

# Role of Fungi in Postfire Stabilization of Chaparral Ash Beds<sup>1</sup>

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Wildfire and flooding after wildfire in chaparral have been problems to land managers for many years. Because postfire floods frequently take the form of mudflows, the problem is complex, involving sediment management and ecosystem management as well as protection of lives and property. It is unrealistic to expect to stop post-fire sedimentation completely, but reducing the size of individual events and minimizing potential damage are attainable goals.

Solutions to the sediment production problem take one of two approaches: engineering and biological. Crib dams, debris basins, flood control dams, and flood control channels are examples of the engineering approach. These structures function by trapping or diverting sediments that would otherwise damage developed areas. Although all these structures are essential to sediment management, they do have drawbacks. They are expensive to build and maintain, and they divert sediments formerly transported to the ocean where they replenished beach sand constantly eroded by wave action (Brownlie and Taylor 1981).

One biological approach, in use for several years, has been to seed burned areas with grass, particularly to annual ryegrass (*Lolium* spp.). This treatment is of questionable value for erosion reduction and has definite drawbacks, and land managers are presently seeking biological alternatives. One such alternative is the use of heat-shock soil fungi, a group indigenous to chaparral. This group, long known to be present but without an identified ecological function, occurs in most ecosystems associated with fire. They require a period of heating before their spores will germinate, yet the organisms are not thermophilic since they will not grow at the

<sup>1</sup>Presented at the Symposium on Dynamics and Management of Mediterranean-type Ecosystems, June 22-26, 1981, San Diego, California.

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Abstract: Raindrop impact is a major agent of soil erosion, and any reduction in its effectiveness reduces sediment production from burned watersheds. A chaparral soil treated with heat-shock fungi in three combinations was compared to sterile soil to test the ability of postfire heat-shock fungi to diminish raindrop impact erosion. Two to three times as much sediment was detached from sterile soil as from any of the three fungal treatments. A 1-month incubation period was sufficient to allow all fungal treatments to resist raindrop impact.

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elevated temperatures characteristic of thermophiles. The heat-shock fungi in ash beds are adapted to the high ammonium and pH conditions of the ash and are capable of very rapid growth rates. They are, however, unable to compete against other saprophytic fungi (El-Abyad and Webster 1968a,b) and are only active during the period following a fire. Fire kills the nonheat-shock saprobes, but they later reinvade from outside areas. There is also a possibility that heat-shock fungi will be eliminated or their numbers seriously reduced if a fire is extremely hot over dry soil or hot over a wet soil (Dunn and DeBano 1977).

Many fungi, including heat-shock fungi, are capable of soil aggregation (Tisdall and others 1978, Harris and others 1966). The mycelium surrounds the soil particles and intertwines among them to form aggregates. The aggregates show a high degree of stability (Harris and others 1966) and thus are resistant to soil detachment by falling raindrops, one of the major soil erosion processes (Mutchler and Young 1975, Wells and Palmer 1981). Heat-shock fungi form definite crusts on the surface of ash beds, and often produce fruiting bodies on this surface or on charred twigs and grass blades poking up through it (Zak and Wicklow 1978, 1980).

In southern California chaparral, there are five principal heat-shock fungi: *Pyronema omphalodes* (Bull. ex St.-Amans) Fuckel, *Aspergillus fischeri* var. *glaber* Fennell and Raper, *Gelasinospora cerealis* Dowding, *Hemicola fuscoatra* Traaen, and *A. fumigatus* Fresenius. These fungi seem to be distributed throughout southern California chaparral soils, although local dominance by a given species tends to vary.

This paper examines the ability of heat-shock fungi to stabilize the ash layer and prevent soil erosion by raindrop impact.

## MATERIALS AND METHODS

The soil used was a Soper loam, an argixeroll, collected in Bluebird Canyon on the San Dimas Experimental Forest in southern California. Litter was collected from the soil surface, and soil was collected from the upper 5 cm of mineral

soil. The litter was ashed until black, but still recognizable. The ash was then sieved to remove soil and large particles and then ground to pass the 0.5-mm sieve of a Wylie Mill. The soil sample was sieved at 2 mm.

The soil was given two treatments. First, moist soil was heat-shocked by oven heating the soil to 60° C and maintaining that temperature for 30 minutes, conditions typical of subsurface layers during fire. The time and temperatures for heat-shocking were chosen on the basis of moisture content (Dunn and DeBano 1977). The second treatment, sterilization, was done by steam autoclaving for 90 minutes on four successive days. Sterility was tested by plating on tryptic soy agar (DIFCO).

All soil was handled under sterile conditions. Soil was moistened to field capacity, placed in petri dishes (100 mm by 15 mm), leveled at approximately 13 mm with a spatula, and sprinkled with ash to a 1-mm thickness. For inoculated samples, 1 ml of the inoculum solution was placed dropwise over the surface of the ash layer. Lids were placed on petri plates and plates were incubated 30 days at 24° C. Plates were watered by misting with sterile water every Monday and Thursday. Before testing, all plates were allowed to dry to 10 percent moisture.

#### Inoculum Preparation

Soil from Monroe Truck Trail on the San Dimas Experimental Forest was heat-shocked for 1.5 hr in a 60° C oven and plated on Martin's II, an agar with penicillin and streptomycin, each at 50 units per ml agar. *Aspergillus fischeri* var. *glaber* was isolated and cultured on Czapek solution agar, which induces production of conidia and ascospores. Conidia were suspended in 0.04 percent sterile saline solution by disturbance with sterile glass beads. Spore counts were made with a hemocytometer and inoculum diluted to  $2.2 \times 10^6$  spores per ml.

#### Rain Tower Testing

A 5-m enclosed rain tower, designed by two of the authors<sup>3</sup>, and built by Keck Engineering Laboratory, California Institute of Technology, was used for testing. Waterdrops were produced individually under a constant head, and a collimator of 90 percent fused alumina was installed near the bottom to screen out drops falling off center. A 19-gauge needle with a square-cut point produced a 3.3-mm waterdrop with a mass of an 18.5 mg.

<sup>3</sup>Wells, W. G. II; Dunn, P. h.; Wohlgenuth, P. M. A 5 meter rain tower for testing soil treatments for surface stability. (Unpublished manuscript).

The samples in 100-mm petri dishes were placed in the bottom of the tower on a small platform which had a 35-percent slope. A thin piece of plastic 110 mm in diameter, with a 10-mm hole in the center, was placed on the surface of the ash to keep it from sticking to the bottom of the sample cup. This was an aluminum cup (resembling a Dixie cup) fabricated with a 10-mm hole in the cup bottom and placed on the plastic with the holes aligning. The aluminum cup was handled with alcohol-rinsed tweezers.

Three drops of water were allowed to strike the exposed 10-mm circle of soil and ash. Any soil or ash splashed was caught in the aluminum cup. The aluminum cup was oven-dried at 105° C for 24 hr and weighed to the nearest 0.01 mg. The cup was rinsed with alcohol and redried, and then a tare weight was taken. At the time of testing, a portion of the sample in the petri dish was removed for soil moisture determination.

#### Experimental Layout

Four treatments were tested in the rain tower: (1) sterile soil and ash, (2) sterile soil and ash inoculated with *A. fischeri* var. *glaber*, (3) heat-shocked soil and ash, and (4) heat-shocked soil and ash inoculated with *A. fischeri* var. *glaber*. Treatment 1 represented the condition where the soil was sterilized with a hot burn over moist soil. Treatment 2 represented the same conditions with an inoculation of *A. fischeri* var. *glaber* as might be used by management. Treatment 3 represented the normal field condition following wildfire. Treatment 4 represented the normal conditions plus a simulated inoculation to enhance the effect of heat-shock fungi.

#### RESULTS

The number of observations per treatment varied from 21 to 47. Means and standard deviations are shown in table 1. It is clear from the table that the two treatments involving *Aspergillus fischeri* var. *glaber* are effective in reducing soil detachment by raindrop impact. The data gathered were not found to be sufficiently normal to permit the use of parametric statistics such as a t-test for

Table 1--Amount of soil suspended by raindrop splash.

Treatment	Number of observations	Soil	
		Mean	S.D.
Sterile	47	0.49	0.28
<i>A. fischeri</i>	47	0.16	0.15
Heat-shock/A.f.	28	0.17	0.19
Heat-shock	21	0.30	0.19

comparative analysis. Results were compared using the nonparametric rank-sum test, employing the rank-sum statistic  $T'$  (Dixon and Massey 1969). The null hypothesis for this test was  $(T_0' - \bar{m}_T + 0.5)/\sigma_T = 0$ , where  $\bar{m}_T$  is the mean of the sum of the ranks for two test samples,  $\sigma_T$  is this rank-sum standard deviation, and  $T_0'$  is the sum of the ranks of the observations in the smaller of the two samples.

Production of rain-splashed sediment was two to three times greater on the sterile soil than on any of the soils with fungi (table 1). When compared with the other treatments, it was significantly different from them at a 99-percent confidence level (table 2).

The natural heat-shock flora reduced the amount of rain-splashed sediment by 40 percent over the sterile treatment. Enhancement with additional *A. fischeri* var. *glaber* produced even greater reductions, 45 percent over the heat-shock treatment and 65 percent over the sterile soil. There was no difference between the two treatments in which *A. fischeri* var. *glaber* was inoculated.

#### DISCUSSION

Two questions must be answered before heat-shock fungi can be suggested as a supplement to or replacement for postfire ryegrass seeding: do fungi stabilize the postfire ash bed, and if so, can this effect be enhanced by applying supplemental heat-shock mycoflora? The results show that heat-shock fungi do stabilize the postfire ash bed against rain-splash erosion and that stabilization against rain-splash erosion can be enhanced. The normal heat-shock fungal flora was not as effective as the heat-shock fungal flora enhanced with additional *A. fischeri* var. *glaber* or sterile soil so enhanced. Since there was no difference between the two *A. fischeri* var. *glaber* treatments, we infer that the effects of the

Table 2--Results of comparative analysis of data for four soil treatments, shown as normalized Z scores.

Treatment	Sterile	Heat-shock	Heat-shock/A.f. <sup>1</sup>	A.f.
Sterile	X			
Heat-shock	-2.89	X		
Heat-shock/A.f.	-5.65	-2.89	X	
A.f.	-6.32	-3.03	<sup>2</sup> Nonreject	X

<sup>1</sup>*A. fischeri* var. *glaber*.

<sup>2</sup>For a two-tailed test at the significance level  $\alpha = 0.01$ , the null hypothesis is rejected when  $-2.58 > Z > 2.58$ .

natural heat-shocked fungi and additional *A. fischeri* var. *glaber* are complementary and not additive. All treatments with fungi were superior to sterile soil in reducing rain-splash erosion.

All test plates were incubated for 1 month at 24° C under field capacity moisture conditions. In the field, such conditions rarely exist and the time, temperature, and moisture conditions required for optimal growth must still be determined. It is known that the pH and nitrogen conditions found in chaparral ash beds are near optimum for all known heat-shock fungi. The ability of heat-shock fungi to respond to a wide range of growth conditions requires further study.

The fungal inoculation described in this paper is effective in reducing erosion caused by rain-drop impact, a major erosional process (Mutchler and Young 1975). The effect of this treatment on other postfire processes, such as dry ravel and rill formation, has not been tested. It has been hypothesized that these two processes are initiated below the soil surface because of small local changes in the intergranular friction of the soil particles (Wells 1981). It is possible that treatments with fungi may cause slight increases in soil shear strength near the surface and, as a result, mitigate erosion by these processes.

Complete control of erosion in mountainous terrain is not attainable and probably not desirable. Steep slopes must maintain their equilibrium with gravity. Oversteepened (>60 percent) slopes must reestablish their equilibrium. Erosion, ultimately, is the only way that this equilibrium can be maintained. Although erosion cannot be prevented, it must be managed to protect lives and property. These fungi cannot prevent erosion, but their ability to reduce the effectiveness of raindrop impact suggests that they can make a useful contribution to our erosion and sediment management efforts. They should be inexpensive to produce and easy to apply, and they have, at present, no known harmful effects on the ecology of the chaparral.

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