United States Department of Agriculture

Forest Service

Pacific Northwest Forest and Range Experiment Station

Research Paper PNW-294 November 1981

Mount St. Helens Ash and Mud:

Chemical Properties and Effects on Germination and Establishment of Trees and Wildlife Browse Plants

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Abstract

Radwan, M. A.; Campbell, Dan L. Mount St. Helens ash and mud: Chemical properties and effects on germination and establishment of trees and browse plants. Res. Pap.PNW-294. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 8 p.

Chemical properties of ash and mud from the 1980 volcanic eruption of Mount St. Helens and their effect on germination and seedling production of selected plants were studied. The volcanic materials were low in some important nutrients and cation exchange capacity, and they adversely affected seedling production. Catsear, a preferred wildlife browse, and lodgepole pine appear promising for revegetation of some of the areas affected by the volcano; but frequent application of fertilizer will also be required.

Keywords: Volcano effects, chemical properties, volcanic ash soil, nutrient analyses, seedling production, germination –) environment, Washington (Mount St. Helens).

Summary

Samples of ash and mud from the 1980 volcanic eruption of Mount St. Helens were collected in western Washington soon after the May 18 eruption. For comparison, one soil sample was also collected near Toutle, 32 kilometers west of the volcano. Chemical properties of the volcanic deposit and effects on seed germination and seedling establishment of five important tree species and four different browse plants were studied. In general, the ash and mud were slightly acidic. Compared to the soil studied, the ash and mud were higher in available P, and Cu, extractable K, total S, and sulfate S; the volcanic materials were also much lower than the soil in cation exchange capacity, total N, extractable Mg, and available Fe. The ash slightly delayed seed germination, but final germination was not affected. For most species, the ash and mud adversely affected seedling production and establishment. Species' performance in volcanic mud was generally much better than in ash. Among the browse plants and tree species tested, performance in both the ash and mud was best with catsear and lodgepole pine and worst with redstem fireweed and red alder. Seedling growth in the ash and mud was generally less than that in soil. Fertilization increased seedling growth of all species in the mud and ash. Revegetation of the area devastated by the volcano will be difficult. Fertilization, especially with nitrogen, will be essential to success of any rehabilitation effort; and frequent application of fertilizer will also be necessary because of the extremely low cation exchange capacity of the volcanic deposits.

Introduction

In 1980, major volcanic eruptions occurred from Mount St. Helens in southwest Washington. These eruptions resulted in deposition of volcanic ash over much forested area in Washington and neighboring States. In addition, the eruptive events caused mud flows, especially along the Toutle River. The deposited ash ranged from light dustings on vegetation and soils, as in Olympia, to very thick layers, closer to the volcano. Similarly, mud varied in depth over the affected areas.

In addition to burying and destroying trees and forbs, the ash and mud will certainly affect natural and artificial regeneration and wildlife and may also influence plant growth by physical means or through chemical component(s). The purpose of this study was to chemically characterize the ash and mud, and to assess potential effects on plants which could be used to rehabilitate the area affected by the volcano for wildlife and timber production.

Materials and Methods

Collection and processing of ash, mud, and soil samples.—All materials were obtained from western Washington locations. Ash samples from three locations were collected: in Olympia, Capitol State Forest which is 16 kilometers west of Olympia, and near Toutle which is 32 kilometers west of the volcano. Olympia ash was from the May 25 eruption; it was collected on plastic sheets the day of the eruption and before any rain had fallen. The Capitol Forest sample was obtained by shaking the ashfall off plant leaves into a glass container. Toutle ash was collected on June 4 in plastic buckets by skimming the top layer from ground deposits. Mud was dug along the Toutle River, near Toutle; and soil was sampled to a depth of 20 cm (excluding any ash present on the surface) from a forest clearcut near Toutle.

Soil was passed through a 2-mm sieve, and ash and mud were screened to remove visible contaminants. Individual samples were thoroughly mixed and air dried at room temperature. Subsamples for chemical analysis were dried to constant weight at 65°C.

Chemical analysis.—The chemical determinations and analytical methods used were as follows: Ca, Mg, and K—extracted with neutral 1N ammonium acetate — and available Fe, Mn, Zn, and Cu—extracted with DTPA (diethylenetriaminepentaacetic acid) (Lindsey and Norvell 1978)—by atomic absorption spectrophotometric techniques (Perkin-Elmer 1976); total S and sulfate S—extracted with $Ca(H_2PO_4)_2$ solution (Fox et al. 1964)—by turbidimetric method (Butters and Chenery 1959); total N by micro-Kjeldahl procedure (Bremner 1965a); ammonium N and nitrate N—extracted with 2N KC1—by steam-distillation methods (Bremner 1965b); available P—extracted with Bray and Kurtz solution 2 (Bray and Kurtz 1945)—by the molybdenum blue technique (Chapman and Pratt 1961); pH—on a 1:1 paste with water—by glass electrode; and cation exchange capacity by the ammonium acetate method (Chapman 1965).

Test plants.—The following tree and browse species were used in the germination and seedling production tests: Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn ex D. Don), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), red alder (*Alnus rubra* Bong.), catsear (*Hypochaeris radicata* L.), redstem fireweed (*Epilobium watsonii* Barbey), dwarf English trefoil (*Lotus corniculatus arvensis* L.), and orchard grass (*Dactylis glomerata* L.). All seeds were from local, low-elevation sources.

Germination.—Before germination tests, seeds of conifers were stratified at 2° to 5°C for 3 weeks; seeds of the other species were tested without stratification treatment. Four replicates of 100 seeds each were used (Association of Official Seed Analysts 1965). The seeds were germinated on moist germination paper or on moist Toutle ash in petri dishes. The dishes were randomly placed in an incubator programed for alternating diurnal temperatures of 30°C for 10 hours and 20°C for 14 hours, with fluorescent light available during the higher temperature. Emergence of radicle was the criterion for germination, and germinants were counted every week for 4 weeks.

Seedling production.—Production and establishment of seedlings were studied in 3-liter plastic pots filled with Toutle ash, ash on top of soil, mud, or soil. The ash-soil combination was obtained by filling the bottom one-half of the pot with soil and the upper half with ash; it was designed to simulate field conditions where ashfall covers the mineral soil.

On July 9, 1980, seeds were sown at a maximum depth of 3 mm. There were two replicates of 100 seeds each per species, and the pots were randomly placed on a bench in a covered lathhouse. Pots were watered as required, and emerged seedlings were counted at weekly intervals until harvest in November.

Fertilization and harvest of seedlings.—Starting on August 15 and continuing until harvest in November 1980, 0.5-strength nutrient solution (Hoagland and Arnon 1950) was used instead of water to irrigate one pot of each species in each of the four planting media. At the end of the experiment in November, seedlings were removed from the pots and roots were washed and examined. Dry weights of seedlings from selected fertilized and unfertilized treatments were determined by drying to constant weight at 65°C.

Results and Discussion

Chemical properties of ash and mud.—Comparative chemical characteristics of the ash and mud are shown in table 1. The data show that the three ash samples appreciably differed in most properties. For example, Olympia ash had the highest content of available Mn, Zn, Cu, total N, and ammonium N. The fact that this sample was collected without any leaching by rain may explain this result. Toutle ash also exceeded the other ash samples in content of Ca, K, total S, sulfate S, and available P. This was probably the result of the closer proximity of the volcano to Toutle, where this sample was collected, compared with the other collection areas.

Volcanic mud was higher in Mg and appreciably lower in Ca than the ash. Other chemical properties of the mud were mostly within the range of values found in the ash samples.

In general, the ash and mud were very slightly acidic and soil much lower in pH. Compared to Toutle soil, the ash and mud were higher in available P and Cu, total S, sulfate S, and extractable K. The volcanic materials were much lower than the soil in total N, extractable Mg, available Fe, and cation exchange capacity. Despite these differences, characteristics of the ash and mud are still within ranges generally found in soils; and soil chemistry would be little affected by moderate amounts of these materials.

Effects of ash on seed germination.—Germination of all seed was somewhat delayed by the ash. Emergence of the radicle was slightly slower on ash than on germination paper. Also, the elongating radicles tended to grow horizontally without penetrating the compact ash (fig. 1), instead of growing vertically into the support medium as they did on the paper. Germination, otherwise, proceeded normally on ash as on the paper.

Table 1—Comparative chemical properties of Mount St. Helens ash and mud[1]

Property	Unit of measure	Ash sample 1	Ash sample 2	Ash sample 3	Mud	Soil
Extractable Ca	ppm	1130	540	1270	75	985
Extractable Mg	ppm	78	40	76	112	538
Extractable K	ppm	260	150	340	270	140
Available Fe	ppm	33	28	25	28	66
Available Mn	ppm	11	5	3	10	4
Available Zn	ppm	28	1	3	2	4
Available Cu	ppm	6	2	3	3	1
Total S	ppm	630	280	770	340	<10
Sulfate S	ppm	53	5	180	33	3
Total N	ppm	497	43	65	82	700
Ammonium N	ppm	7	1	2	2	[2]—
Nitrate N	ppm	3	1	2	1	[2]—
Available P	ppm	178	186	246	149	3
pH	pH	6.8	7.0	6.7	6.8	5.0
Cation exchange capacity	meqts./100 g	2	1	1	2	22

[1]Ash samples 1 and 2 were collected in Olympia and in Capitol Forest, which is west of Olympia, respectively. Ash sample 3, mud, and soil were obtained near Toutle, 32 kilometers west of Mount St. Helens.
[2]Not determined.

Figure 1.—Germination of lodgepole pine on compacted ash. (Note horizontal growth of radicles.)

Table 2—Effect of Mount St. Helens ash on cumulative germination percents of different plant species[1]

Plant Species	Germination medium	
	Germination paper	Ash
Douglas-fir	89	88
Western hemlock	70	69
Western redcedar	74	81
Lodgepole pine	97	97
Red alder	57	62
Catsear	90	90
Redstem fireweed	82	75
Dwarf English trefoil	70	64
Orchard grass	96	92

[1] Percents are averages of four 100-seed replicates.

Table 3—Established seedlings as percentages of seeds sown in different media [1]

Plant species	Growth medium			
	Ash	Ash on soil	Mud	Soil
Douglas-fir, sample 'a'	13	1	33	39
Douglas-fir, sample 'b'	26	10	43	79
Western hemlock	14	1	48	51
Western redcedar	19	0	49	56
Lodgepole pine	54	66	85	89
Red alder, sample 'a'	0	0	1	17
Red alder, sample 'b'	4	3	8	54
Catsear	94	62	82	81
Redstem fireweed	15	1	17	31
Dwarf English trefoil	48	67	50	46
Orchard grass	88	47	79	93

[1] Percents are averages of two 100-seed replicate pots.

Cumulative germination of the different species ranged from 57 percent with red alder to 97 percent with lodgepole pine on filter paper, and from 62 percent to 97 percent with the same species on ash (table 2). For individual species, germination was about the same on ash as on filter paper; the difference between germination on the two different media did not exceed 7 percent. Germination capacity of all species tested, therefore, was not impaired by the ash.

Seedling production and establishment in ash and mud.—Seeds of all species germinated in adequate numbers in all media at the beginning of the pot experiment. In the soil, most germinants grew into established seedlings and seedling production for the majority of species was higher than in ash or mud (table 3). On the other hand, many young germinants of most species were unable to get established in the ash. Upon watering after the seed had been sown, the ash became densely compacted like cement (fig. 2). Compaction limited aeration and resulted in a physical barrier to the radicles, restricting their ability to penetrate and grow into the ash. Many germinants, therefore, remained on top of the ash with their radicles and newly elongating aerial parts exposed (fig. 3) until they withered and died. At the end of the experiment, the number of established seedlings in the ash varied widely among the species. Among the browse plant and tree species tested, production of established seedlings was best with catsear and lodgepole pine and worst with fireweed and red alder.

Seedling production in the ash-soil combination was less than that on ash for most species. Causes for this are unknown.

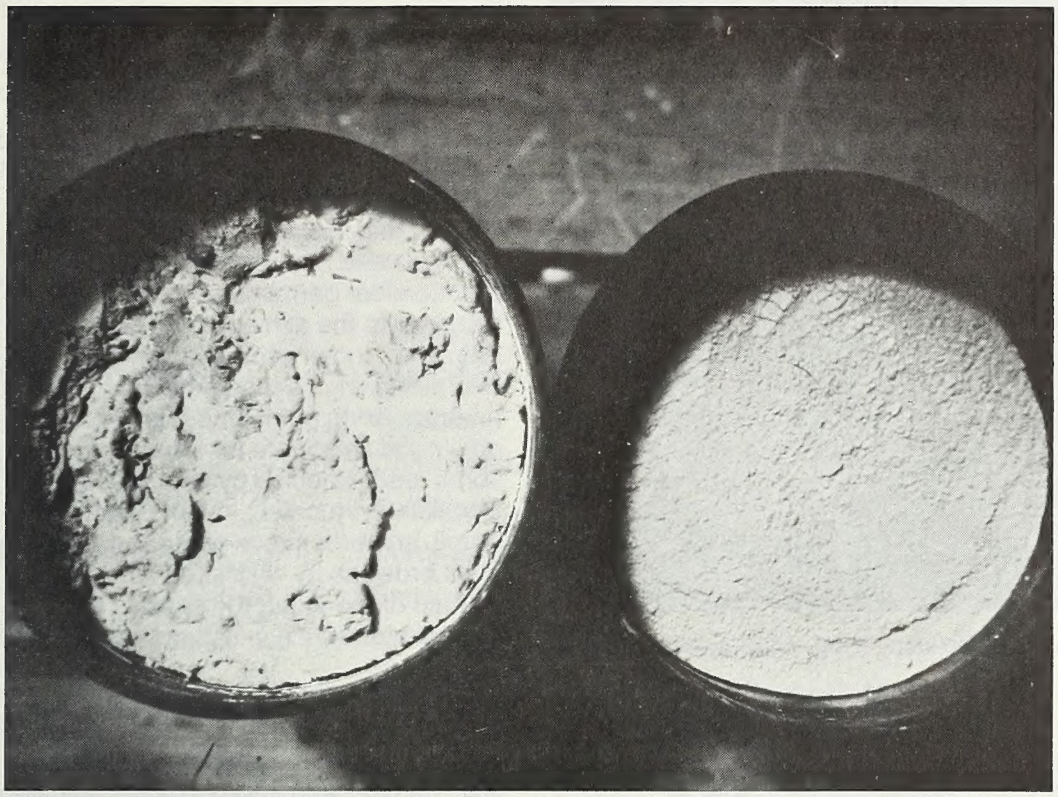
Figure 2.—Mount St. Helens ash, before (right) and after (left) watering.

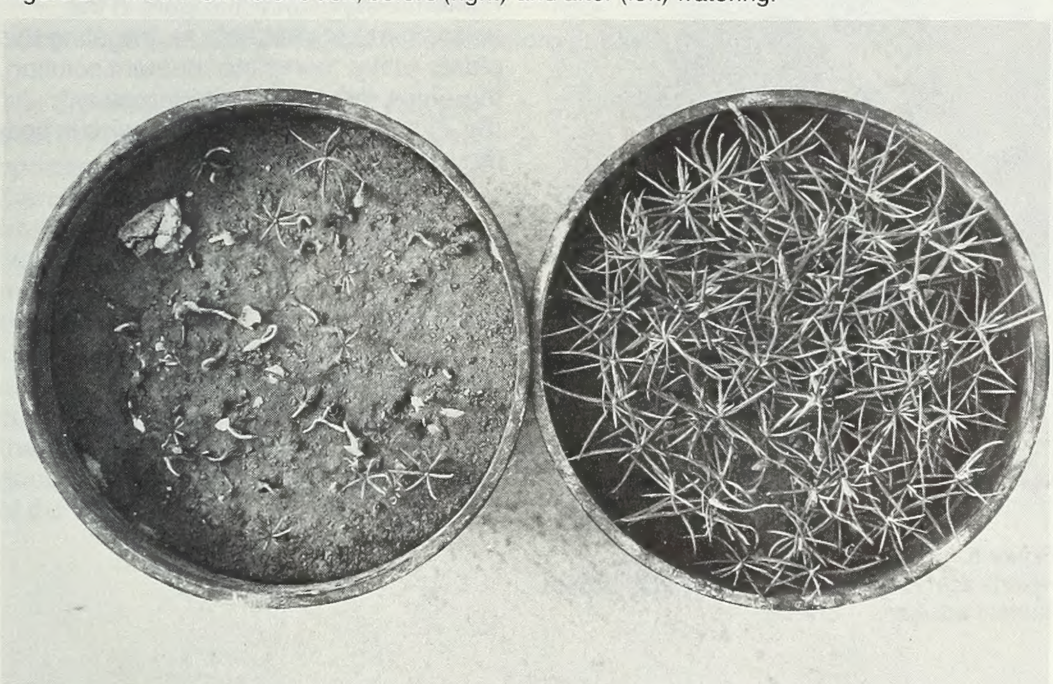
Figure 3.—Growth of Douglas-fir in Mount St. Helens ash (left) and in Toutle soil (right).

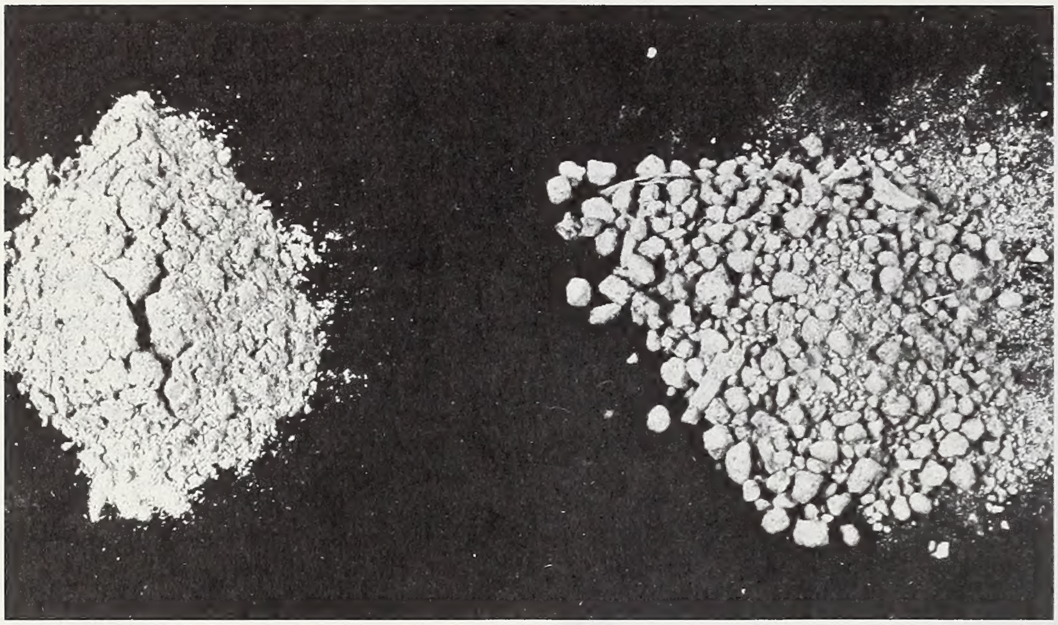

Figure 4.–Volcanic ash (left) and mud (right) (x 2) used in the study. (Note larger particles of mud.)

Figure 5.—Catsear growing in Mount St. Helens ash, without (left) and with (right) added nutrient solution.

Species' performance in volcanic mud was generally much better than in the ash. The mud contained much large-particled sand (fig. 4) making it a much better medium than ash for seedling growth and establishment. Again, as with the ash, performance in mud was best with catsear and lodgepole pine, and worst with fireweed and red alder. Apparently, the red alder germinants were more sensitive to the ash and mud environment than those of other species. This was surprising because red alder, a nitrogen-fixing plant, had been considered a good candidate for rehabilitation of some areas affected by Mount St. Helens' eruption. Fortunately, dwarf English trefoil, an herbaceous nitrogen-fixing plant browsed by wildlife can be used instead of red alder; the species gave a good performance in ash and mud.

Effects of fertilization on biomass production.—Seedling growth in ash and mud was generally less than that in soil. This was expected because of limited nutrients, especially nitrogen, in the volcanic materials (table 1). Irrigating the plants with a "complete" nutrient solution, therefore, increased seedling growth (fig. 5) and dry weight of all species in both the ash and mud (table 4).

Table 4—Effect of fertilization on growth of different plant species in Mount St. Helens ash and mud

Plant species	Fertilization treatment	Dry Weight (g) Growth medium Ash	Mud
Western hemlock	Unfertilized	0.1	0.7
	Fertilized	.2	.8
Western redcedar	Unfertilized	.1	.6
	Fertilized	.5	1.1
Douglas-fir	Unfertilized	[1]—	2.8
	Fertilized	[1]—	3.2
Lodgepole pine	Unfertilized	1.3	1.9
	Fertilized	1.7	4.4
Dwarf English trefoil	Unfertilized	1.5	1.6
	Fertilized	5.7	3.5
Catsear	Unfertilized	5.0	.5
	Fertilized	9.8	7.1

[1]Seedlings destroyed by small rodents before harvest.

The dry-weight data (table 4) also show that: (1) with and without fertilizer, most species produced more biomass in mud than in ash; (2) regardless of fertilizer treatment, catsear was the leader in biomass production in ash; and (3) in mud, maximum biomass was produced by fertilized catsear, followed by fertilized lodgepole pine. These results confirm earlier observations that mud was more suitable for plant growth than ash, and that catsear and lodgepole pine were good candidates for revegetation of some of the areas affected by the eruption.

Conclusions

In moderate amounts, the volcanic deposits of Mount St. Helens investigated here would not have much effect on soil chemistry or growth of established plants. Revegetation of the area devastated by the volcano, so it can once again become useful for both timber production and wildlife, will be difficult, however. Ash becomes densely compacted upon wetting, it forms a physical barrier to successful establishment of young germinants, and adversely affects regeneration by seeding. Planting success may also be limited unless seedlings are planted in the soil beneath the ash. Fertilization, especially with nitrogen, will be essential to success of any rehabilitation effort; and frequent application of fertilizer will also be necessary because of the extremely low cation exchange capacity of the volcanic deposits. Species which appear promising for rehabilitation work include catsear, a preferred wildlife browse, and lodgepole pine.

Results of this study do not apply to areas around the volcano where deposits of materials such as pumice are different from those studied here.

Acknowledgments

We thank Joseph Kraft, USDA Forest Service, for preparing the photographs and assisting in chemical analysis and Stanley Olmstead, U.S. Department of Interior, Fish and Wildlife Service, for assisting in sample collections and conducting seed germination tests.

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