Plant Responses in Forests of the Tephra-Fall Zone

Joseph A. Antos and Donald B. Zobel

4.1 Introduction

Tephra fall is the most widespread disturbance resulting from volcanic activity (del Moral and Grishin 1999), including the 1980 eruption of Mount St. Helens (Sarna-Wojcicki et al. 1981). Tephra is rock debris ejected from a volcano that is transported through the air some distance from the vent that produced it. Fine-textured tephra (less than 2 mm in diameter) is referred to as volcanic ash. Tephra may be transported far from a volcano and affect vegetation over thousands of square kilometers, well beyond the influence of other types of volcanic ejecta. Individual tephra deposits from volcanoes in the Cascade Range have been traced east into the Great Plains, and others cover much of the Pacific Northwest (Shipley and Sarna-Wojcicki 1983). Mount St. Helens has been the most frequent source of tephra in the Cascades for 40,000 years, producing dozens of tephra layers equal to or larger than the 1980 eruption, three experienced by trees alive in 1980 (1480, 1800, and 1980; Mullineaux 1996). The likely extent and magnitude of past volcanic eruptions are apparent in Cascade Range soils near or downwind from major volcanoes, soils that are largely formed from tephra (Franklin and Dyrness 1973), and in the large amounts of tephra in soils far east of the Cascade Range (Smith et al. 1968).

Tephra has had major effects on plants in many parts of the world (Table 1.1). Some trees may survive burial by tephra 2 m deep, but smaller plants are killed by much thinner deposits (Antos and Zobel 1987). Thin layers (a few millimeters thick) are likely to have little effect on plants. Between these extremes, various combinations of depth, texture, and frequency of deposition produce a wide range of plant responses (Antos and Zobel 1987). Effects of tephra on plants may include direct damage from impact, alteration of leaf gas and energy exchange by tephra adhering to foliage, modification of the soil environment, and burial of small plants and seed banks. Leachate from tephra may contain toxic elements that damage root systems. Conversely, tephra can be a source of plant nutrients, although it lacks nitrogen and most of its phosphorus is not easily leached (Hinkley 1987). Fine-textured tephra may harden after wetting to produce a surface crust with poor permeability to water. Such a crust is often dense and strong enough to restrict plant growth. For smaller plants, burial is the most important effect of tephra, and the ability to grow through the deposit is a key to survival (Griggs 1919, 1922; Antos and Zobel 1987).

From 1980 to 2000, we have studied the effects of Mount St. Helens tephra on understory plants in old-growth conifer forests with trees more than 500 years old, using two sites at each of two tephra depths, 4.5 and 15 cm, located 22 and 58 km northeast of the crater (Table 4.1). The sites are on flat topography at elevations between 1160 and 1290 m, in the Abies amabilis (Pacific silver fir) vegetation zone of Franklin and Dyrness (1973). Large conifer trees, including Tsuga heterophylla (western hemlock), T. mertensiana (mountain hemlock), Pacific silver fir, Pseudotsuga menziesii (Douglas-fir), and Chamaecyparis nootkatensis (Alaska cedar), dominate the sites, with a patchy distribution of smaller trees, primarily Pacific silver fir and Tsuga spp. (hemlocks). Before the eruption, understories contained ericaceous shrub layers 1 to 1.5 m tall with 17% to 45% cover, primarily Vaccinium membranaceum (big huckleberry) and V. ovalifolium (ovalleaf huckleberry). Herbaceous layers varied considerably among sites in cover (6% to 35%) and diversity (Table 4.1), but included a variety of growth forms. Bryophyte layers (9% to 36% cover) were dominated by Dicranum spp. (broom mosses) and Rhytidiopsis robusta (pipecleaner moss) (Zobel and Antos 1997). Wood more than 5 cm in diameter covered 3% to 11% of the preeruption surface. For 3 years after the eruption, from 1980 to 1983, we also sampled sites with 2- and 7.5-cm tephra at 550 and 880 m in elevation, respectively, in the western hemlock zone (Antos and Zobel 1985b, 1986). Our intent was to study long-term effects of tephra deposits on understory plants; thus, our intensive study sites have gentle slopes, although most Cascade Range topography in the tephra-fall zone is steep. On some very steep slopes, erosion was extensive, producing much greater understory cover. However, on many steep
slopes erosion was limited to small channels. The residual tree canopy and resultant litterfall appear to have quickly stabilized the tephra surface. Conversely, few areas, including the flattest, completely lacked erosion channels. Our sites experienced minimal erosion. The conditions we studied represent the maximum likely impact from the deposition of 4.5 to 15.0 cm of tephra.

At each site, we used repeated sampling of permanent plots of two types (one with natural tephra and one with tephra removed soon after the eruption). Within each site, plots were arrayed in several transects, with plots at 2-m intervals, and transects several meters apart. The plots sampled at each site were located within an approximately 1-ha area. Each sample plot was 1 m square. At each site, 100 plots were established on undisturbed tephra. In 50 additional plots, we removed the tephra carefully during the summer of 1980. These cleared plots were used to estimate the preruption vegetation of the site. Transects of cleared plots were interspersed among those with natural tephra. At the deep-tephra, herb-rich site (DR; see Table 4.1), 50 additional plots were cleared in late summer 1982 (2 years postdisturbance). These 50 plots were used to demonstrate vegetation change following delayed erosion of tephra.

Plant cover and density were measured for each species of vascular plant, and cover was measured for each bryophyte taxon. Seedling data were separated for preruption and posteruption trees, and for first-year and older seedlings. All sites (see Table 4.1) were measured in 1980 to 1983, 1989 or 1990, and 2000. Sites with deep tephra were also assessed in 1984 and 1987. At the shallow-tephra, herb-rich site (SR; Table 4.1) we did not assess herb density in 1989. We consider 1981 values for cleared plots to be effective estimates of preruption species importance for our sites (Zobel and Antos 1997).

We have used data from these permanent plots along with studies of plant growth through tephra (Antos and Zobel 1985a,c; Zobel and Antos 1987a,b), ability of plants to survive burial (Zobel and Antos 1986, 1992), and tree-seedling growth in tephra (Zobel and Antos 1991b) to evaluate the course and mechanisms of vegetation change following disturbance by tephra. Here we summarize and synthesize our work and that of others in the tephra-fall zone, present recent findings from sampling conducted in 2000, and evaluate possible factors controlling vegetation change, prospects for future change, and how vegetation change in the tephra-fall zone differs from that responding to other forms of disturbance.

4.2 Characteristics of the Tephra Disturbance

At elevations of 1160 to 1250 m near Mount St. Helens, snowpack is typically present during May. In May 1980, both of our two main study areas still had a patchy distribution of snowpack as well as areas without snow. At each area, a slightly higher elevation site with a dense herbaceous layer and moister soil was mostly snow covered, whereas a nearby site with a poorer herb layer was mostly snow free (Antos and Zobel 1982; see Table 4.1). No plants had developed new foliage at our main study sites. There was no evidence that the temperature of the tephra during deposition was high enough to damage plants.

Our sites received tephra depositions of about either 4.5 cm or 15 cm in depth, thicknesses that were first measured after several rains had compacted the new-fallen tephra. The compacted thickness of tephra is sometimes only half the noncompacted thickness displayed in geological reports, at least for fine tephra (Sarna-Wojcicki et al. 1981). We recognized three strata in the tephra deposits (Zobel and Antos 1991a): (1) debris from the lateral blast produced a dark, fine-textured, sticky basal layer, 4 to 7 mm thick in 1987; (2) a coarse, single-grained pumice layer 33 mm deep at 58 km from the crater and 114 to 135 mm deep at 22 km; and (3) a crust dominated by fine particles, 8 mm thick at 58 km and 16 mm thick at 22 km, which hardened after wetting and drying. Eruptions after May 18 contributed only scattered gravel and sand to the surface of the deposit. Texture was coarser near the volcano: particles less than 2 mm in diameter represented 82% of the mass of the crust at 22 km and more than 99% at 58 km; corresponding values for the single-grained layer were 70% and more than 99% for particles less than 2 mm in diameter, respectively (Zobel and Antos 1991a).

Tephra properties varied within stands. Depths ranged from 12 to 18 cm at the deep-tephra sites in areas without erosion or slumping of the deposit. Crust was thicker beneath the forest

<table>
<thead>
<tr>
<th>Site code</th>
<th>Conditions (tephra depth/herb diversity)</th>
<th>Tephra depth (cm)</th>
<th>Number of herb species</th>
<th>Elevation (m)</th>
<th>Distance to crater (km)</th>
<th>Snow cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>Shallow/poor</td>
<td>&lt;5</td>
<td>9</td>
<td>1245</td>
<td>58</td>
<td>29</td>
</tr>
<tr>
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<td>26</td>
<td>1290</td>
<td>58</td>
<td>92</td>
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<tr>
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<td>12</td>
<td>1160</td>
<td>22</td>
<td>11</td>
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<td>32</td>
<td>1240</td>
<td>22</td>
<td>88</td>
</tr>
</tbody>
</table>

At each site, there were one hundred 1-m² plots on natural tephra and fifty 1-m² plots with tephra removed in 1980; at site DR, there were fifty 1-m² plots with tephra removed in 1982. Plots were read (cover and density by species) at all sites in 1980, 1981, 1982, 1983, and 2000; plots were read at DR and DP in 1984, 1987, and 1990 and at SR and SP in 1989.

Source: Details of the sampling procedures are given in Antos and Zobel (1985b) and Zobel and Antos (1997).