USING SOIL ISLAND PLANTINGS AS DISPERSAL VECTORS IN LARGE AREA COPPER TAILINGS REFORESTATION[1]

George Scherer and Richard Everett[2]

Abstract: The Wenatchee National Forest undertook the reforestation of the 80 acre (35 ha) Holden copper mine tailings of Washington State in 1989 by using 20, one-fourth acre, triangular shaped soil islands as a source of plant propagules targeted for gravel-covered tailings surfaces. The islands were constructed of soil and surface litter transported from a nearby gravel pit, and planted with four species of conifer seedlings, the shrub Sitka alder (*Alnus sinuata*) and eight species of grasses. Conifer and alder seedlings were also planted in graveled covered tailings with amendments. Since reproductive status of the conifers would not occur for several years, this propagule vector hypothesis was tested by measuring the distances traveled onto the tailings surface by grass seeds. The number of grass shoots established in four treatment blocks in target plots downwind from the soil island source plantings was also determined. After 36 months, grass seed had migrated to a distance of 32 feet (11 m) from the soil island source. Grass shoots were present within 10 feet (3 m) downwind of the soil island, the most frequent being Mountain brome (*Bromus marginatus*). Among the tree species, lodgepole pine (*Pinus contorta*) and Sitka alder grew an average of 6 inches (15-16 cm) after 40 months on the soil islands but somewhat less on the tailing surface. By the third growing season, the only tree species in reproductive condition on the tailings was alder. The soil-island technique is successful for grass dispersal and may have potential for conifer and alder migration.

Additional Key Words: mine reforestation, *Alnus sinuata*, *Bromus marginatus*, *Pinus contorta*, Holden mine.

Introduction

The rehabilitation of the abandoned Holden copper mine tailings has been a compelling issue since its 1957 closure, due to the high scenic value and intense recreational use of the Railroad Creek valley (Huyck and Reganold 1989). This valley is a principle gateway route to the Glacier Peak Wilderness area and the site of Holden Village retreat center, attracting six thousand visitors each summer season (CRD 1993). During 20 years of operation, 8 million tons of tailings were created that cover nearly 80 acres (35 ha) to a height of 150 feet (45 m) adjacent to Railroad Creek (ORB 1975). The uniform, silt-like, particle size of the tailings material creates airborne dust pollution (Thorsen 1970). Previous attempts to establish vegetation cover on the tailings piles were difficult due to the persistent drying and wind erosion and the harsh acid metallic chemistry of the substrate (McDonald and Shirts 1978).

In 1991, a 6 inch (15 cm) gravel layer was placed over the tailings surfaces to reduce water and wind erosion (Dauble et al. 1989). Revegetation of the graveled spoils was undertaken to blend the tailings piles with the adjacent forest and restore the scenic quality of the area (ORB 1975). Unfortunately, the gravel layer is nutrient poor and provides a harsh plant environment (Kramer et al. 1998). There was, however, a minimal amount of topsoil available from the gravel-pit surface materials. Dauble, et al. (1989) recommended the placement of 20 small soil islands on the tailings surface that would serve as initial planting spots from which propagules would spread to the surrounding gravel surface over time. This paper evaluates that technique by examining planting success on soil islands, seed dispersal from soil islands, and plant establishment and growth on the adjacent gravel covered tailings.

Methods and Materials

Site

The Holden Mine tailings are located at an elevation of 3,200 feet (1,000 meters) in the central Cascade Mountains of Washington State (Figure 1). The mine site is on steep sideslopes of a glaciated valley in the *Tsuga heterophylla* (western hemlock) zone of the Northern Cascades physiographic province (Franklin and Dyrness 1973). Average annual precipitation is about 35 inches (900 mm) with most precipitation occurring between November and March as snowfall. Summer temperatures are often greater than 85 F (30° C).

---

[1]Paper presented at the 1998 National Meeting of the American Society for Surface Mining and Reclamation, St. Louis, Missouri, May 17-22, 1998.

[2]George Scherer is Biological Technician, and Richard Everett is Science Team Leader, USDA-Forestry Science Lab, 1133 Western Ave., Wenatchee, WA 98801

Proceedings America Society of Mining and Reclamation, 1998 pp 78-84
DOI: 10.21000/JASMR98010078

https://doi.org/10.21000/JASMR98010078

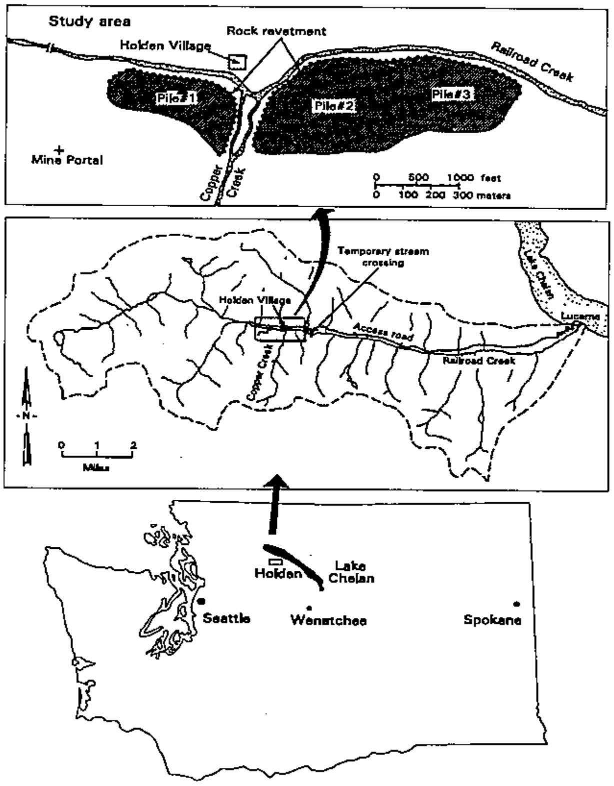

Figure 1. Location of Holden Copper Mine tailings in Washington State with depiction of soil islands on tailings surface.

Mineralogy of the mine ore material consists largely of chalcopyrite, with smaller amounts of magnetite, quartz, pyrrhotite, pyrite, sphalerite, galena, molybdenite, silver and gold (Youngberg and Wilson 1952). The metallic ore was crushed, ground, and processed by a flotation method; suspended waste material was allowed to precipitate in holding ponds producing the tailings deposits (ORB 1975). The tailings are acidic (pH ranges from 2.6 to 5.4) and the silt-sized material is subject to wind erosion during dry summer months. Nutrient content, selected metals concentrations, and pH of tailings in the study are shown in Table 1.

Ameliorative Treatments

Twenty soil islands were constructed in 1990-91. Figure 2 shows construction details. In addition to the first layer—a lime-rock barrier placed into excavated tailings—about 12 inches (30 cm) of local forest topsoil was added. The next layer was 4 inches (10 cm) of gravel. Finally, pieces of logs, tree fall, branches and forest litter were placed in clusters and piles over the surface of the soil island. Conifer and alder seedlings were planted among this surface detritus for protection from extreme heat and wind.

Random block treatment plots were constructed to test the potential of species planted on soil islands to establish and grow, and then migrate to the gravel-covered mine tailings surfaces. One set of plots contained a 4-by-8 matrix of selected native conifers and alder planted in drilled holes on the mine tailings surface and soil islands. Another set of plots consisted of eight grass species planted on six soil islands just upwind of treatment blocks. The grasses were expected to flower and seed within the first two seasons, several years before the conifers and alder, and thereby more quickly demonstrate soil island capability as a propagule vector site.

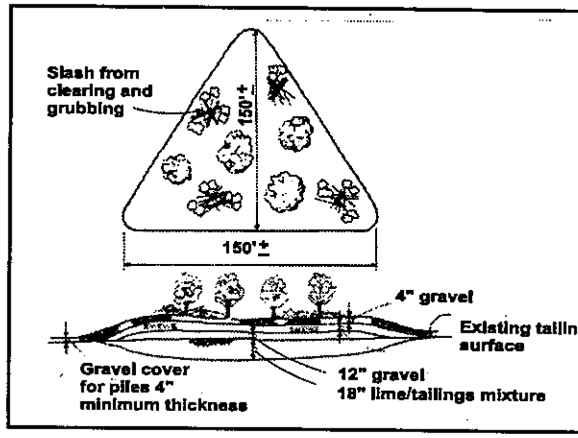

Figure 2. Plan view and surface profile of vegetation soil island on Holden Copper Mine tailings.

Alder/Conifer Treatments

In 1992 we planted tree seedlings on eight of the soil islands and on the adjacent gravel-covered tailings surface. Four treatments, each with two replications, were applied to the planting holes for conifers and alder in the gravel-covered tailings adjacent to the eight soil islands. These were: 1) a commercial compost mixture at 1 lb/ hole (454 grams); 2) compost + lime at 2 oz/hole (56 grams) (a rate of 12 T/ha); 3) compost + fertilizer (milorganite) at about 4 oz/hole (100 gr) (or about 440 kg/ha); and 4) planting holes with no treatment. The compost was a commercial product called EKO[3] that was 66% solids with 2.2% N (total), 0.5% total P and 0.8% K. The commercial fertilizer consisted of a ground sewage sludge product ("Milorganite") containing 6% total N, 2% P- P_2O_5, zero K, and 4% Fe.

[3] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the USDA Forest Service of any product or service.

Table 1. Substrate and soil properties, Holden copper mine tailings 1995. Range of values for pH, organic matter (OM), selected nutrients, and metallic elements in gravel covered tailing horizons and soil island material at time of planting.

	N-NO_3 (ug/g)	P-PO_4 (ug/g)	K (ug/g)	Ca (meq/100g)	Mg (meq/100g)	S-SO_4 (ug/g)	Al (ug/g)
Tailing	0.04-2.0	12-31	30-68	0.37-0.78	0.12-0.21	7.1-4.5	74-101
Soil Isl.	0.5-1.1	14-21	30-92	2.0-3.9	0.12-0.38	7.0-7.1	MD
Gravel	.023-.09	0.27-1.8	2.8-9.8	MD	1.3-9.7	2.3-12.8	1.4-8.9
Optimum	5-15	8-20	12-200	3-20	0.75-4.0	6-20	NA
	Fe (ug/g)	**Cu (ug/g)**	**Mn (ug/g)**	**Zn (ug/g)**	**pH**	**% OM**	
Tailing	161-336	4.7-7.7	60-416	9-30	3.2-4.1	MD	
Soil Isl.	25-50	.04-.07	1.1-7.8	0.2-0.5	6.1-6.6	2.4-3.7	
Gravel	3.9-21.3	0.2-3.6	0.7-5.9	.01-5.9	MD	MD	
Optimum	5-30	0.2-2.0	2-10	1-10	6.0-7.0	0.8-2.0	

Notes: MD=missing data value, NA=value not available. Optimum values from Cascade Analytical Laboratory, Wenatchee, WA., database of regional agricultural soil nutrient and mineral properties.

The conifers/alder were planted in a 4-by-8 matrix at 8 foot (2.5 m) spacing. The planting holes were about 10 inches (25 cm) deep by 4 inches (10 cm) diameter and were drilled through the gravel topping into tailings material and into the soil islands. Treatment amendments were added to the tailings backfill that was placed in the hole. Each tree hole was irrigated with about a gallon (3.7 liters) water after hole fill. Tree seedlings were selected randomly from mixed nursery bags for each treatment block. Soil island blocks did not receive planting hole amendments. Tree species were chosen from those native to the adjacent forest that had previously shown some potential to colonize the Holden tailings. The tree species included: ponderosa pine (*Pinus ponderosa*), western white pine (*P. monticola*), lodgepole pine (*P. contorta*), Douglas-fir (*Pseudotsuga menziesii*) and tree/shrub Sitka alder (*Alnus sinuata*).

Grass Plots Treatments

The four treatments on the grass immigration plots included: 1) a commercial N P K fertilizer at 100 lbs/acre (220 kg/ha) of nitrate nitrogen, about 54 lbs/acre (120 kg/ha) each of phosphorous and potassium; 2) a simulated "carbon load" consisting of a commercial straw mat covering of about ½ inch (1 cm) thickness, embedded in plastic mesh; 3) fertilizer + straw; and 4) a block with no treatments. The blocks were 10 by 40 feet (3.2 by 12.5 m) areas. These grass treatment plots were replicated six times.

Seed from eight grass species was broadcast seeded and raked into the surface of the soil island immediately upwind of the treatments blocks from the gravel covered tailings (Figure 3). The grass seed mixture was also raked into the gravel-covered tailings surface just downwind of the treatment blocks to test for establishment on the tailings surface. Grass species were nearby native species believed to be tolerant of summer drought conditions in the Holden area. They were provided by local commercial seed sources. Selected grasses included bluebunch wheat grass (*Agropyron spicatum*), thickspike wheatgrass (*A. dasytachyum*), slender wheatgrass (*A. trachycaulum*), mountain brome (*Bromus marginatus*), western fescue (*Festuca occidentalis*), basin wildrye (*Elymus giganteus*), blue wildrye (*E. glaucus*), and bottlebrush squirreltail (*Sitanion hystrix*).

Data Collection and Analysis

In the conifers/alder study, heights were measured at initial planting and after the fourth growing season. One-way analysis of variance and Kruskal-Wallis rank sum tests were performed to detect differences in growth-height among treatments. For the grass immigration study, individual grass plants were counted in the treatment blocks, soil island, and tailings plantings. Also, grass seed presence was recorded in the treatment blocks at each meter of distance downwind from soil island sources. Significance of differences in plant counts were tested by using Kruskal-Wallis procedures (Systat 1992).

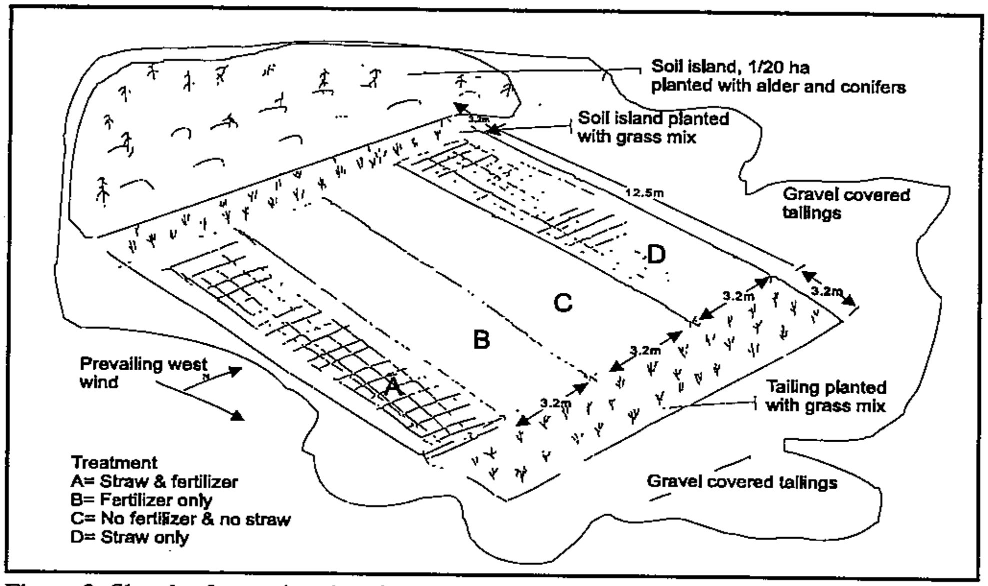

Figure 3. Sketch of grass immigration plots adjacent to soil island planted area with four treatment blocks and gravel covered tailings planted block depicted.

Results and Discussion

Conifers/Alder Growth and Survival

The four conifer species and the alder all successfully established and grew on the soil islands (Figure 4). Lodgepole pine and alder grew best, with average height accumulations of about 6 inches (15-16 cm) following four growing seasons. Douglas-fir grew least, with accumulation of less than 3 inches (about 8 cm) for the period. The relatively poor growth for Douglas-fir is of concern, since this species is a prominent component of the adjacent forest. Douglas-fir survival was relatively high (Figure 5), suggesting the likelihood of improved performance over time.

Not all seedling species survived in all treatments, however. Among the treatment plots, the best survival and growth accumulations for all tree species occurred in Compost only and Lime + compost blocks (Figure 4 and 5). There were no significant differences in the growth achieved between these two treatments.

There was, however, a significant difference in growth between the Fertilizer + compost treatment and all other treatments. Growth and survival were lowest for all seedling species in this and the None treatment block and, except for one ponderosa pine seedling, no trees survived in the Fertilizer + compost block. We believe that the Fe component was a confounding presence in the rooting zone since the tailings material already contained excess Fe materials. The low pH of the tailings material make Fe more soluble and could potentially a create toxic condition for normal plant uptake (Mengel and Kirkby 1979). Further, since potassium (K) in the tailings material was also low (Table 1), lack of this element in the fertilizer supplement may have contributed to low establishment success.

Sitka alder achieved the greatest cumulative height of the species selected for this study. It grew best in the Lime + compost and Soil island blocks. This species is a local endemic that was seen growing nearby in unamended, non-gravel covered tailings material. Sitka alder appears particularly adapted to the copper tailings substrate. It is a non-leguminous, nitrogen-fixing species (Binkley 1982), with wide distribution at these elevations and in northern latitudes. It tolerates the acidic tailings material, but it clearly achieves better growth in the more moderate pH conditions of the soil islands and Lime + compost treatment. By the fourth season, Sitka alder was the only member of the tree seedlings used here that had produced reproductive structures, with catkins on specimens growing in the Soil islands and in the Lime + compost treatments.

Grass Establishment and Immigration

Of the eight grass species sown onto the upwind soil island, and downwind from the gravel covered tailings test plots, only four established well enough for measurement. Figure 6 shows which grasses established on the treatments by number of plants per block. There were no significant differences in the number of grass

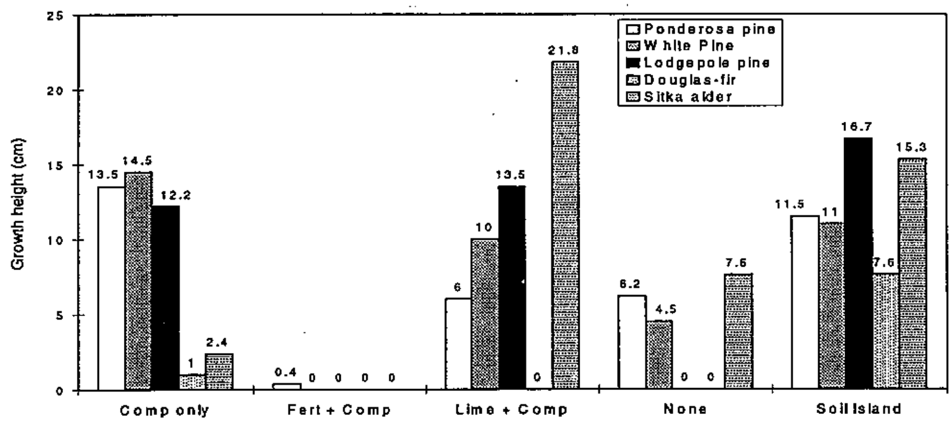

Figure 4. Growth height achieved after four growing seasons by four conifers and Sitka alder seedlings on amended copper mine tailing. Holden mine 1995. Values are averages, N varies.

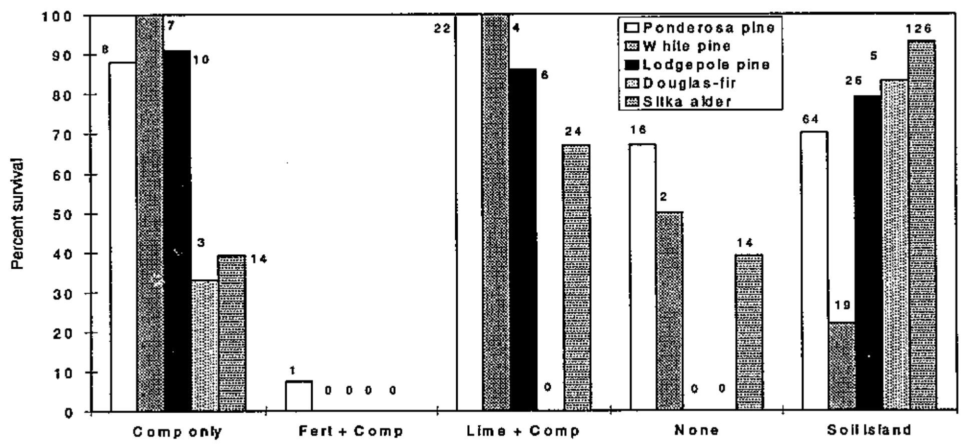

Figure 5. Survival after four growing seasons of four conifer and Sitka alder seedlings planted on amended copper mine tailings. Holden mine 1995. Data labels are number of trees counted each species.

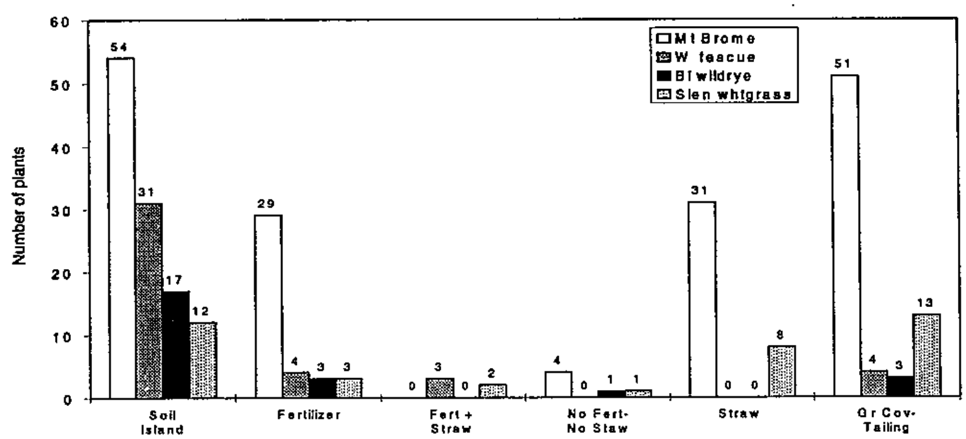

Figure 6. Number of plants for four established grass species on soil island source, treated gravel covered tailings and gravel covered tailing only. Holden mine 1995.

plants that established on the soil island block and gravel-covered tailings test plot. Mountain brome appeared to be best adapted to the site.

After the fourth growing season, there were 89 grass plants on the treatment blocks of the plot. Blocks with Fertilizer treatment and Straw only treatments had significantly more (P=0.011) grass plants than blocks with No treatment or Fertilizer + Straw treatment. These consisted mostly of mountain brome plants. Most of the treatment block grass plants were located within three meters of the soil island seed source.

Grass seeds appeared on the gravel covered tailings treatment blocks as far as 32 feet (11 m) from the soil island seed source. Figure 7 shows grass seed distances into the treatment blocks from the soil island source. Most seeds appeared within about 13 feet (4 m) of the soil island, where 114 grass plants were available as a seed source. We think there is potential for greater immigration as more grass plants become established onto the tailings surfaces. It may be necessary to modify the treatment amendments of the tailings surfaces to better accommodate establishment of a greater diversity of the species mix.

Conclusions

1. Soil islands are providing sites for rapid plant establishment and growth of grasses and woody plants.

2. The application of the concept of soil islands as sites for dispersal onto the tailings is hampered by the infertility/toxicity of the tailings material. The gravel covering over the tailings appears to be providing "safe sites" for propagule establishment from both the soil island sites and the adjacent forested area.

3. Successful off-island establishment of planted tree seedlings is enhanced with substrate amendments, particularly those with carbon loads such as the compost and straw treatment. Where commercial fertilizers are employed, care must be taken not to aggravate or create toxic conditions in the rooting zone.

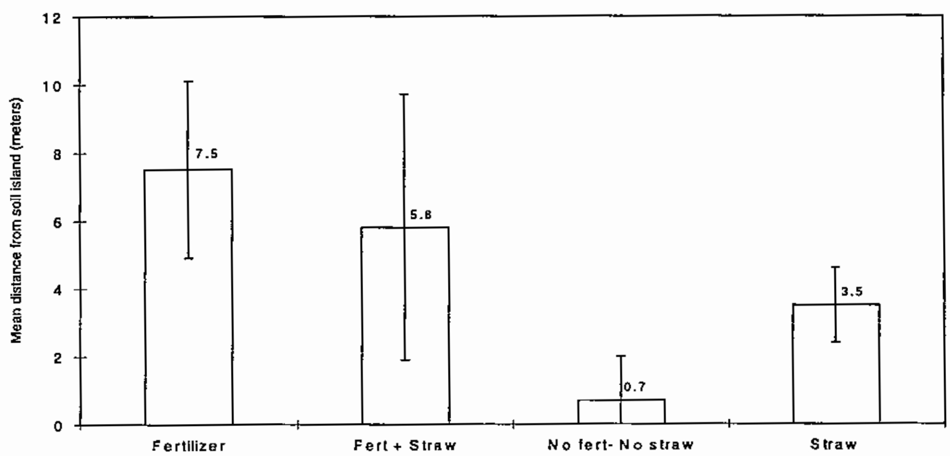

Figure 7. Grass seed migration from soil island propagule source into four treatment blocks. Holden mine 1995. Values are means, N=6. Error bars are 95% confidence intervals.

Literature Cited

Binkley, D. 1982. Nitrogen fixation and net primary production in a young Sitka alder stand. Canadian Journal of Botany 60: 281-284.
https://doi.org/10.1139/b82-036

Chelan Ranger District (CRD) 1993. Report of Wilderness Ranger. File notes at Chelan Ranger District Ranger, WNF, 1202 Woodin Ave. Chelan, WA 98816.

Dauble, D.D., J.P. McKinley and W.H. Walters. 1989. Report for the National Forest Service. Assessment of construction activities on Railroad Creek at Holden, WA. Battelle Pacific Northwest Laboratories, Richland, WA. DOE Contract DE-AC06-76RW 1830.

Franklin, J.F. and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. OSU Press, Corvallis, OR. 452pp.

Huyck, L. and J.P. Reganold. 1989. Environmental policies and issues surrounding Holden Mine tailings: A case study of an orphaned mine. Environ. Impact Asses. Rev. 9:97-123.
https://doi.org/10.1016/0195-9255(89)90022-X

Kramer, P.A., D. Zabowski, R.L. Everett and G. Scherer. 1998. Native plant restoration of biosolids-amended copper mill tailings. In: Proceedings of the 1998 National Meeting of the American Society of Surface Mining and Reclamation, St. Louis, Missouri, May 17-22, 1998.
https://doi.org/10.21000/JASMR98010092

McDonald, W. R. and M.B. Shirts. 1978. Progress in stabilizing acidic copper tailings at Holden Village, WA. USDI, Bureau of Mines. Report 8314. 15pp.

Mengel, K and E.A. Kirkby. 1979. Principles of plant nutrition, 2 ed. International Potash Institute, Bern, Switzerland. 593pp.

ORB Architects, Planners, Engineers 1975. Holden Mine tailings rehabilitation. SEAM contract 004807N. 112p.

Systat. 1992. Systat for Windows: Statistics, Version 5 Edition. Evanston. Il: Systat, Inc.1992. 750pp.

Thorsen, G.W. 1970. Holden tailings. State of Washington, Department of Natural Resources, Division of Mines and Geology. 20 pp.

Youngberg, E. A. and T.L. Wilson. 1952. The geology of the Holden Mine. Economic Geology 47:1-12.
https://doi.org/10.2113/gsecongeo.47.1.1