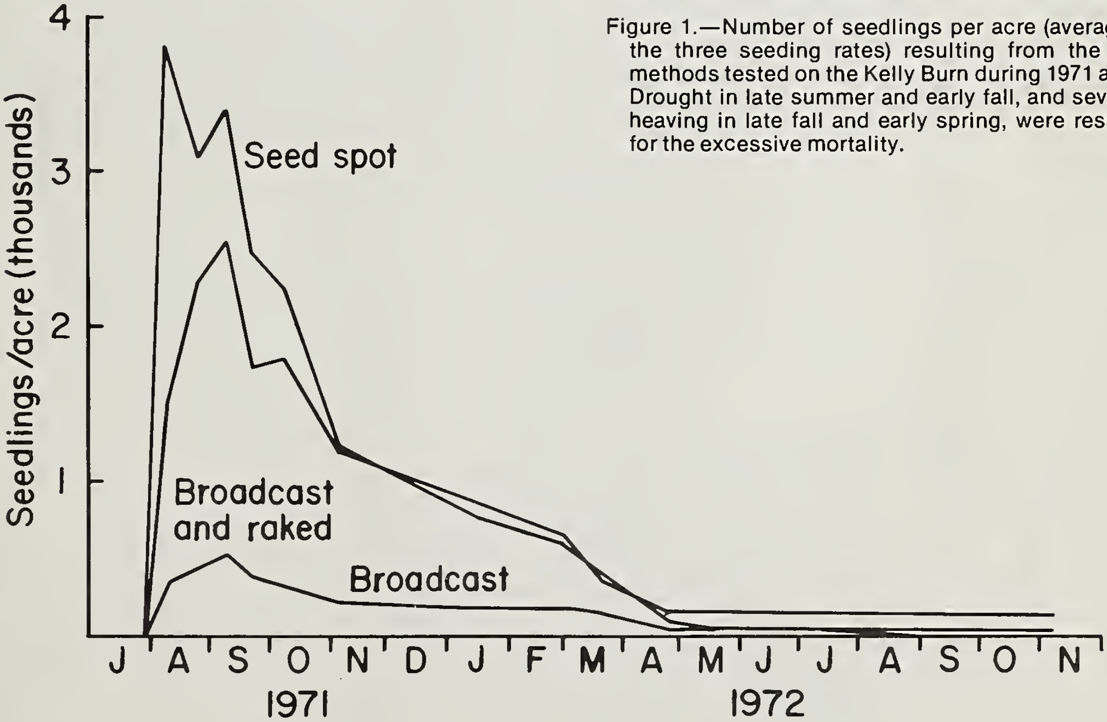

Figure 1.—Number of seedlings per acre (averaged over the three seeding rates) resulting from the seeding methods tested on the Kelly Burn during 1971 and 1972. Drought in late summer and early fall, and severe frost heaving in late fall and early spring, were responsible for the excessive mortality.

Seedling Mortality.—While seed germination was generally good in the seed-spot and broadcast-and-rake treatments, seedling mortality began immediately and involved a number of agents. Drought and frost heaving were the most devastating. By May 1972 there were only a few surviving seedlings on the entire experiment (fig. 1).

Some of the first seedlings to emerge were clipped by rodents or birds, and only their tiny stubs remained to record their emergence. Clipping was not extensive, however, and occurred for only a short period of time.

Erosion and burial caused by heavy showers also accounted for small losses during the germination period when seedlings were small and shallow rooted. Partial burial of seedlings by soil washing did not seem harmful.

Competition from a heavy growth of weeds and grass contributed to some seedling losses to drought during the summer when rainfall was sparse for 1- to 2-week periods, and for heavier losses during September and early October when rainfall declined (fig. 1).

The greatest seedling loss, however, was caused by frost heaving during late fall and early spring (fig. 1). By July 1972, after 2 periods of frost heaving and a severe spring drought, only 10 seedlings were alive on the entire experiment. These were concentrated on a part of the study area where a few dead snags provided partial shade. All seedlings, regardless of age or method of seeding, appeared to be equally susceptible to frost heaving. Pine seedlings whose deaths were ascribed to frost heaving either lay on the ground partly uprooted, remained upright but considerably raised, or were broken off at the root collar. Some seedlings survived, although they were raised a half-inch or more. Some seedlings listed as dead from drought may have died from injuries inflicted by heaving stresses on the root collar and root system.

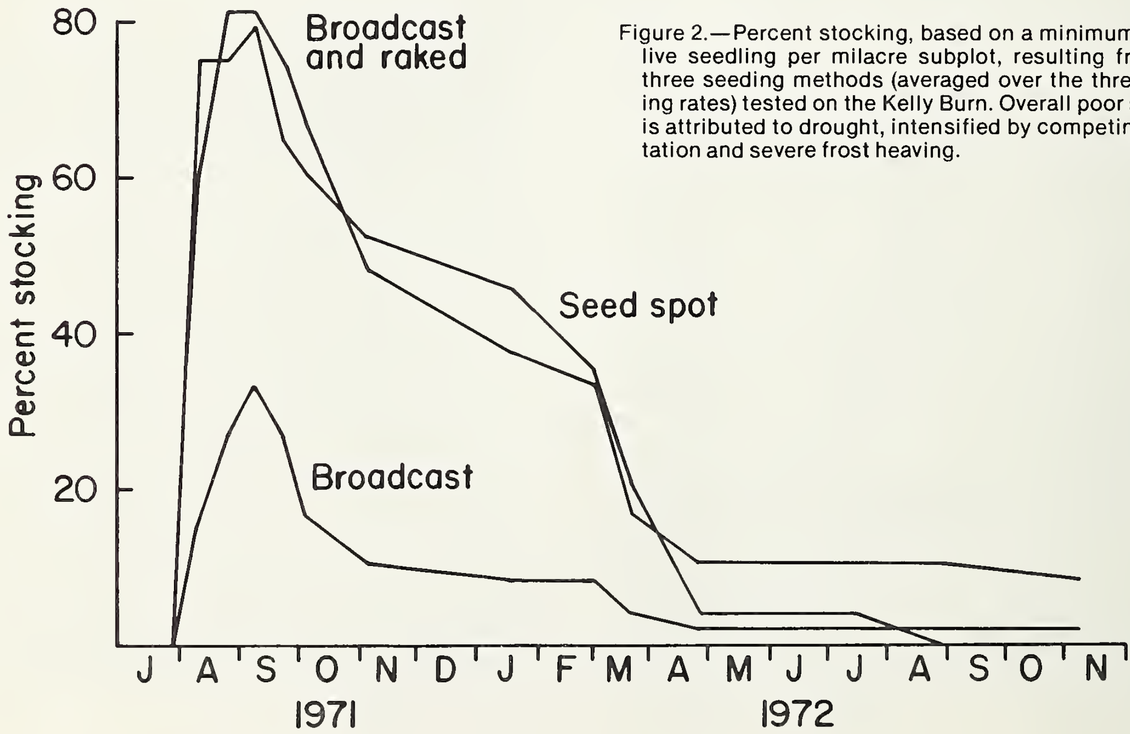

Figure 2.—Percent stocking, based on a minimum of one live seedling per milacre subplot, resulting from the three seeding methods (averaged over the three seeding rates) tested on the Kelly Burn. Overall poor survival is attributed to drought, intensified by competing vegetation and severe frost heaving.

Rattle Burn Experiment

Applying sodium tetraphosphate to the soil prior to seeding significantly depressed speed of emergence and number of seedlings (table 1). Gypsum was also inhibitory in some instances, but the effect was variable and may have been due to chance. Germination and number of seedlings were highest on subplots receiving no chemicals and on seed spots covered with sand. The sand acted as a mulch during the summer, but most of it was washed away during heavy rains in October 1972.

Depressed germination caused by sodium tetraphosphate and possibly gypsum was unexpected since these compounds were found to be nontoxic at the same concentrations in the laboratory (Heidmann and Thorud 1976). The soils were similar in the two cases: a fine sandy loam on the Rattle Burn compared to a fine silica sand used in the laboratory tests. A possible explanation for the observed toxicity may involve fire-induced soil water repellency and its effect on soil cation exchange capacity.

Germination.—The seed-spot method was clearly superior in speed of emergence and number of seedlings (table 1, fig. 3). Following the onset of summer showers on July 16, numerous seedlings were apparent in seed spots by July 25 compared

Table 1.--Speed of emergence (SE)[1] and number of seedlings per acre resulting from the two seeding methods and two seeding rates, tested on the Rattle Burn in 1972 and 1973

Seeding method and frost-heaving retardant	Speed of emergence		Seedlings/acre (Nov. 1, 1973)	
	4 lb/acre	8 lb/acre	4 lb/acre	8 lb/acre
			- - *No.* - -	
SEED SPOT:				
None (control)	0.360	0.895	4,125	8,125
Gypsum	.343	.371	2,500	3,125
Sodium tetraphosphate	.296	.263	1,625	2,625
Sand	.471	.860	2,750	8,875
BROADCAST AND RAKE:				
None (control)	.064	.108	750	1,500
Gypsum	.035	.158	750	2,625
Sodium tetraphosphate	.017	.036	250	625

[1]SE = Σ number new emerging seedlings/number days from beginning of rainfall.

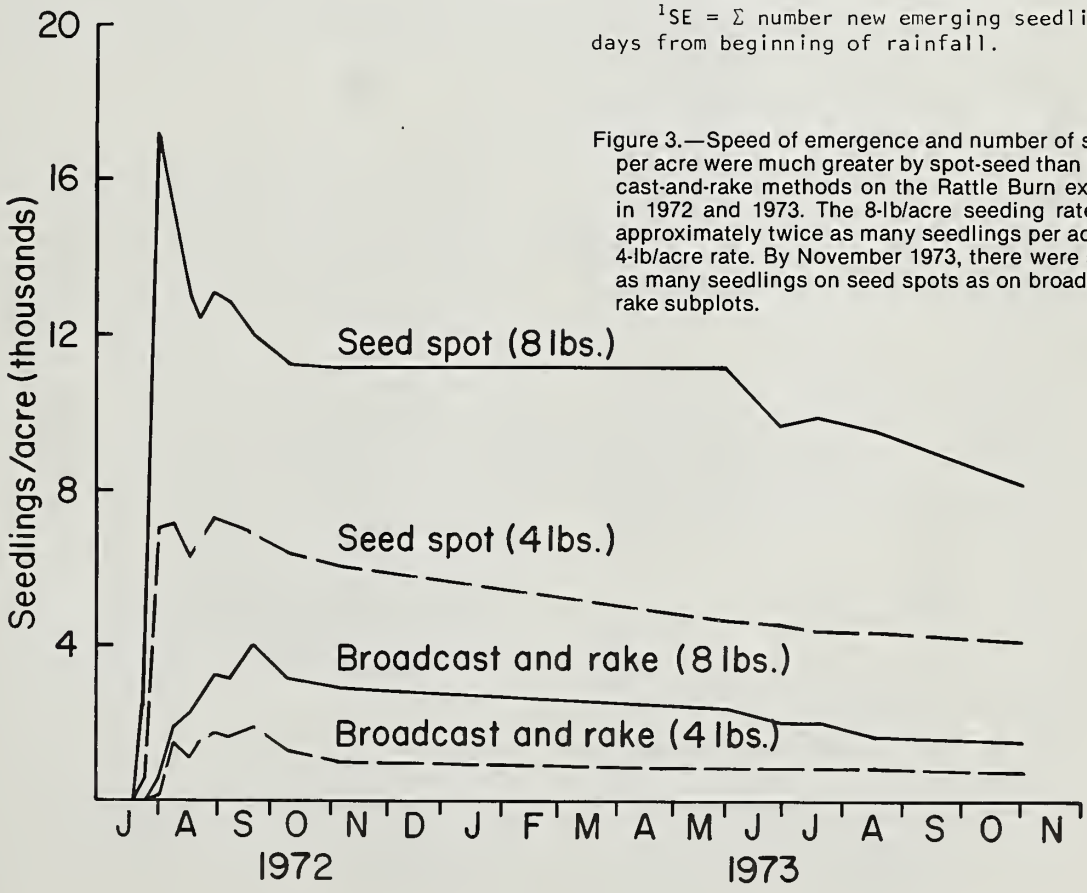

Figure 3.—Speed of emergence and number of seedlings per acre were much greater by spot-seed than by broadcast-and-rake methods on the Rattle Burn experiment in 1972 and 1973. The 8-lb/acre seeding rate yielded approximately twice as many seedlings per acre as the 4-lb/acre rate. By November 1973, there were 5.4 times as many seedlings on seed spots as on broadcast-and-rake subplots.

to only a few seedlings on broadcast-and-rake subplots by July 31. At the end of 2 growing seasons, spot-seeded plots had 5.4 times as many seedlings per acre (with no frost-heaving control) as broadcast-and-rake plots (table 1). The 8-lb/acre seeding rate yielded approximately twice as many seedlings, by either seeding method, as the 4-lb/acre rate. Percent stocking quickly rose to 100 percent on seed spots and stayed at that level through 2 growing seasons for the 8-lb/acre rate; the 4-lb/acre rate dropped to 75 percent stocking (fig. 4). The broadcast-and-rake method yielded a more scattered distribution of seedlings—62.5 and 50 percent stocking, respectively—after 2 growing seasons.

Percent stocking can be misleading when not used in conjunction with number of seedlings per acre. It is a measure of seedling distribution. Many stocked broadcast-and-rake milacres had only a single live seedling, while most spot-seeded milacres supported several seedlings.

Differences in germination between the two seeding methods were primarily due to the presence of hydrophobic (water-repellent) soils resulting from the fire. Most of the water repellency appeared to be located in the surface inch of soil. Thus depressions made for seed spots penetrated the layer, while raking did not. Water penetrated in seed spots, like small holes in a sheet of plastic, whereas excessive runoff was observed from broadcast-and-rake subplots. Immediately following a rain, dry soil was found at a depth of 0.5 inch. Part of the difference in success of the two methods may also be attributed to seed losses from erosion.

Best results from broadcast-and-rake seeding were observed in locations where soil was considerably disturbed. Apparently, mechanical soil disturbance is needed after eliminating competing vegetation and exposing mineral soil by fire.

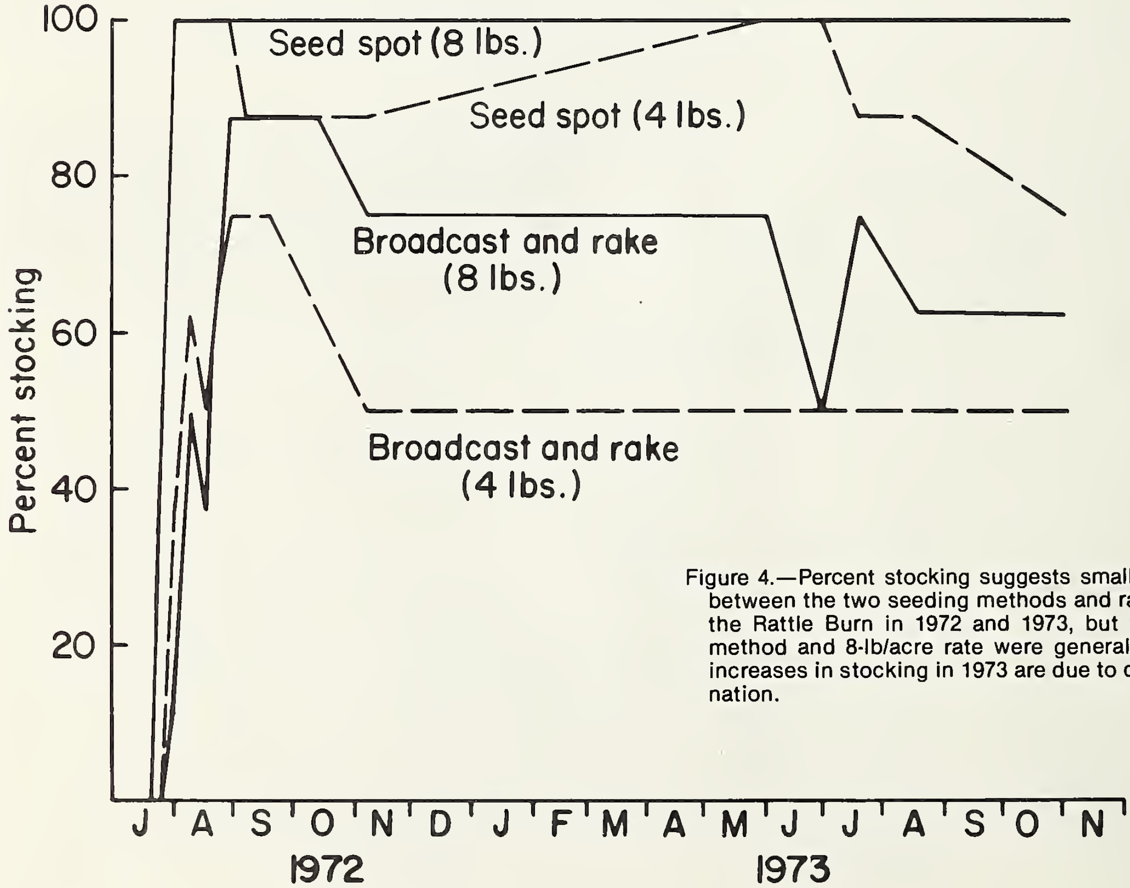

Figure 4.—Percent stocking suggests smaller differences between the two seeding methods and rates tested on the Rattle Burn in 1972 and 1973, but the seed-spot method and 8-lb/acre rate were generally better. The increases in stocking in 1973 are due to delayed germination.

Seedling Mortality.—Differences in number of seedlings and percent stocking at the end of 2 growing seasons were primarily due to differential germination, since mortality was similar in both seed methods (fig. 3). Mortality, not excessive in either method, was due to clipping and drought shortly after germination. More losses due to water stress were also incurred during the fall drought in September and October. A heavy snowpack which developed early and persisted late into the spring of 1973 protected the seedlings from frost heaving, normally prevalent during the first winter. Dead trees on the experimental area, which provided overhead shade to preserve the snowpack, also reduced the severity of day-night thawing and freezing cycles. Losses of 2-year-old seedlings to frost heaving during the winter of 1973-74 were small despite saturated soil conditions conducive to heaving.

Comparisons of seedling survival in relation to germination date was not valid because too few seedlings germinated late in the season, compared to those germinating early. For germination dates within the period July 25 to August 16, represented by adequate numbers of seedlings, survival differences were not significant on June 1, 1973. Larson (1961) found that seedlings germinating early (July) had better survival the following summer than seedlings starting late (August, September).

General

These results demonstrated that the outcome of direct seeding may be extremely variable, depending on the net influence of several factors affecting seed germination and seedling survival. The initial number of seedlings depends mainly upon seeding method and rate, soils, seed predation by rodents and birds, and moisture stress.

While it is not too difficult to obtain satisfactory seed germination, the principal problems limiting success are in keeping those seedlings alive. The seeding method has little effect on such seedling mortality factors as rodent and bird depredation, moisture stress (intensified by competition), browsing, and frost heaving—which can totally eliminate a sizable seedling population. For these reasons, it is extremely difficult to estimate the size of an initial population of seedlings needed to yield a minimum number of surviving seedlings after a specified period of time.

The cost of direct seeding on seed spots, with a minimum rate of 4 pounds of seed per acre, is comparable to planting. Assuming the operational costs of spot seeding at the 4-lb/acre rate and planting 680 seedlings per acre are similar, the current per-acre costs for seed and planting stock are $79 and $33, respectively.[2] Considering the cost comparability, planting is favored because it avoids or seriously reduces the problems with frost heaving, rodent and bird depredation, and variable stocking. Containerized tree seedlings can be raised in as little time as 4 months.

This discussion discourages direct seeding on recent burns, in comparison to planting, at least until solutions are found for the problems of poor seedling survival and variable stocking. Direct seeding, as applied here, is an artificial regeneration method and should be distinguished from natural seeding, which is encouraged by regeneration cuttings and supplemental site preparation. The latter method has good potential for timely, inexpensive regeneration, and is receiving more attention.

Conclusions and Recommendations

The spot-seeding method proved to be consistently better than the broadcast-and-rake method with regard to speed and completeness of germination, and number of seedlings per acre. Distribution of seedlings was similar. The broadcast method was a failure due to slow, incomplete germination and to low numbers of seedlings.

Because of high cost and variability of results, direct seeding has limited potential as a regeneration method on recent burns. Seed should be carefully applied in spots at a rate of at least 4 pounds of seed per acre. Only the best sites should be selected for seeding; clay soils should be avoided. If planting stock from seed of local origin (Schubert and Pitcher 1973) is available, it should be utilized on burns in preference to seeding. When direct seeding fails, time is lost, and it may be necessary to invest more money in site preparation prior to planting.

[2]Personal communication with Dr. John A. Pitcher, U.S. Forest Service, Region 3, Albuquerque, New Mexico. Seed costs are high because Working Capital Fund overhead costs are included. Using commercially collected seed, the cost of 4 pounds of seed (about $32) is still comparable with planting stock on a per-acre basis.

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