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Engelmann Spruce, Lodgepole Pine and Subalpine Fir Seed Germination Success on Ashbed Conditions

Abstract

In the lodgepole pine, Engelmann spruce, and subalpine fir association, pine seedlings commonly dominate immediately after fire disturbances. To test if this outcome is a response to seed availability or environmental conditions, Engelmann spruce, lodgepole pine, and subalpine fir seeds were germinated under controlled laboratory conditions. Germination beds consisted of ash covered seedbeds and sterile media moistened with one of five different concentrations of soluble ion leachates decanted from ash. One half of the seeds for each treatment were cold stratified (a pregermination treatment where moist seeds are exposed to near freezing temperatures) on one of the five germination seedbeds, while the other half of the seeds were first cold stratified on moist filter paper and then transferred to germination seedbeds. We found that all three species are capable of germinating on burned seedbeds. Lodgepole pine was unaffected by stratification or treatment procedures used. Significant differences in final germination percentages did exist among the five treatments for spruce and fir but these differences were not consistent with relative differences in specific conductance or ion concentrations. Spruce seed germination was significantly improved when seeds were stratified on ashbed conditions. Our results clearly show that the chemical conditions of the ashbed do not favor pine establishment when all three species are subjected to similar conditions.

Introduction

Combustion residue of ash, charred material, and charcoal remain on the soil surface subsequent to the passage of a forest fire. Tree seed germination success is highly influenced by the physical, chemical, and biological properties of this seedbed medium (Thrupp 1939, Tryon 1948, deKeijzer and Hermann 1966, Woodard 1983). The effect of combustion residue on tree seed germination varies by tree species tested and between experiments involving the same species (deKeijzer and Hermann 1966, Woodard 1983). Conflicting results can often be attributed to the research environment (laboratory versus field), type of residue used (ion rich ash versus inert charcoal), or to sampling designs or procedures used. Most previous studies have failed to test the ion concentration effects of ash during the stratification phase of germination (deKeijzer and Hermann 1966, Woodard 1983). The intake of water versus soluble ion (particularly cations) may significantly affect the germination success of certain tree species by affecting the water potential gradient between the leachate and the endosperms at the integument or, perhaps, the enzymatic activity required for cell enlargement and the eventual emergence of the radicle.

The objectives of this study were to: (1) verify the results of Woodard (1983), who showed that

lodgepole pine (*Pinus contorta* Dougl.) and Engelmann spruce (*Picea engelmannii* Parry) seed germination was reduced by the soluble chemicals in the combustion residue, although the effect was only statistically significant for pine, and (2) to determine the stage during the germination process when an effect, if any, occurred. In addition, this study tests the chemical effects of combustion residue on subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) seed germination. The information gained from this study might also answer the ecological question of why, after fire, lodgepole pine seedlings dominate on sites once occupied by spruce, fir, and pine. Is it principally due to the high concentration of available pine seed which is released from serotinous cones or to the physical and chemical conditions which exist as a direct or indirect result of burning?

Study design and methods

Lodgepole pine, Engelmann spruce, and subalpine fir seeds were stratified under two different regimes and germinated under controlled laboratory conditions on five different substrates: (1) 30 ml washed combustion residue placed on filter paper and moistened with 80 ml of distilled water (black body effect), (2) filter paper moistened with 80 ml of dilute combustion residue

leachate (4 parts of distilled water: 1 part combustion residue), (3) filter paper moistened with 80 ml of a medium strength combustion residue leachate (2:1), (4) filter paper moistened with 80 ml of a concentrated combustion residue leachate (1:1) and, (5) 30 ml of untreated combustion residue placed on filter paper and moistened with 80 ml of distilled water. The control treatment consisted of germinating seeds of all three species on filter paper moistened with 80 ml of distilled water. The physical conditions common to all treatments consisted of closed 150 mm diameter x 15 mm high petri dishes lined with one layer of Kimpac (a multilayered absorbent batting; marketed by Seedburo Equipment Co.) and covered with two sheets of Whatman No. 1 white filter paper.

One hundred seeds were sown to 20 individual petri dishes for each species. The seeds in half of the dishes ($n=1000$ seeds; 10 reps of 100 seeds) and the control treatment were cold stratified on Whatman No. 1 white filter paper and Kimpac moistened with 80 ml of distilled water (Stratification Treatment 1), while the remaining seeds were cold stratified on the same substrates which would eventually serve as germination beds (Stratification Treatment 2). Stratification consisted of cold storing (4°C) seeds in closed petri dishes in sealed plastic bags in the absence of light for 21 days (ISTA 1976). At the conclusion of the stratification treatment, seeds in Stratification Treatment 1 were transferred to their appropriate germination substrates prior to transfer to the germination chamber. Seeds processed under Stratification Treatment 2 were transferred directly to the germination chamber.

Seedlots¹ were cleaned of debris and light seeds using a North Dakota blower and counted into each dish using an electronic seed counting device. All seeds were x-rayed prior to treatment in an attempt to identify the number of partially full seeds per seedlots thus allowing for correction of final germination percentages.

¹Engelmann spruce (seedlot number: DB 21-10-5-76-Se) and lodgepole pine (DR 36-12-5-77Pl) seed were provided by the Pine Ridge Forest Nursery, Alberta, Div. of Energy and Natural Resource, Smoky Lake, Alberta; while the subalpine fir seedlot (a mixture of seedlots 2504 and 5107) was provided by the Ministry of Forests and Lands, Seed Center, British Columbia Ministry of Forests and Lands, Duncan, B.C.

Combustion residue seedbeds and leachates were prepared from preburn organic (L, F, H) materials collected from several mixed pine/spruce/fir soils near Hinton, Alberta ($53^{\circ}24'N$, $117^{\circ}37'W$). A composite sample of material from all sites was oven-dried at 70°C and burned with the aid of a propane torch under ambient conditions until glowing and smouldering combustion had ceased. The residue consisted of gray ash and chips of charcoal. Leachates were prepared by soaking combustion residue in various amounts of distilled water for seven days prior to suctioning the liquids through a Buchner funnel lined with a Whatman No. 42 filter paper (deKeijzer and Hermann 1966). The washed combustion residue was prepared by rinsing the residue remaining from the preparation of the dilute leachate solution with an additional volume of distilled water equal to 15 times the volume of combustion residue initially used.

Measurements of total ions using electrical conductivity at 22°C and soluble ion concentrations for Ca, Mg, Na, K, S, P using Inductively Coupled Plasma Analysis were determined from solutions of each treatment. The solution used to measure the conductivity and soluble ions present in the concentrated combustion residue was prepared by mixing enough residue with 200 ml of distilled water to make a thick paste. After soaking this mixture for 24 hours the liquid was suctioned through a Buchner funnel lined with Whatman No. 42 filter paper following procedures described by deKeijzer and Hermann (1966). The final rinse from the washed residue treatment and extracts from the other residue leachates were used to test for electrical conductivity and soluble ions. Measurements of specific conductance were performed immediately. Soluble ion concentrations were determined from 20 ml samples of solutions which were preserved for analysis by adding 0.75 ml of concentrated HNO_3 in the samples and then refrigerating (at 4°C) until tests could be performed by the staff at the Northern Forestry Centre, Canadian Forestry Service, Edmonton. The pH and conductivity of the distilled water used in this experiment was 6.9 and 0.005 mS/cm, respectively.

Germination tests were carried out in a controlled environment cabinet following accepted procedures (ISTA 1976). Lodgepole pine and Engelmann spruce were subjected to 8 hours of light at 30°C followed by 16 hours of darkness

at 20°C for a period of 21 days. Subalpine fir was germinated under the same time/temperature/light regime but for a period of 28 days. Light levels in the cabinet ranged from 3,000 lx (unobstructed) to 1500 lx in the center of stacked dishes enclosed in clear plastic bags. Dish positions within stacks and the location of stacks within bags were changed daily in an attempt to eliminate the effect of dish position on germination success. Humidity and moisture regimes were considered favorable for germination success because there was no need to add fluids to any of the treatment dishes throughout the duration of the experiment. Dishes were checked at two-day intervals. Germinants were counted and removed from the dishes when the length of the radicle exceeded four times the length of the seed (ISTA 1976).

The effects of treatment (5 levels), stratification (2 levels) and their interactions were tested by two-way ANOVA. The control group was not included in this analysis due to absence of a control for stratification method 2. Differences among eleven treatment groups (treatment x stratification + control) were tested by one-way ANOVA. To make the variances homogenous, the data were transformed using the arc sin of the square root of the proportion of seeds that germinated before analysis (Steel and Torrie 1980). The Tukey-HSD procedure was used to compare individual means.

Results

Repeated washing of ash with distilled water removed most soluble ions and reduced the specific conductance (Table 1). The highest con-

ductivity readings and ion concentrations were found in solutions prepared from untreated ash or in the concentrated combustion residue leachate while the lowest values were determined for the washed residue treatment. As expected, the concentrated residue and leachate have far more ions than washed ash or diluted solutions. The trends in conductivity and ion concentrations are similar to those reported in previous literature (Muri 1955, Woodard 1983). However, in comparing these results with those from prior studies, the type of plant material ashed and the methods used to obtain these values must be considered.

Total germination was highest for lodgepole pine, followed by spruce and then by fir (Figure 1). The average germination success for each treatment was based on 10 replications of 100 seeds for each species. Information gained by x-raying seeds prior to treatment did not improve the accuracy of these results as we had anticipated. Although we could distinguish between full and partially full seeds on x-rays, we were not able to identify all viable seeds accurately. In addition, corrections for partially full seeds did not measurably enhance differences between means by reducing standard errors. Therefore, results were analyzed on the basis of total germination success for each dish of 100 seeds rather than the number of germinants per number of full seeds.

Lodgepole pine germination success (89%; S.E. = 2%) did not vary significantly among treatments ($p=0.227$) or stratification procedure ($p=0.474$). This result was confirmed by the one-way ANOVA procedure. For spruce and fir, where the S.E. was 2 percent for both species, we found

TABLE 1. Electrical conductivity and concentration of some specific ions present in treatment solutions and substrates.

Treatment	Electrical Conductivity at 22°C (mS/cm)	Elements (ppm)					
		Ca	Mg	Na	K	S	P
control	0.200	23	3	15	2	10	0.1
washed residue	0.075	10	2	2	9	1	1.0
dilute leachate	0.990	160	19	8	131	156	0.2
medium leachate	1.530	274	31	15	236	296	0.2
conc. leachate	2.490	526	55	26	346	513	0.3
conc. residue	2.020	878	92	36	541	743	0.4

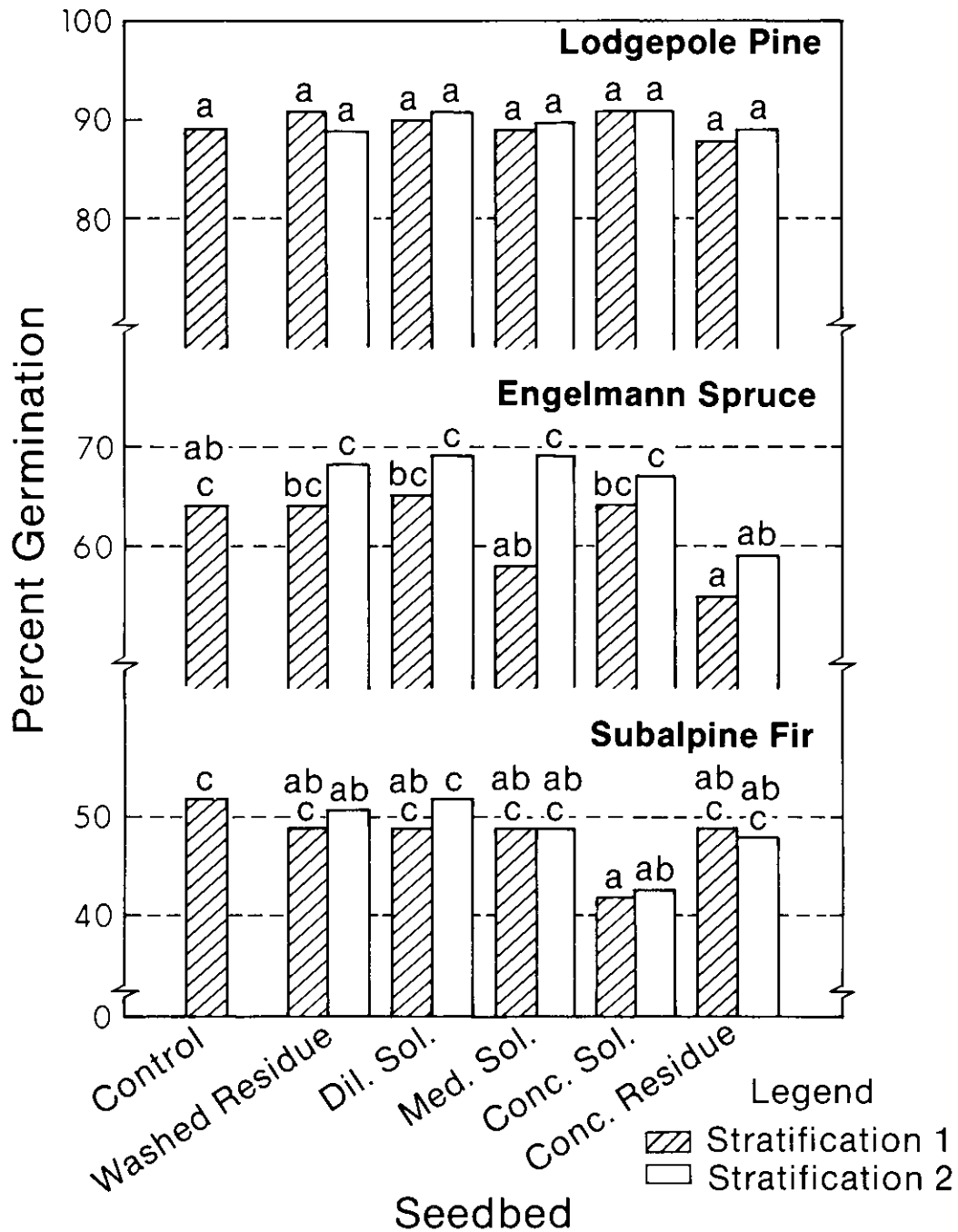


Figure 1. Percent germination by stratification treatment for spruce, pine, and fir seeds sown to a control and five different seedbeds (washed ash residue, concentrated ash residue, and white filter paper moistened with dilute, medium and concentrated ash leachate solutions). Among seedbeds, means identified by the same letter are not significantly different at the 5 percent level.

significant differences among treatments ($p < 0.001$). Stratifying seeds on ash or on substrates moistened with ash leachates significantly and consistently increased spruce germination by 5 percent on average, for all treatments ($p < 0.001$) while for fir the increase was 2 percent but this effect was not significant ($p = 0.234$). The interaction between treatments and stratification methods was not significant for spruce ($p = 0.190$) or fir ($p = 0.853$), indicating the differences between stratification method were constant across the treatments.

The physical and chemical characteristics of the ash or the leachates from the ash had no impact on rate of germination. Well over 90 percent of the total germination for a given species occurred on the same sample day as controls regardless of treatment. Lodgepole pine germinated the fastest (9 days), followed by Engelmann spruce (11 days), and subalpine fir (22 days).

Discussion

Statistically significant variation in final germination percentages among treatments do exist for spruce and fir but these results were not consistent with, or directly related to, ion concentrations or conductivity levels determined for leachate solutions or ashbeds. The concentrated leachate solution did significantly reduce the mean total germination for the subalpine fir seedlot when compared to control values, but this response is not consistent with results of other treatments. Also, the fact that seeds of all three species tested germinated better when stratified under the influence of ash or ash leachate further strengthens the conclusion that ash or its characteristics has no detrimental physical or chemical effect on the total germination.

The results of this work are consistent with some previously published data which support the conclusion that ashbeds and their chemical constituents have no effect on tree seed germination success [Fisher 1935 (lodgepole pine), Tarrant 1954 (Douglas-fir), Muri 1955 (Engelmann spruce, subalpine fir), deKeijzer and Hermann 1966 (Douglas-fir), Jarvis 1966 (black spruce, white spruce and jack pine), Sims 1968 (jack pine) and Woodard 1983 (Engelmann spruce)]. However, our results conflict with results from other studies which found ash materials inhibit

[Fabricius 1929 (pine, spruce, fir), Tryon 1948 (white pine), Gayle and Gilgan 1951 (lodgepole pine, Douglas-fir), Ahlgren 1959 (black spruce)] or promote tree seed germination [Fisher 1935 (western white pine, Douglas-fir, ponderosa pine, white fir), Herman and Chilcote 1965 (Douglas-fir), Woodard 1983 (lodgepole pine)]. It is difficult to explain the inconsistencies in published results largely because of variations in experimental design and methods, perhaps genetic differences in seedlots, types of residues used, and the limited number of studies pertaining to the species tested. Many previous studies have shown that all of the above factors can influence tree seed germination success. For example, Jeglum (1979) reported that black spruce seed germination on burned feather moss (*Pleurozium schreberi* [Brid.] Mitt.) was increased, decreased, or unaffected depending on frequency of watering. Hence, the justification for standard seed testing procedures (ISTA 1976). In this study, all seeds were subjected to identical conditions and the procedures followed are currently accepted by the International Seed Testing Association. Therefore, our approach eliminates most of the variation in environmental conditions which would impact on germination success and confuse the interpretation of our results.

Conclusions

Lodgepole pine seed germination was not significantly affected by the physical or chemical constituents of ash or leachates from ash used in this study. Engelmann spruce and subalpine fir seed germination was affected, but the effect was not consistent or directly related to changes in specific conductance and ion concentrations and the magnitude of these effects was not large enough to be considered ecologically significant. The rate at which germination occurred was not affected by ash or leachates of ash. Although the results of this experiment are only specific to the seedlots used, they do suggest seedbeds covered with ash similar to that used in this study do not favor any one of the three species tested when germination conditions are identical and currently accepted germination procedures are used. Seeds of all species tested were capable of germinating on burned-over seedbeds without reducing the speed of germination or the total number of germinants.

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