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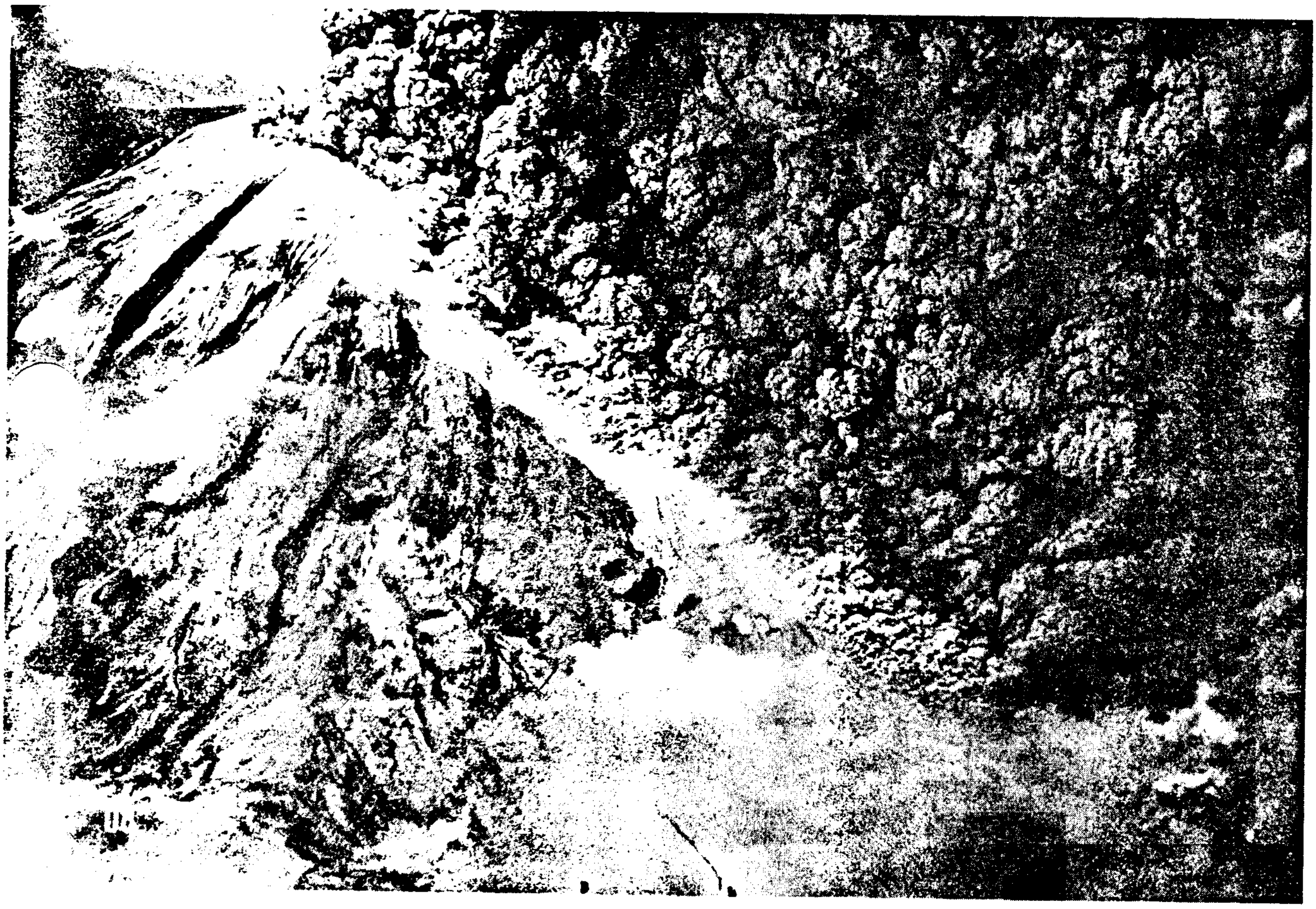
Mt. St. Helens Ash: Considerations of Its Fallout on Rangelands



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ST. HELENS ASH: CONSIDERATIONS OF ITS FALLOUT ON RANGELANDS

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COVER: Photo by Charles Rosenfeld, associate professor of geography, Oregon State University

SUMMARY

Field and laboratory studies were conducted on volcanic ash from Yakima, Moses Lake, Spokane, Washington, and Moscow, Idaho, three weeks after the May 18, 1980, eruption of Mt. St. Helens in southwestern Washington. These studies examined 1) the chemical, physical, and water retentivity properties of the ash, 2) the effect of the ash upon germination and emergence of crested wheatgrass and cheatgrass, 3) the impact of ash upon *in vitro* digestion of common forages fed to cattle and the rate-of-passage of ash in steers, and 4) the influence of the ash layer on water infiltration into a range soil and the amount of sediments in the runoff water. In addition to the above short term studies, small field plots of various ash treatments were initiated to monitor the effects of the ash over the long term, both on individual native plants and the native and seeded plant community. These field studies are being conducted in an environment similar to that on which the ash fallout occurred and will allow ash response to be compared with absolute control areas of no ash.

Mineral concentrations were similar in ash among the four collection locations and not unlike that of ash derived soils of eastern Washington rangelands. The ash has low to medium fertility levels and, except for moderately high soluble salts and sulfate sulfur levels, will not affect production or animal performance. Physical differences in the ash were readily apparent with sand textured fallout occurring in the Yakima area; ash falling farther east was dominated by silt-sized particles and was classified as a silt type loam. Those physical differences strongly influenced soil water retention. Plant available water in the silt loam types was three to five times as great as that of the sand type ash.

Seed germination of crested wheatgrass and cheatgrass was reduced in both ash types but the silt loam ash was most depressive, reducing germination about 65 to 90 percent. Seedling emergence and height of seedlings were decreased by ash burial with greater depths of burial being more deleterious. Overall emergence in the ash type was less than one-half that in a sand-clay-loam soil. Emergence rate of the two grasses was the same in the sandy-clay-loam soil but that of cheatgrass emergence was reduced severely by burial under the sand textured ash. Seedling emergence through ash depths greater than 0.4 inch was low or nil for both grasses.

Water infiltration into a sandy loam range soil was enhanced by adding the sand textured ash to its surface, and sediments in the runoff water were less than that from the native soil surface. Conversely, the silt-loam ash reduced water infiltration and percolation into the soil and the sediment in its runoff was about five times as great as that from the undisturbed range soil.

In vitro digestion of commonly fed forage and forage range grasses was not influenced by ash additions to the forage or by rumen digest from steers receiving two pounds of ash daily for 10 consecutive days. Ash administered directly into the rumen increased fecal ash concentrations in 24 hours and peaked in about five days at about 30 to 35 percent. The fecal ash concentrations of the steers returned to normal levels in about five days.

THE SOURCE OF THE PROBLEM

On May 18, 1980, Mt. St. Helens in southwestern Washington erupted with violent force. The explosion reduced the 9,682-foot (2,951-meter) mountain to about 7,303 feet (2,226 meters) and an estimated .6 mi^3 (2.6 $kilometers^3$) was moved from the summit. Of that total amount, 0.3 to .18 $mile^3$ (0.14 to 0.73 $kilometer^3$) was elevated by the blast as ash, and borne by the winds to the north and east. Twenty thousand $miles^2$ (51,800 $kilometers^2$) or more are estimated to have received an ash layer of greater than .04 inch (1 millimeter) (Figure 1). About 9,600 $miles^2$ (25,000 $kilometers^2$), primarily in central Washington, received between 0.39 to 2.8 inches (10 to 70 millimeters). Approximately half of that area, about 3 million acres (1.2 M hectares) is dominated by a sagebrush-wheatgrass association (numerical data extracted from Sarna-Wojoicki et al., ca. 1980, and Brown, 1980). This report is directed principally to the effect of ash depositon and the physical and chemical attributes of the ash on a rangeland environment and the influence the ash has on germination, seedling emergence, plant growth, species response, water infiltration, sediment runoff, and forage utilization.

FORMAT

Approximately 2,500 pounds (1.1 metric T) of ash were collected from each location - - Yakima (May 28), Moses Lake (June 3), and from Moscow (June 5) - - and transported to the Squaw Butte Experiment Station 42 miles west of Burns, Oregon. About 15 pounds (7 kilograms) of ash were received from a Spokane source which collected it June 7.

At Squaw Butte, 20 subsamples of each ash lot were weighed as obtained, oven dried, and moisture content and bulk density determined. The dried subsamples were composited into five sample units and subsamples from each sent to H. Mayland, who supervised the chemical and physical analyses. Sublots of the ash were also sent to R. Evans and J. Young for seed germination and emergence studies and to M. Vavra for use in animal digestion and rate-of-passage trials.

The remaining ash amounts were allocated to three field studies at Squaw Butte. One study was designed to measure water infiltration and sediment runoff under the supervision of J. Buckhouse. Continuing measurements of that study and of the other two (on native range) will provide long-term data on the effect of ash on forage production, native plant response, community response, and associated soil variables. These projects, set up by the lead author and C. Britton, will be maintained over the years by the Squaw Butte range staff. The primary purpose of these long-term studies is to document vegetation response to the ash on a rangeland similar to that in the fallout areas but where a control (no ash fallout) exists to provide a comparison.

The livelihood of residents within the fallout area goes on, it is important to them that as much information as possible is available to them as they try to live in, adjust to, and plan for coping with the ash. Results of the short-term studies may provide some insights into the magnitude of problems facing the residents of that area (perhaps the ash may offer some new opportunities in rangeland management.)

PROCEDURE AND RESULTS

Chemical, Physical and Water Retention Characteristics

The pH was determined on a 1:5, ash:water, mixture and the electrical conductivity was measured on the subsequent filtrate. The water extractable minerals in this same filtrate were determined by atomic absorption, except P which was determined colorimetrically by the vanadate-molybdate method and F which was determined by specific ion electrode. Major soil cations were also determined by atomic absorption on an 1N ammonium acetate (NH_4HOAc) extract of the ash. Phosphorus was determined on a 0.5 M, pH 8.5 sodium bicarbonate ($NaHCO_3$) extract using the ammonium molybdate-stannous chloride procedure. Organic N was determined on finely ground (100 mesh) ash by semi-micro kjeldahl procedure. Trace element levels were determined by atomic absorption after extracting ash with a diethylenetriamine pentaacetic acid (DTPA) solution.

Particle size was determined by continued dry sieving of ash through a series of sieves until the less than 47 µm fraction changed by less than 0.2 g/min. Particle sizes less than 40 µm were determined by the hydrometer method. Surface area was determined by ethylene glycol sorption. Bulk density was determined on dry ash samples by the core method for disturbed samples while specific density was determined using 25 ml pycnometers. Water retentivity was measured using the tempe cells and pressure plate technique and plant available water was calculated by subtracting the percentage water held at 15 bar tension from that held at 0.3 bar tension. The above procedures are described by Black (1965), Walsh and Beaton (1973), Bouyoucos (1962), and Richards (1965).

Results of chemical and physical analyses of the five sub-samples may differ somewhat from that reported by others because these analyses were conducted on ash that had received some rainfall. The rain may have leached some of the soluble salts. The delay in sample collection and analysis also encouraged degassing and increased settling of the ash. Fallout in Spokane and Moscow locations was light and greater contamination of those samples probably occurred in the collection.

Differences among locations for most chemical constituents were small (pH, K, Mg, Mn, Ca, Zn), regardless of extraction process (Table 1). Electrical conductivity, Na, Ca (water extractable) tended to decrease as distance from Mt. St. Helens increased but cation exchange capacity (CEC), P, Fe, and Zn concentration increased as distance from the volcano increased and smaller particle sizes were dominate in the ash. The higher values of N in samples from Moscow and Spokane than in Yakima and Moses Lake samples are believed to result from residual organic matter debris in the sample. In general, these tests on the ash indicate that it is equivalent to a soil of low fertility.

Chemical data on the ash have been assembled from other sources (Table 2) and compared with values obtained in this study. These data indicate that sulphate sulfur is the only plant nutrient of real value in the ash. The ash also contained appreciable soluble salts, but this might only be of concern where several inches of ash occurred. The soluble salt might produce a temporary setback to germinating seeds or emerging seedlings.

Additional chemical data (Table 3) were obtained on the total ash by x-ray flouresence or by various wet chemistry techniques (see respective references). Differences in reported values are noted between labs in several instances. The values reported for the Bozeman lab were obtained within hours of the actual fallout. There was no leaching or degassing of samples. In contrast, leaching occurred through the USDA ash samples which were collected and analyzed after a time delay.

Physically, ash from Yakima differed strongly from that of the three other more easterly locations (Table 4). The texture of Yakima ash contained 92 percent sand compared with 42, 48, and 30 percent for Moses Lake, Moscow and Spokane, the later three were classified as silt loams. Much of the fallout ash was characterized as having a silt loam texture (Table 2). Specific density of ash was similar for all locations but bulk density decreased from a high of 1.28 at Yakima to 1.1 at Moscow. Surface area of ash particles increased in samples from west to east which is reflected in the greater amounts of silt-size particles in the more easterly locations.

Plant available water was much lower in the sand-ash type from Yakima than in the silt-loam ash of Moses Lake and of Moscow (Table 5). Moisture retention of both types was similar to that of the natural developed soils of those textural classes.

Germination Study

Twenty-five seeds of crested wheatgrass and of cheatgrass were placed in petri dishes on one thickness of germination paper (control) or on ash from Yakima or from Moses Lake. The units were then wet with tap water, covered and placed in dark germinators. Constant germination temperatures of 41, 50, 59, 68, 77, and 78°F (5, 10, 15, 20, 25, and 30°C) were maintained for four weeks. Germination counts were made weekly with germination recorded when the radicle had emerged 0.2 inch (5 mm) or more. Treatments were replicated four times and allocated within a randomized complete block design. Percent germination at the end of four weeks was analyzed in a three-factor analysis of variance with treatment mean differences tested with Duncan's multiple range test.

Differences ($P<0.05$) in percent germination resulted between species, among substrates, among germination temperatures, and with all interactions except species x substrates. Mean germination was highest (89 percent) in the controls, reduced to 75 percent in Yakima ash, and was lowest (64 percent) in the silt-like ash of Moses Lake (Figure 2c). Overall, germination of cheatgrass was highest (80 percent) yet it was most sensitive varying from 98 to 20 percent (Figure 2a) to ash source and particularly temperatures. When germinating at 50°F (10°C) in Yakima ash or 86°F (30°C) in Moses Lake ash (Figure 2b), crested wheatgrass germination was reduced to about 40 percent from a mean germination of 72 percent. This adverse temperature effect on cheatgrass seed occurred only at 86°F (30°C) (Figure 2a) and was absent in controls. Overall, germination was highest at 68 and 77°F (20 and 25°C), intermediate at 41 and 59°F (5 and 15°C), and lowest at 50 and 86°F (10 and 30°C).

eedling emergence

Twenty-five seeds of crested wheatgrass and cheatgrass were evenly placed on the surface of a sandy clay loam soil contained within 3.5 inch (9-centimeters) diameter paper cups. The seed was buried by additions of ash or soil. Burial depths varied with the bulk density of the ash or soil. Yakima ash burial depths were 0.2, 0.4, 0.6, 0.8, and 1.0 inch (0.5, 1.0, 1.5, 2.0, and 2.5 centimeters) for Moses Lake ash, 0.3, 0.7, 1.0, 1.3, and 1.7 inch (0.8, 1.7, 2.5, 3.4, and 4.2 centimeters) and the sandy clay loam soil 0.2, 0.4, 0.6, 0.7, and 0.9 inch (0.4, 0.9, 1.4, 1.8, and 2.2 centimeters). The experiment was conducted in a greenhouse where soil and ash in the containers were kept moist during the growing period. Emerged seedlings were counted, measured, and pulled after two weeks with final counts and measurements made at the end of four weeks. The study design was a randomized complete block with four replications. Numbers of emerged seedlings and average height of seedlings at two and four weeks were analyzed in a three-factor analysis of variance with treatments mean differences tested with Duncan's multiple range test.

At two weeks, differences in emerged seedlings were statistically significant ($P<0.05$) among burial material, burial depths, and all interaction between those factors and species (Figure 3). There was no significant difference in numbers of emerged seedlings between species. Numbers of seedlings emerging between two and four weeks were small and did not alter the relationships exhibited at two weeks.

Emergence through Moses Lake ash was reduced 2 1/2 times that of soil coverage, with Yakima ash exhibiting a similar depressive effect (Figure 3c). Mean emergence decreased from 65 to 3 percent as burial depth increased (Figure 3d) but this was strongly influenced by species and burial material (Figures 3a and 3b). Cheatgrass failed to emerge when buried with 0.4 inch (1.0 centimeter) or more of Yakima ash or 1.4 inch (3.4 centimeters) or more of Moses Lake ash. Crested wheatgrass was more successful, with some emergence at all but the deepest burial depths of Moses Lake ash but failing to emerge through Yakima ash depths of 0.8 inch (2.0 centimeters) or more. Overall cheatgrass emergence was greater than crested wheatgrass in sandy clay loam soil but was poorer performing when emerging from the two ash media.

Seedling height at two and four weeks displayed similar differences because of burial material and burial depths as was obtained for numbers emerged (Figure 4). Differences ($P=0.05$) between species were the only comparison not significant. Height of seedlings emerged through ash (Figure 4d) was one-half of those seedlings emerged through soil, with the deepest burial depth reducing seedling height 80 percent of those emerging through the shallowest depth (Figure 4c). Seedling heights of crested wheatgrass (like emergence) were greater than cheatgrass, particularly in the two ash types, but seedling height was least from the Moses Lake ash (Figures 4a and 4b).

Watershed study

The rate of water infiltration and the potential sediment yield of an ungrazed crested wheatgrass field with two levels of ash, 8,900 and 17,800 pounds/acre (100,000 and 200,000 kilograms/hectare) from Yakima and Moses Lake were determined in late September 1980. Three plots, 5.0 x 20 feet (1.5 x 6 meters) per treatment with controls placed in a randomized complete block design, were treated with ash on June 10. Approximately 3.9 inches (10 centimeters) of simulated rain was applied through a Rocky Mountain infiltrometer (Dortignac, 1951) over a cluster of three, 2.5 foot^2 (0.23 m^2) subplots per plot. Water infiltration rates were determined at five-minute intervals throughout a 28-minute simulated rainstorm (Figure 5). The 3.9-inch (10 centimeter), 28-minute rainstorm simulates a 50 to 75 year storm return period that is characteristic of the high intensity-low frequency convectional summer storm of the sagebrush-bunchgrass region. Potential sediment yield was collected from each subplot. Sediment yield was determined by collecting a portion of runoff water, evaporating the aqueous portion, weighing the sediments, and converting them to kg/ha.

The coarser, sand ash from Yakima increased the infiltration rate of water well above, but the fine ash type of Moses Lake decreased the infiltratio rate below that from the control plots (Figure 5). Mean differences were not always statistically different at the 5 percent level. Conversely, potential sediment yield was greatest from plots treated with the finer Moses Lake ash averaging about 3,250 pounds/acre (3,650 kilograms/hectare) (Figure 6). This amount is about 25 times the amount of potential sediment measured from plots treated with Yakima ash which were more stable than the undisturbed soils of the control plots. Differences between levels of ash applied for both ash types were not large for either infiltration rate or sediment production.

Forage digestion and rate-of-passage

Two rumen fistulated steers were used in a switch-back design (Figure 7) to evaluate the ash effect on in vitro forage digestion and ash passage rate through the animal. The steers were maintained on ad libitum alfalfa-grass hay with one steer receiving two pounds of ash daily introduced through the fistula every morning before feeding. The dosing of the ash was maintained for 10 consecutive days followed by a two week recovery period with steer treatment and/or ash source then alternated. Twenty-four hours after the tenth day of ash dosing, rumen liquor was extracted from both steers and separate but simultaneous in vitro digestions of five forage types (Table 6) were conducted following procedures of Tilley and Terry (1963) as modified by Vavra et al. (1973). The forage types represent common forages harvested in the Northwest and native forages on forested rangeland. Additionally, before in vitro digestion, ash from the same ash source as fed was added to the forage samples at 0, 5, 10, 15, and 25 percent by weight. All in vitro treatments were run in duplicate. During one 22-day period of the study, fecal material from each steer was collected daily and percentage ash determined.

The presence of ash in the rumen innoculum and/or in the forage did not have a significant effect ($P>0.05$) on in vitro digestibility. Table 6 presents the mean digestion coefficients for the forages tested. Percent of ash in the fecal material reveals that ash appeared in the feces about 24 hours after administration and by the fifth day increased to about 30 percent (Figure 8). Within five days after going off the ash treatment, the amount of ash in the feces returned to about 15 percent or less.

Field Studies

The crested wheatgrass study described in the watershed section also provided for production and quality impacts of the ash on crested wheatgrass. Two 9.6 foot^2 (0.9 meter^2) subsamples were harvested at ground (ash) level from each plot on August 29. Herbage samples were weighed green, oven dried, and reweighed. The samples were ground and analyzed for ash, nitrogen, and phosphorus. Those results are in Table 7.

Herbage dry matter, phosphorus, and crude protein concentrations of mature crested wheatgrass were not influenced by ($P>0.05$) either the ash depth or the source of ash. Ash concentration of crested wheatgrass growing on ash treated plots was slightly higher than that growing on control plots. Herbage yield from plots with Yakima ash was reduced approximately 22 percent; yield from plots of Moses Lake ash was reduced 38 percent from the controls. However, levels of ash from the two sources were not consistent in this yield depression effect and the yield differences were small.

Response of native species, as individuals, will be followed in a separate study. Ten individual plants of each species: bluebunch wheatgrass (Agropyron spicatum), Thurber needlegrass (Stipa thurberiana), Junegrass (Koleria cristata) bottlebrush squirreltail (Sitanion hystrix), and Idaho fescue (Festuca idahoensis) received 1,189 grams (equivelant to 60 tons per acre) of either Yakima or Moses Lake ash. A circular 1 foot^2 (0.09 m^2) area around each plot was treated with ash. Ash containment was achieved using plastic garden edging. The ash was applied to plots on June 11, 1980, with an additional 10 non-treated plots of each species marked for controls. Before growth initiation in 1981, standing dead herbage from each plant will be removed and the ash retaining ring discarded. Basal area of each plant will be measured using a photographic technique and will be subsequently monitored annually after plant maturity. Beginning in the fall 1981, before basal photography, the number of reproductive stems/plant, plant height, and herbage yield will be measured and expressed in units of basal area. Chemical analysis of herbage will be completed for macro and micro mineral elements. A minimum of three years data is anticipated for response differences, if such occur.

Six 13 x 13-foot (4 x 4 m) plots were located on native sagebrush-bunchgrass site (in good condition). On June 10, 1980, three plots were treated with approximately 67 tons/acre (150 M tons/hectare) of ash from the Moscow source. This was equivalent to a depth of about .6 inch (1.5 cm) Soil moisture blocks and temperature probes will be located centrally in each plot in the spring of 1981 and monitored on a weekly basis through spring, summer, and fall. Net radiation over treated and untreated plots will be measured periodically. Total vegetation will be monitored annually with frequency of occurrence techniques with special concern directed towards the annual vegetation component. These plots, fenced to exclude large animals, will be asessed annually and monitored for long term trends.

INTERPRETIVE

Chemical analyses suggest that the ash deposition on these rangelands should neither effect a strong fertilizer response nor a strong toxicity impact on herbaceous plants. In that respect the ash is simply a low fertility soil amendment. This also is tentatively supported by the low crested wheatgrass response in yield and in N, P, and Ca concentrations in the 1980 year from ash additions to plots at the Squaw Butte Station. Yield reductions of crested wheatgrass from ash treated plots in 1980 are believed to have resulted from the covering of some leaf portions and the physical raising of the ground level from which the herbage yield was harvested. More supporting evidence of vegetation response to chemical concentrations in the ash will be available after the 1981 growing season.

Physically the ash separates into two types: the sand textured ash in the Yakima area and the silt textured ash that was deposited east of Yakima which covers the major portion of the ash deposition area. These two ash types will impact rangeland differently and produce different vegetation responses, as well as presenting differences in how management improvements may or may not succeed.

The sand textured ash increased water infiltration with little or no sediment production. With its low moisture holding capacity and rapid drying characteristics of a sand layer, it represents an impediment to seeds germinating on or within the sand layer. Reduced germination of both crested wheatgrass and of cheatgrass was evident in the laboratory trials when the ash system was maintained in a moist condition under constant germination temperatures. A greater reduction in germination in the field can be expected if the ash layer dries out or is dry and wet alternately. Reduced germination from residual seed under the ash layer or of seed planted under the ash layer also might be expected because emergence through the ash layer was impaired in laboratory trials, particularly if the sand textured ash layer exceeded 0.5 centimeters in depth. However, crested wheatgrass was more successful in emerging through the ash layer than was cheatgrass.

These newly formed sand particles are sharp edged and when in motion are extremely abrasive. If windy and drying conditions prevail during seedling emergence, the seedling may be cut severely by the blowing sand.

On the positive side, the sand ash enhances water infiltration thus increased soil moisture replenishment can be expected, particularly from the spring and early summer rains. Additionally, the sand-ash layer, when dried out (which it does quite rapidly) should act like a mulch, breaking the upward capillary action. This action of increasing water infiltration and reducing evaporation should enhance soil moisture condition both in quantity and in duration. This should effect a positive response from the established perennial plants. A yield response in 1981 may thus result from 1) more effective moisture use and/or 2) from a slight fertility response. Special attention will be necessary in measuring the plant variables to detect which effect or both are present.

Like most sands with low organic matter and low clay concentration, the sand-ash tends to compact and form a dense layer with a smooth surface. Seeds falling on the surface will find few places to anchor. Thus, natural establishment of native species or of seeds broadcast on the surface in the interspaces may be reduced in the interspaces and concentrated in and about other established species or protruding objects.

The finer silt loam ash deposited east of Yakima and covering the major portion of the ash fallout area presents a more serious problem to the rangeland environment. Here, the fine ash, when wet, swells and seals, retards infiltration, increases surface runoff, and erodes easily. Consequently, under heavy rains or rapid snow melt, sediment carried into the streams will be high, lowering water quality and adversely affecting aquatic habitat. If fully penetrated by rains, the sediments will clog underlying soil pore spaces, reducing further infiltration with decreased soil moisture entry. Thus, the perennial plant system may suffer from a shortage of soil moisture and the advantage shifted to the annual plant component.

Overall germination of cheatgrass and crested wheatgrass was slightly less on the fine ash compared with sand ash but differences were small. Some crested wheatgrass emerged through all but the deepest depth of Moses Lake ash but only through the three shallower depths of Yakima ash. Similarly, some cheatgrass emerged through the three shallower depths of Moses Lake ash but emerged only through the shallowest depth of Yakima ash.

Germination and emergence values were obtained with the ash systems maintained in a moist state. Field conditions over the germination and emergence period seldom will be that favorable; thus, field results most likely will be more severe.

Thus, while the watershed characteristics of the fine ash type are more negative than the sand ash type, the seed germination and emergence characteristics are most positive for the fine ash type. Additionally, the fine ash type with high silt and clay fraction, upon drying, will crack and provide seed niches for naturally dropped seeds or broadcast seeds. Furthermore, the water available to plants retained in the fine ash favors greater opportunity for seedlings to establish themselves than in the sand ash type which dries out rapidly. The extent to which the fine ash type enhances the annual plants over the perennial component, to a large extent, depends upon the frequency and intensity of storm systems.

Reduction, incorporation, or stabilization of the ash is a paramount issue to improve the environment for the health of the residents in the fallout area as well as the domestic and wild animals that forage on the land and that are dependent on relatively clean streams and ponded water. The deposition of ash may reduce the annual and weedy component for a few years; however, the year effect is still the dominant factor influencing the vegetative response. The ash additions, it is believed, have not altered significantly the primary deterent to rehabilitating those areas and that is reduction of competing species. Nevertheless the ash deposition, particularly that of the fine ash, may present us with an opportunity to rehabilitate low condition ranges because the ash layer may provide a suitable medium for seed coverage of aerial applied seed. This ash layer may be receptive to aerially broadcast seeds in 1) the fall (depending on the extent of its loosening up or its cracking) and 2) throughout the winter when the surface of the ash layer is saturated or when a free water surface system is on the ash layer. Reducing competition for the above situation requires the use of either a contact or residual type herbicide applied before seeding. Herbicides of both types are approved for such use.

If herbicides aerially applied for brush and weed control combined with aerially broadcast seeding (pelleted or unpelleted) are not successful, other alternatives for range improvement should be examined. Such alternatives should attempt to minimize cost, energy outlay, time, and environmental pollution. If chemical control of competitive species is successful but aerially broadcast seeding a failure, surface seeding combined with chemical control should be explored. Environmental pollution and wear on equipment should receive priority. Thus, seeding into the ash layer with roller equipment should be tested (i.e. Brillion-type seeders, land imprinter, Oregon Press seeder). Should all these combinations fail to provide a suitable way to rehabilitate poor condition range with an ash layer, we must return to competition reduction by discing or plowing and direct seed placement by drilling. Although this method has been proved suitable, in its seeding year, it will add considerably to air pollution but will incorporate the ash into the soil system quickly. The number of acres that can be treated in such a fashion are limited because 1) it is costly and 2) plowing and drilling on rangeland are slow. Therefore, if the ash layer offers a new dimension in rehabilitating those ranges in poor condition, such needs to be known quickly so the opportunity can be used.

In vitro digestion of commonly fed hays or of forest range grasses was neither enhanced nor reduced by the addition of ash to the forages or by the rumen innoculum from steers receiving two pounds (0.9 kilograms) of ash daily for 10 consecutive days. These results are consistent with the chemical analyses from which it was inferred that the ash was not rich in nutrients nor were toxic levels of metals indicated. Furthermore, there were no field reports in the 1980 grazing season from within the fallout zone that indicated strong animal performance reduction from cattle grazing those ranges. It is quite likely that the 1980 ash intake by grazing animals in the fallout zone approached the amount fed in these trials. Soil ingestion by cattle in Idaho on a silt loam range supporting a cheatgrass vegetation was measured up to 1.5 pound daily with soil concentration in feces estimated as high as 30 percent (Mayland *et al.* 1975).

Increased ash concentration in the feces of the ash treated animals was evident within 24 hours and peaked at 30 to 35 percent after approximately five days of daily ash treatment. Ash concentrations returned to a near normal level in about five days after ash treatment ceased. Here, too, the results suggest that the ruminant animal is quite capable of handling a high intake of ash without a significant effect on its performance.

But these trials were quite limited in nature. We do not know if ash particles embedded themselves in the digestive tract and, if so, what effect such will have in the long term or upon quality when the animal goes to slaughter. These newly formed ash particles are sharp-edged and abrasive; the wear and tear on the sensitive membranes of the digestive systems under continued exposure are unknown. In view of results from the digestion studies the greater impact of the ash may occur from its effect on the respiratory systems. With continued high intake of ash, the incidence of urinary calculi (water belly) could increase. Cattle were observed kicking at their belly, a sympton of water belly, (personal communication, J. A. Schlepp). Respiratory and urinary calculi problems can be reduced or minimized by having an ample supply of clean water available for grazing animals.

It is likely that tooth wear in the grazing animals within the fallout zone will increase. This increase in tooth wear will result not only from the increased ash ingested with the forage but also from the sharpness of the particles. There is no evidence to date that suggests St. Helens' ash to be harder, per se, than existing soil particles.

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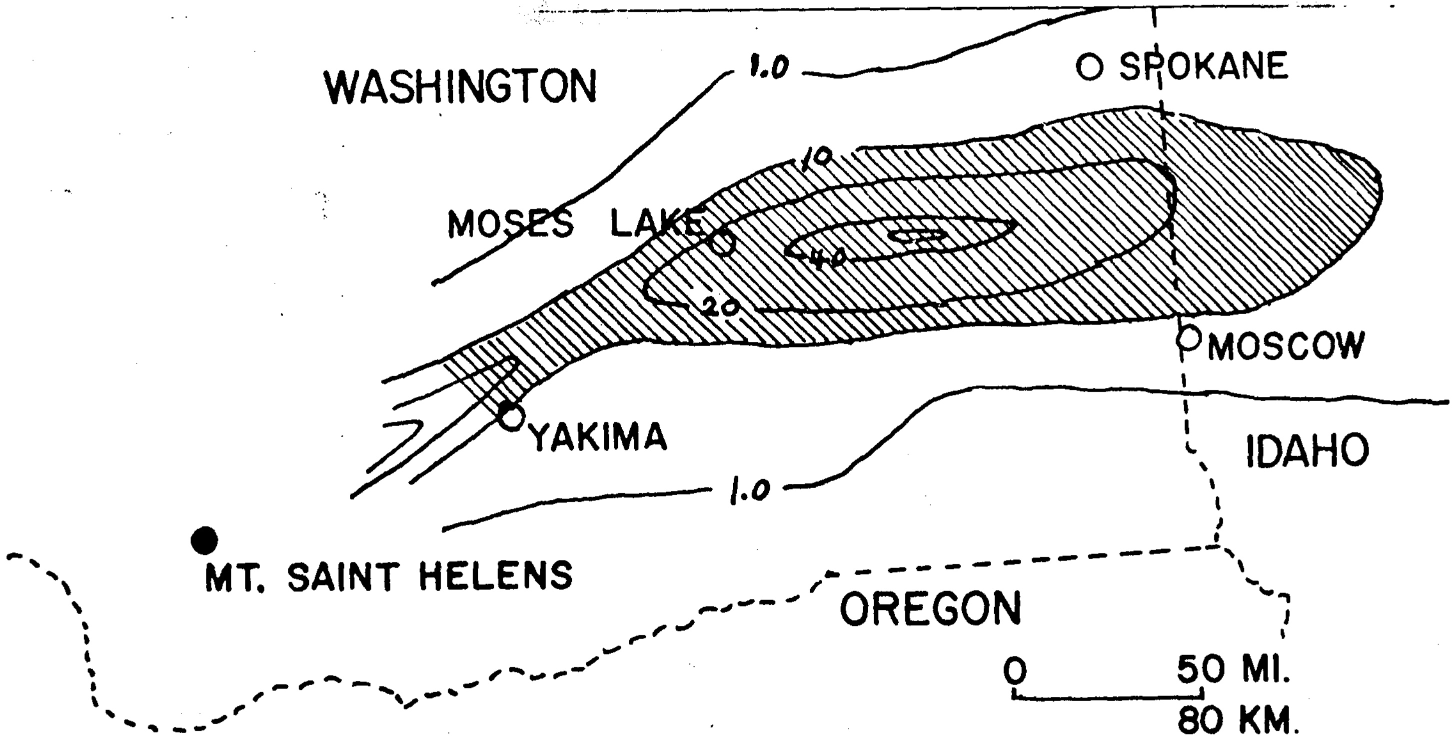

Figure 1. Ash fallout in mm (adapted from Sarna-Wojoicki et al. 1980)

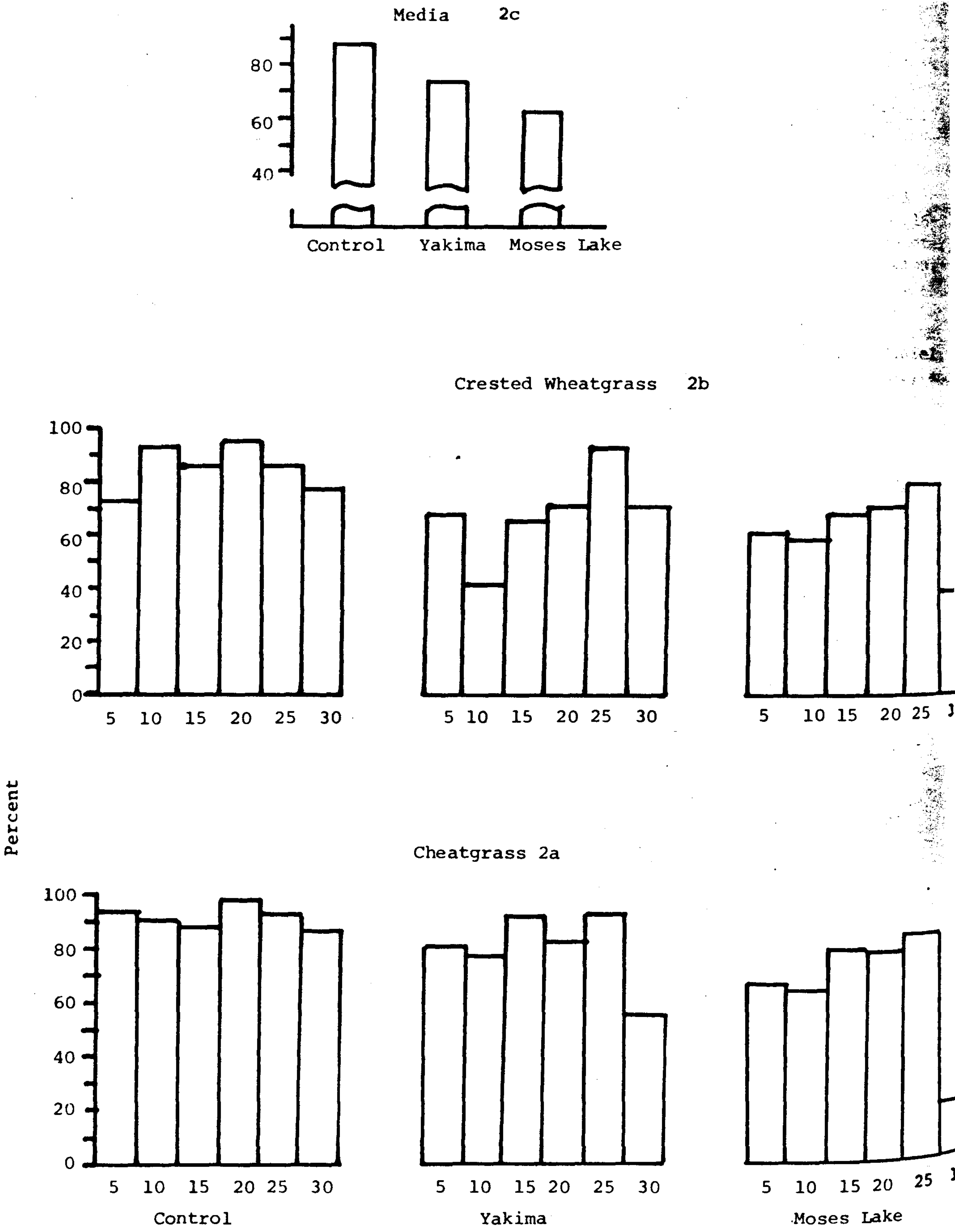

Figure 2. Seed germination in incubators as influenced by ash source and constant temperature (°C) (2a and 2b) and mean temperature response by location of ash source (2c).

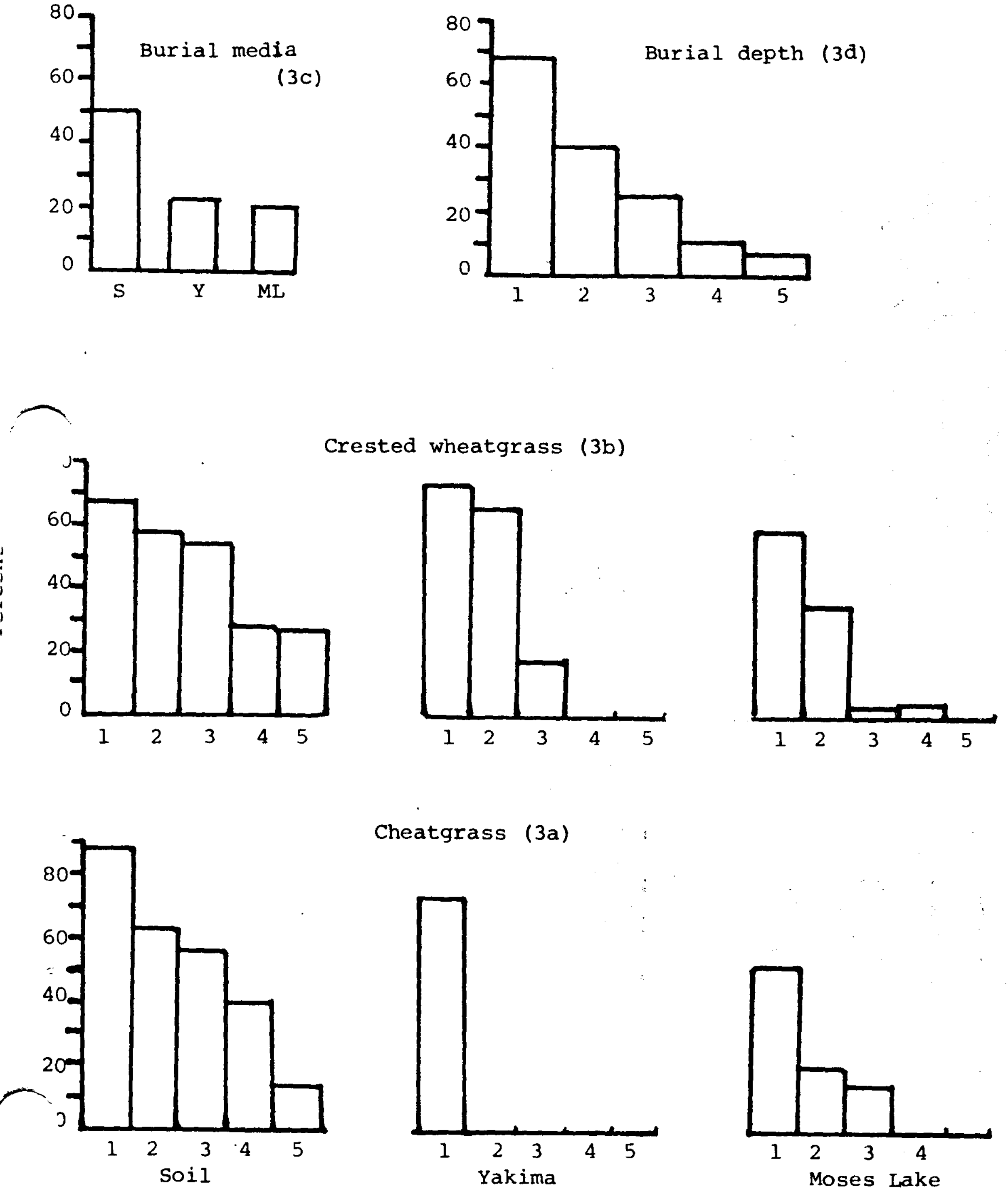

Figure 3. Seedling emergence as influenced by ash source and five depths of seed burial: 1, 2, 3, 4, and 5 = 0.4, 0.9, 1.4, 1.8, and 2.2 cm soil (S); 0.5, 1.0, 1.5, 2.0, 2.5 cm Yakima ash (Y); 0.8, 1.7, 2.5, 3.4, and 4.2 cm Moses Lake ash (ML) (3a and 3b); and response means for burial media (3c) and burial depths (3d).

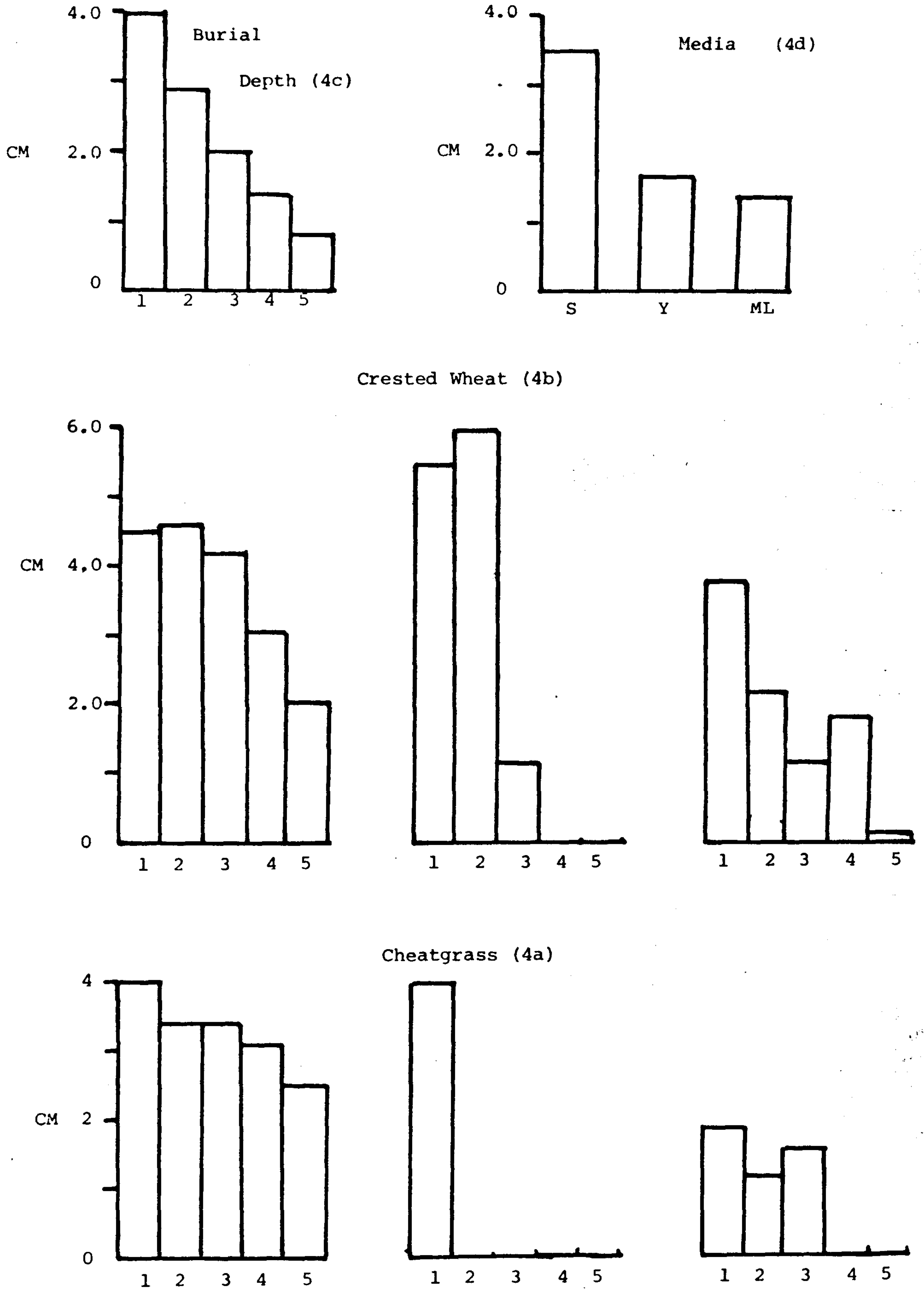

Figure 4. Seedling height as influenced by ash source and five depths of seed burial: 1, 2, 3, 4, and 5 = 0.4, 0.9, 1.4, 1.8, and 2.2 cm soil (S); 0.5, 1.0, 1.5, 2.0, 2.5 cm Yakima ash (Y); 0.8, 1.7, 2.5, 3.4, and 4.2 cm Moses Lake ash (ML) (4a and 4b); and response means for burial depths (4c) and burial media (4d).

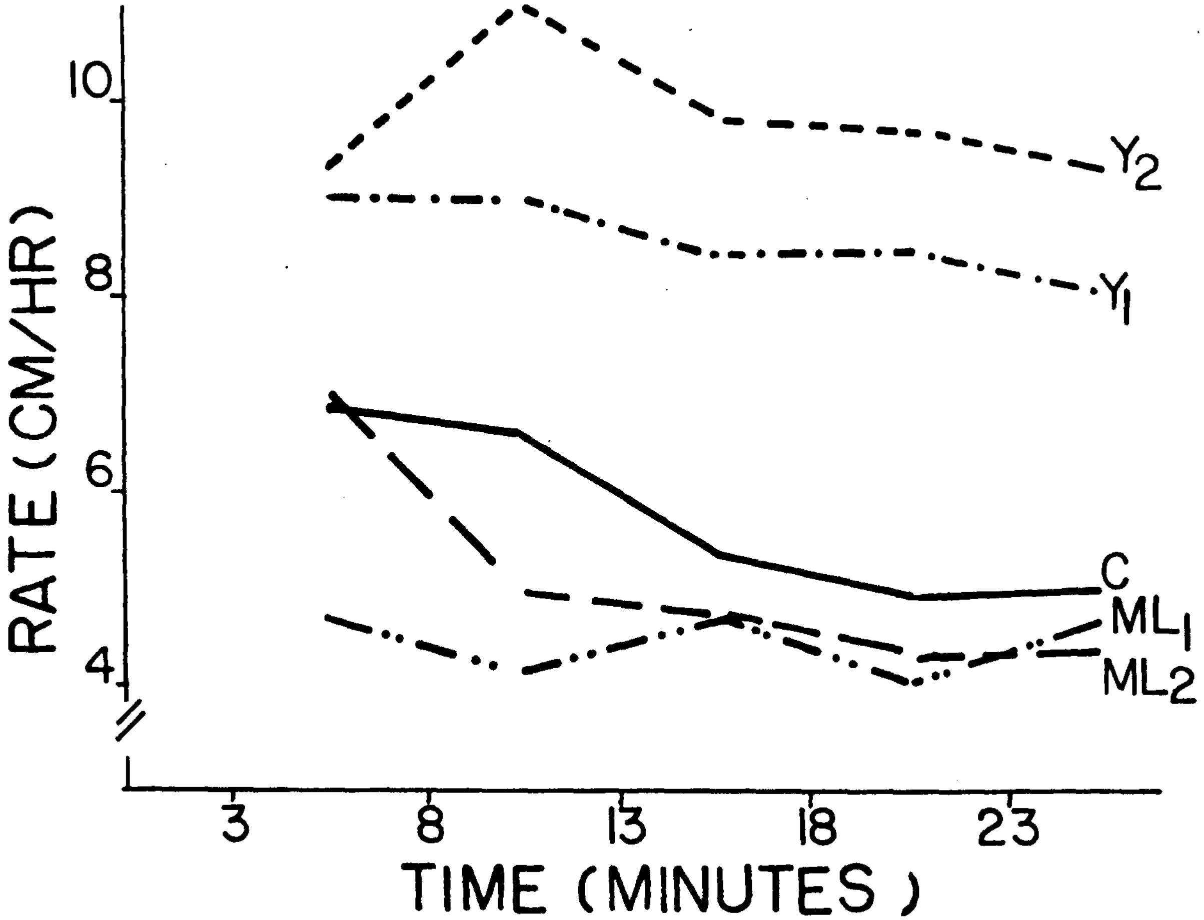

Figure 5. Rate of water entry into a sandy loam range soil supporting a mature crested wheatgrass stand as influenced by ash from Yakima (Y) and from Moses Lake (ML) applied to the soil surface at 100,000 (1) and 200,000 (2) kg/ha from a 10 cm/28-minute simulated rainstorm.

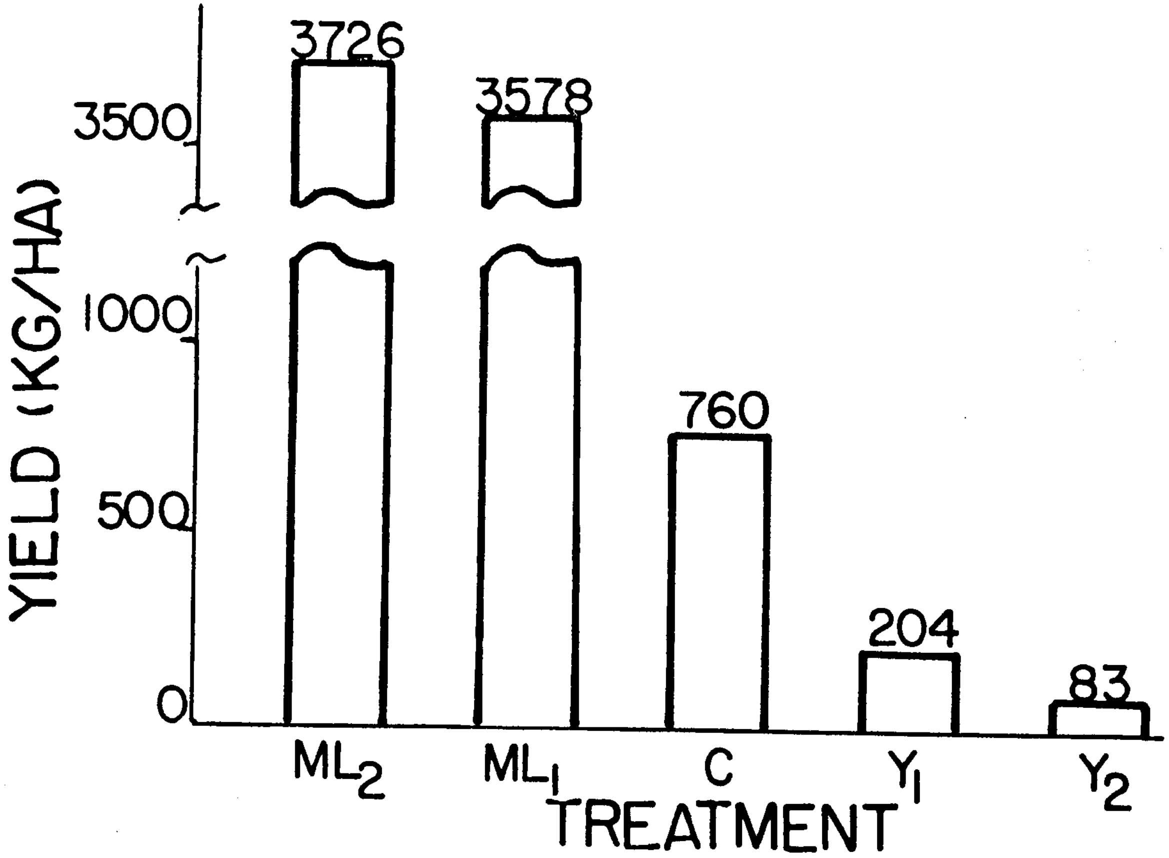

Figure 6. Sediment yield in the runoff of a 10 cm/28-minute simulated rainstorm applied to a sandy loam soil supporting mature crested wheatgrass as influenced by ash from Yakima (Y) and Moses Lake (ML) applied to the soil surface at 100,000 (1) and 200,000 (2) kg/ha.

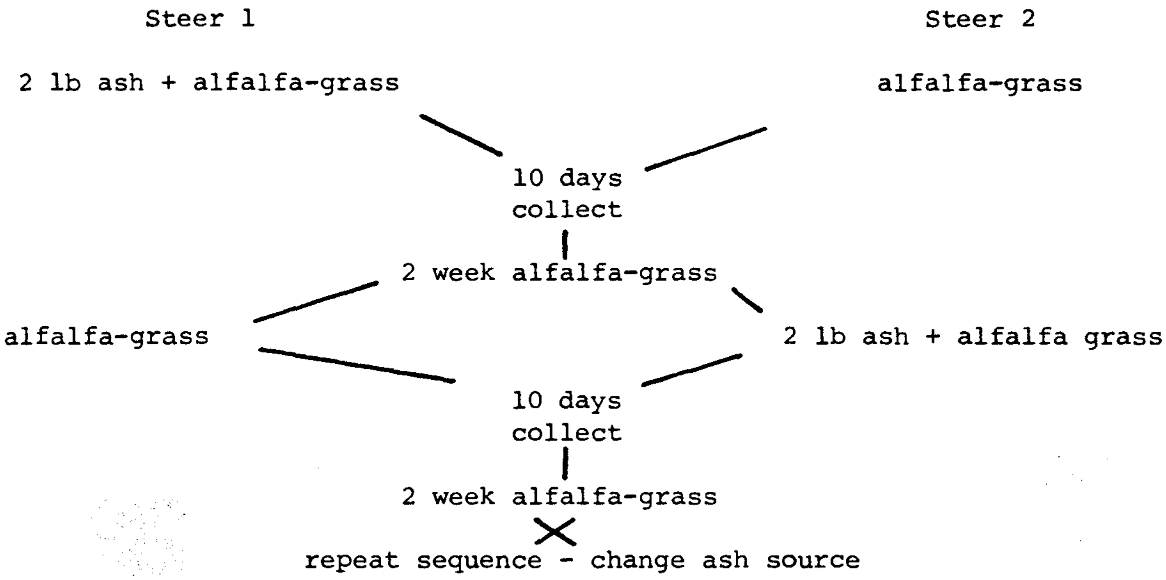

Figure 7. Switch back design for ash *in vitro* digestion study with cattle.

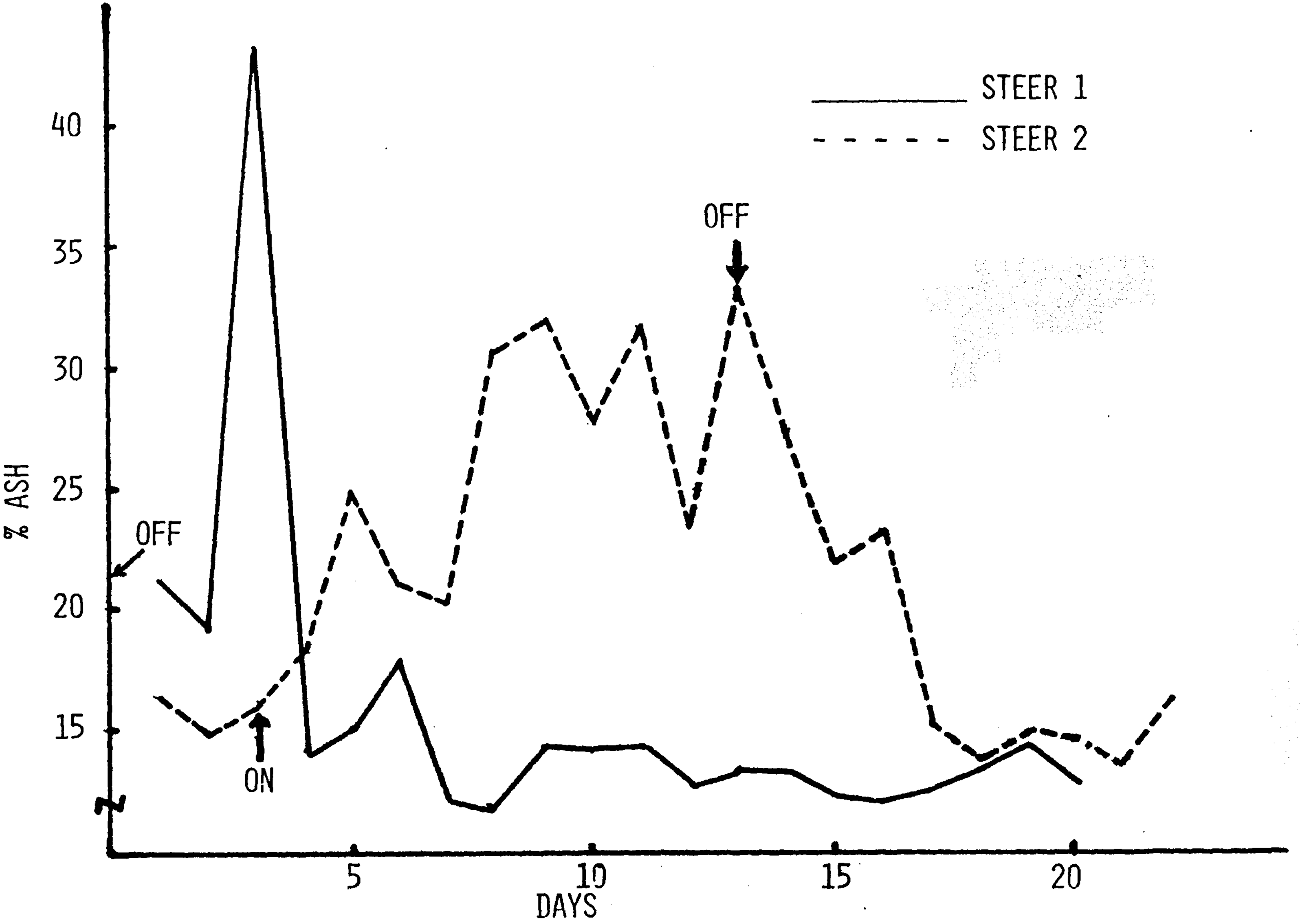

Figure 8. Percent ash in feces of steers administered ash via the rumen fistula. "On" refers to the first ash administration and "off" to the last day of ash administration.

Table 1. Chemical data on oven dry soil base, except p^H and EC of ash from the May 18, 1980, eruption of Mt. St. Helens

Characteristic	Collection Site Yakima	 Moses Lake	 Moscow	 Spokane
p^H, ash:water, 1:5	7.1	7.2	7.2	7.2
EC, 1:5, µmhos/cm	350	530	530	190
CEC, meq/100g by NH_4+	1.0	1.9	2.1	3.9
Water Extract (1:5)				
Na, ppm	120	220	85	66
K, ppm	32	37	20	34
Ca, ppm	120	200	54	42
Mg, ppm	17	29	14	15
P, ppm	< .0	< .2	< .5	< .5
Fe, ppm	1.3	1.5	2.0	1.7
Mn, ppm	2.9	3.9	1.8	2.1
Cu, ppm	< .0	<0.5	< .0	< .0
Zn, ppm	.0	.0	.0	.0
*F, ppm	.7	[1]	-	-
NH_4HOAC Extract				
K, ppm	45	80	63	90
Na, ppm	130	240	120	94
Ca, ppm	290	490	400	560
Mg, ppm	34	65	47	83
**P, ppm	1.2	1.9	3.6	-
Total N, ppm	20	16	90	590
DTPA Extract				
Fe, ppm	12	12	13	24
Mn, ppm	6	9	6	12
Cu, ppm	1.7	2.3	1.7	2.0
Zn, ppm	0.6	1.1	2.9	3.6
Rainfall from time of fallout until collection date, mm	11	84	73	39
Date of sample collection	28 May	3 June	5 June	7 June
Distance from St. Helens	130 km	250 km	390 km	400 km

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* F determined in a 100 g ash:33g H_2O extract by ion electrode.

** $NaHCO_3$ extractable P.

[1] not determined.

Table 2. Chemical data of oven dry ash from the May 18, 1980 eruption of Mt. St. Helens, except OSU data that are for the June 12, 1980 eruption, as related to agricultural production

Characteristics	USGS[1/]	MSU[2/]	WSU[3/]	WSU[4/]	USDA[5/]		OSU[6/]	UI[7/]	UI[8/]
General									
Texture	Silt loam	Silt loam	Silt loam	Silt loam	Sand	Silt loam	Sand	-	-
p^H, saturated paste	6.7-7.2	6.1	5.5	6.1	7.1	7.2	5.7	5.4	5.9
EC, mmhos/cm	1.4	4.1	6.5	5.0	0.3[5/]	0.4[5/]	0.4	3.5	3.6
CEC, meq/100 g	-	-	-	-	1.0	2.6	0.7	1.5	1.8
SAR	-	-	-	-	-	-	-	3.0	3.9
Saturated paste extract									
Na, ppm	48	-	260	-	120	120	-	150	190
K, ppm	18	-	27	-	32	30	-	23	18
Mg, ppm	9	-	54	-	17	20	-	36	47
Ca, ppm	66	-	270	-	120	100	-	240	240
Cl, ppm	54	-	640	-	-	-	-	330	370
SO_4-S, ppm KH_2PO_4+KCℓ extract	95	-	150	-	-	-	-	240	210
NH_4HOA_c extractable (except WSU)									
Na, ppm 1N NH_4OA_c,p^H7.0	200	220	410	230	130	150	23	124	130
K, ppm "	340	130	130	120[4/]	45	78	22	47	62
Mg, ppm	36	60	74	60	34	65	24	26	34
Ca, ppm	320	1100	1030	690	290	480	100	240	300
P, ppm	-	-	3	1.5[4/]	1.2[5/]	2.8[5/]	-	3.2[7/]	1.8
SO_4-S, ppm	-	950	-	340	-	-	8.5	-	-
DPTA extractable (except USGS)									
Cd, ppm	.02	-	.05	.04	-	-	-	-	-
Fe, ppm	15	76	40	18	12	16	-	17	12
Mn, ppm	3	19	15	13	6	9	1.6	7.0	12
Cu, ppm	3	8	4	4	2	2	0.8	4.0	4
Zn, ppm	.3	4	.8	.7	.6	2.5	0.5	0.7	0.7
Other									
P, acid flouride, ppm	-	65	-	-	-	-	33	-	-
B, hot water soluble, ppm	-	-	1.4	1.0	-	-	0.4	0.5	0.5
N, total, ppm	-	-	-	-	-	230	100	-	0.5
As, conc. HCl, ppm	-	-	T	-	-	-	-	-	-
Cl, hot water, ppm	-	-	590	400	-	-	-	-	-
F, spec. ion electrode, ppm	-	-	-	-	0.7	-	-	-	-
NO_3-N, ppm 2M KCℓ extract	-	-	-	-	-	-	0.3	-	4.7
NH_4-N, ppm	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]

1/ Mean nutrient concentrations in ash collected from eight sites (collected June 16-20, 1980) along a 75 km transect south from Ritzville, Washington, (approximately 5 cm of precipitation occurred during this period). Data were provided by L. P. Gough and R. C. Severson, U.S. Geological Survey, Denver, Colorado. Trace minerals were extracted by DTPA-NH_4HCO_3 (Soltanpour and Schwab 1977).

2/ Nutrient concentrations in ash collected at Bozeman, Montana. Data were provided by the Soil Testing Laboratory, Montana State University. Analysis performed immediately upon fallout.

3/ Nutrient concentration in ash collected May 18, 1980, at 9 pm PDT on a plastic surface at Pullman, Washington and analyzed by the Soil Testing Laboratory. Data were provided by A.R. Halvorson. The acetate extractable K, Mg, Ca, and P were extracted by NaHOAC.

4/ Mean nutrient concentrations in ash collected from 13 sites in Grant County (Columbia Basin), Washington (see note for WSU).

5/ Nutrient concentration in ash from Yakima (sand) and mean values for ash from Moses Lake, Moscow and Spokane from this study. Saturated paste was a 1:5, ash:water mixture and P was extracted in $NaHCO_3$.

6/ Mean nutrient concentration in ash from the June 12, 1980, eruption of . St. Helens and collected at eight locations within a 12 km radius of .llsboro, Oregon, following moderate rainfall. Data were provided by Ron Doerge and Hugh Gardner, OSU, Soil Testing Laboratory, Corvallis. pH measured using a 1:2 ash:water mixture.

7/ Nutrient concentrations in ash collected May 18, 1980, on the University of Idaho campus and analyzed by the Soil Testing Laboratory. Data were provided by Denny V. Naylor. The P was determined in a NaHOAC extract and NO_3- and NH_4- N determined by steam distillation.

8/ Mean nutrient concentrations in ash collected from five sites in the Moscow to Coeur d'Alene, Idaho area. Data were provided by Denny V. Naylor and R. McDole. The P was determined in a NaNOAC extract and NO_3- and NH_4-N were determined by steam distillation.

Table 3. Elemental analysis on the total ash from the May 18, 1980 Mt. St. Helens eruption

Element		Bozeman†	Fruchter,‡ et al.	Cook,§ et. al	Hooper,¶ et al.	USDA#
SiO_2,	%	69.5	65	60-70	66	-
Al,	%	4.6	8	8.5-9.5	8.8	-
Fe,	%	3.3	3.4	-	1.2	3.2
Mg,	%	1.5	1.3	-	.9	1.1
K,	%	.53	1.2	-	1.4	1.3
Ca,	%	.41	3.5	-	3.1	3.3
Na,	%	.12	3.4	-	3.4	-
Ti,	%	-	.41	-	.36	-
S,	%	.30	.08	-	-	-
P,	%	.17	.16	-	.07	-
N,	%	.09	-	-	-	-
F,	ppm	120	6‡	-	-	0.7
Cl,	ppm	-	660	-	-	-
Cr,	ppm	120	17	10-30	-	-
Ni,	ppm	96	15	6-27	-	-
Co,	ppm	75	19	15-30	-	-
Mn,	ppm	52	600		500	550
Cu,	ppm	26	36	25-40	-	33
Zn,	ppm	16	53	45-70	-	73
As,	ppm	5.8	3	< 2	-	-
Se,	ppm	1.3	< 1	< 1	-	-
Hg,	ppm	.05	.01	< .01	-	-
B,	ppm	<700	30	-	-	-
Mo,	ppm	< 75	3	-	-	-
Pb,	ppm	< 10	9	5-13	-	-
Cd,	ppm	< .2	< 3	< 3	-	-

† Total elemental concentration in ash fallout of the May 18, 1980, eruption collecte from an automobile windshield in Bozeman, Montana, and analyzed immediately by Laszlo Torma, chief of laboratory and staff of the Montana Department of Agriculture and Montana Agricultural Experiment Station, Bozeman.

‡ Total elemental concentration in ash fallout along a 550 km transect from Tietron, Washington, to Missoula, Montana. Fluorine is in the water soluble fraction. Data are from Fruchter, J.S. et al. (1980).

§ Total elemental concentration reported by Cook et al. (1981). Data are primarily those of Fruchter et al. (1980) and Hooper et al. (1980).

¶ Total elemental concentration determined by X-ray fluorescence of ash obtained during a time series of collections in the Moscow-Pullman area and reported by Hooper et al. (1980).

Total elemental concentrations determined by Mayland in this study.

. Physical characteristics of ash from the May 18, 1980, eruption of Mt. St. Helens

	Collection Site			
aracteristic	Yakima	Moses Lake	Moscow	Spokane
rticle size distribution				
% by dry sieving				
>1000 µm	T	.3	.2	.6
<1000 µm	100	99.7	99.8	99.4
< 500 µm	98	99	99	97
< 250 µm	75	99	99	96
< 105 µm	12	86	98	91
< 47 µm	8	57	68	66
% by hydrometer				
<50 µm	6	55	58	57
<20 µm	3	40	33	23
<10 µm	2	23	16	13
< 5 µm	1	10	7	4
< 1 µm	1	4	2	0
xture				
[illegible], %	92	42	28	30
t, %	7	51	68	68
Clay, %	1	7	4	2
Texture	Sand	Silt loam	Silt loam	Silt loam
ecific Density g/cm^3	2.64	2.42	2.46	2.41
rface Area, m^2/g	21	34	61	64
lk density, g/cm^3[1]	1.28	0.84	1.01	-

Determined from disturbed samples.

Table 5. Water retentivity characteristics of ash from the May 18, 1980, eruption of Mt. St. Helens

	Collection Site		
Characteristics	Yakima	Moses Lake	Mosc
Tension (bars)		Water Retention (%)	
0.1	12	41	44
0.3	8	36	27
1.0	7	18	12
2.0	3	7	6
4.0	2	4	4
8.0	2	4	4
15.0	2	4	4
Plant Available Water, %	6	32	23

Table 6. Forages digested and percent *in vitro* digestibility

Forages	Percent
First cut alfalfa - grass hay	56
First cut alfalfa - grass hay + barley	61
Second cut grass	60
Forested range forage - June	
1	58
2	55
3	55
Forest range forages - September	
1	42
2	40
3	44

Table 7. Effects of ash depth and source on the production and quality of crested wheatgrass at Squaw Butte

Attribute	Control	Yakima (1)[1]	Yakima (2)	Moses Lake (1)	Moses Lake (2)
Dry matter (%)	96	96	96	96	96
Ash (%)	9	11	10	10	10
Phosphorus (%)	.088	.088	.093	.086	.092
Crude protein (%)	3.6	3.5	3.2	3.4	3.7
Yield (gm/9.6 ft^2)	170	131	138	115	99

Ash applied June 10, at (1) 100,000 and (2) 200,000 kg/ha.