Influence of Volcanic Ash on Infectivity and Reproduction of Two Species of *Meloidogyne*[1]

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Abstract: Mount St. Helens volcanic ash was incorporated into a loamy sand greenhouse soil mix to produce concentrations of 0, 0.5, 1.0, 2.0, 4.0, 8.0, 25, 50 and 100% ash. Chemical and physical properties of the various mixtures were determined. Three experiments were conducted in a greenhouse to determine if volcanic ash had any influence on root-knot nematode survival and infectivity. Tomato, *Lycoperscion esculentum,* seedlings cv. Columbia, susceptible to *Meloidogyne hapla* and *M. chitwoodi* were planted into pots of the soil-ash concentrations and infested with one of the two nematode species. Tomato seedlings were harvested 30, 50 and 60 days later and the roots examined for nematode infection and reproduction. Ash incorporation had no deliterious effect on root-knot nematodes in any of the experiments reported here. Nematode infection and reproduction on tomato were not affected at any ash concentration.

The Cascade mountain range which extends some 1,125 km from northern California through Oregon, Washington, and into British Columbia, Canada, has a geologic history of volcanic activity. On 18 May 1980 Mount St. Helens, located in southwest Washington violently erupted. An estimated 3–3.5 × $10^9 m^3$ of volcanic ash was deposited in amounts up to 300 metric T/ha over 2 × $10^5 km^2$ of land that extended east-northeast from Mt. St. Helens (1,3). The majority of ash from the eruption was deposited in a belt extending across central and eastern Washington (Fig. 1) and then decreasingly into Idaho and western Montana. Depositions ranged from 8 cm to a detectable trace with most areas receiving < 2.5 cm. Predictably, the particle-size distribution changed with distance from the eruption site. Particle size near Yakima (about 125 km from Mt. St. Helens) ranged from 0.001–0.3 mm. Correspondingly larger proportions of finer grained dust-size particles of a maximum particle size near 0.05 mm were encountered at greater distances. This resulted in three generalized areas of ash fall consisting principally of coarse, intermediate, and fine ash deposition. These areas were defined by the percentage of ash passing through a No. 200 sieve (75 μm) (5).

The two main constituents of the ash were pumiceous volcanic glass (SiO_2) and crystal fragments of feldspar (Ca, Na-Al silicates). Amphibole, pyroxene, and magnetite were also present in lesser amounts. These minerals existed as oxides of Ca, Fe, K, Mg, Mn, Na and P. Trace elements detected in the ash were Cd, Cl, Co, Cu, F, Hg, Ni, Se, Zn, and also sulfate S. Ash pH was variable but generally on the acid side (1). Morphology of numerous soils in the northwest are identifiable with past eruptions of greater magnitude.

Much of the arable land inundated with ash was in the fertile Columbia Basin of central Washington and the large wheat producing area to the east. Root-knot nematodes are widespread, particularly in the Columbia Basin where the Northern (*Meloidogyne hapla* Chitwood) and Columbia (*M. chitwoodi* Golden et al.) root-knot nematodes are the dominant species. Questions arose concerning the effect of ash incorporation into the soil profile on these two nematodes. Experiments were conducted to observe the influence of varying ash concentrations incorporated into soil on

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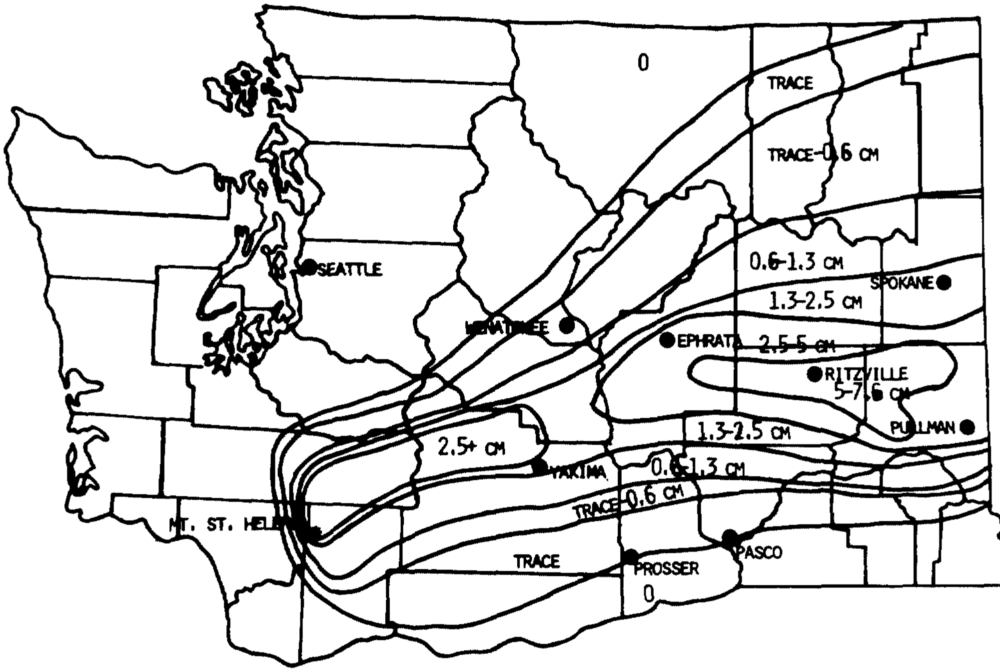

Fig. 1. Volcanic ash distribution in Washington state shortly after the eruption of Mount St. Helens. (Courtesy Washington State Department of Natural Resources.)

the survival and the ability of *M. hapla* and *M. chitwoodi* to invade and develop on tomato (*Lycopersicon esculentum* Mill.) seedlings.

MATERIALS AND METHODS

Three experiments were conducted in a greenhouse using various concentrations of volcanic ash collected in central Washington from the 18 May Mt. St. Helens eruption. The physical and chemical characteristics of the ash used in our studies are shown in Table 1.

Various volumetric concentrations of air dry ash were added to regular, methyl bromide fumigated, greenhouse potting soil containing a sand:sandy loam mix (1:1) and blended in a soil mixer while tap water was added to wet the mixture to 75–80% of field capacity. Four hundred ml of the mix was placed in plastic bags into which 10,000 eggs of either *M. hapla* or *M. chitwoodi*

Table 1. Chemical and physical properties of soils with various amounts of volcanic ash.

	Properties						Particle-size distribution (%)		
Soil % ash	pH	Organic matter (%)	NO_3* Nitrogen (ppm)	P† (ppm)	K† (ppm)	Salts (mmhos/cm)	<2 μm	2-50 μm	>50 μm
0	7.5	0.3	0.7	4.2	140	0.42	3.2	10.5	86.3
0.5	7.5	0.2	1.2	5.8	147	0.86	3.3	11.4	85.3
1.0	7.5	0.2	1.5	5.8	151	0.85	3.4	10.8	85.8
2.0	7.5	0.2	1.6	6.4	155	1.03	3.4	11.2	85.4
4.0	7.4	0.2	1.9	5.8	147	1.20	3.6	12.4	84.0
8.0	7.5	0.2	2.5	6.1	151	1.80	3.9	11.8	84.3
25.0	7.5	0.3	1.1	3.7	140	1.77	3.3	13.1	83.6
50.0	7.2	0.2	3.7	5.1	131	4.45	6.1	22.7	71.2
100.0	7.0	0.3	8.7	6.4	155	6.80	11.6	37.0	51.4

*Phenoldisulphonic acid method.
†Bicarbonate method.

were pipetted. Eggs were obtained from tomato cultures using the NaOCl method described by Hussey and Barker (4). Bags were stored for 1 wk at 24 C, then the contents were poured into 10-cm plastic pots and each concentration and nematode species were randomized on a greenhouse bench in five replicates. Pots were watered daily with tap water to maintain soil moisture. The ambient greenhouse temperature mean was 22 C. After 1 wk, a single month-old tomato seedling cv. Columbia was transplanted into each pot. Seedlings were watered regularly and observed for any adverse symptom expression. The first two experiments were harvested after 30 and 50 d, respectively, and were not provided supplemental fertilization. The third, harvested after 60 d, received supplemental N-P-K at 45 d. At harvest the roots were carefully removed from the pots, washed free of soil-ash mix, and given a visual gall/infection rating with the aid of a stereoscopic microscope. In the third experiment, numbers of egg masses were also determined. The roots were then incubated in plastic bags for 4 d before juvenile counts were made. Roots were weighed moist and the number of juveniles/g root determined.

RESULTS AND DISCUSSION

No apparent foliar differences other than slight leaf nutritional deficiency of plants in the control soil were observed between treatments, not even with those plants grown in 100% ash.

In our samples ash pH was > 7 (Table 1), and the conductivity of 50% and 100% ash was 4.45 and 6.80 mmhos/cm, respectively. This conductivity would be considered excessive to salt intolerant crops, but no effect was visible in our plants. Particle-size diameters greater than 50 μm are considered the sand fraction of a soil (7). In our studies about 51% of the ash particles were greater than 50 μm; in the soil-ash mixtures the percent of particles greater than 50 μm ranged from 71.2 to 86.3 (Table 1) as determined by the hydometer method (2).

The first experiment showed that ash incorporation had no deleterious effect on root-knot nematodes, and suggested that it might even enhance their ability to infect plants (Table 2). Subsequent experiments did not substantiate this, but did show that nematode infectivity and reproduction were not impaired by ash.

After the eruption at least 99% of the ash settled as a layer on the soil surface. Since the ash does not melt, dissolve, or readily percolate into the soil profile, it is either carried off by erosion or incorporated into the soil by machinery. Therefore, soil incorporation will occur during normal tillage practices. In the last experiment (Table 3) a small amount of ash was mixed with soil to produce mixtures that represent field conditions after the ash is incorporated into the soil. Infection rating and egg mass production were similar in all combinations. However, number of juveniles extracted from roots increased with ash content (Table 3), but this was significant ($P = 0.05$) only for *M. chitwoodi*.

In the three experiments reported here, *M. chitwoodi* infection and egg production were consistently lower than *M. hapla* on Columbia tomato. Columbia was used be-

Table 2. Effect of various percentages of volcanic ash in a soil-ash mix on gall and infection ratings of tomato, *Lycopersicon esculentum* cv. Columbia, 30 and 50 d after inoculation with *Meloidogyne hapla* or *M. chitwoodi*.

% Ash (v:v)	*M. hapla* Gall* 30	*M. hapla* Gall* 50	*M. hapla* Infection† 30	*M. hapla* Infection† 50	*M. chitwoodi* Gall* 30	*M. chitwoodi* Gall* 50	*M. chitwoodi* Infection† 30	*M. chitwoodi* Infection† 50
	Days after inoculation							
0	82	>100	2.5	2.6	67	90	1.0	2.4
25	>100	>100	4.0	3.2	100	90	2.0	2.6
50	>100	>100	4.0	3.8	100	60	2.5	2.0
100		>100		3.6				2.4

*Number of galls/plant; values are means of five replicates.
†Subjective rating, 0–4: 0 = no infection, 4 = severe infection.

Table 3. Effect of various percentages of volcanic ash in a soil-ash mix on infection of tomato, *Lycopersicon esculentum* cv. Columbia, by *Meloidogyne hapla* and *M. chitwoodi*, and the reproduction (egg mass rating and juveniles/g root) of the nematode after 60 d.

% Ash (v:v)	*M. hapla*			*M. chitwoodi*		
	Infection*	Egg mass†	Juveniles ($\times 10^3$)‡	Infection*	Egg mass†	Juveniles ($\times 10^3$)‡
0	3.8	3.8	14.5 a	4.0	2.6	1.8 bc
0.5	4.0	4.0	13.9 a	2.6	1.8	1.2 c
1.0	4.0	3.8	15.6 a	3.8	2.8	3.2 ab
2.0	4.0	4.0	15.1 a	4.0	2.8	2.9 ab
4.0	4.0	4.0	19.1 a	3.6	2.6	5.4 a
8.0	4.0	4.0	15.7 a	3.8	3.0	3.0 ab

*Subjective rating, 0–4: 0 = no infection, 4 = severe infection.

†Subjective rating, 0–4: 0 = no egg masses, 4 = many egg masses.

‡Values are mean numbers of juveniles recovered by root incubation from five replicates. Data followed by the same letter in columns are not significantly different ($P = 0.05$) accordiing to Duncan's multiple-range test.

cause galls are readily formed with *M. chitwoodi* infections, which does not always occur on other cultivars.

While the ash is lethal to certain insects because of abrasion (1), under the conditions reported here, ash had no measured effect on two species of root-knot nematodes. However, affects that develop over a long period may be pronounced. The ash-covered surface has a higher albedo and a lower permeability for water than the underlying soil. This condition may persist even after the ash is fully incorporated with the tillage layer. In time the finer particles may fill in the spaces around coarser fragments and reduce porosity and drainage. The greater reflectance of ash-covered surfaces has also resulted in lower soil temperatures and less soil water evaporation (1).

It is generally believed that the new ash fall will have little influence on long-term agriculture, since the 1980 eruption was modest by comparison with some of the others during the more than 35,000 years of eruptive history of Mt. St. Helens (6).

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