

Prescribed Burning as a Restoration Tool

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Background

As fire ecology research matures, interactions among fire, smoke, seeds, plant growth, and soil have been revealed to be exceedingly complex, often perplexing. A sampling of recent research emphasizes this complexity. Germination of *Nicotiana attenuata* after wildfire is controlled by both smoke-derived cues (+) and destruction of inhibitory signals in unburned litter (-) (Preston and Baldwin, 1999). Fire-nutrient interactions influence quality and quantity of browse (Rundel P W, et. al, 1980). Charcoal from forest fires reduces phytotoxic compounds; effect may last 100 years (Zackrisson, et al, 1996). Picogram amounts of unknown compound in smoke separated by gas chromatography stimulates germination of *Nicotiana attenuate* (Baldwin et al., 1994). Oxides of nitrogen in smog stimulate germination of particular chaparral species. These compounds are also found in smoke from burning vegetation. Smog may untimely cue germination and alter species composition (Keeley and Fotheringham, 1997). Compared to the control, seeds of several range grasses treated with smoke from burning sagebrush grew faster and had greater plant mass (Blank and Young, 1998).

Our research unit has been investigating the ecological consequence of fire in sagebrush ecosystems, particularly interactions involving soil chemistry, the soil seedbank, and the effects of smoke on seeds. Most recently, in cooperation with

Dr. Jeanne Chamber of the USDA-Forest Service, we have investigated the utility of prescribed burning in ecosystem restoration of degraded riparian ecosystem of central Nevada.

Fire Ecology and Interactions Important in Restoration

Nutrient Release and Enzyme Activities

Human experience and research has shown that fire fosters the release of soil nutrients. The source of these nutrients is from pyrolysis of soil organic matter and organic debris and alteration of the clay complex. As a result, plant available N, Ca, Mg, S, K, and many micronutrients generally increase after a fire. Our prescribed fire research in sagebrush encroached riparian ecosystem of central Nevada has confirmed past studies. Pertinent to prescribed burning in heterogeneous environments, such as sagebrush communities, is the effect of microsite on the quantity of nutrients released as shown in the following graphs. This microsite effect is largely a combination of differential fire temperatures (greater fuel load in sagebrush fosters higher temperatures for longer periods of time) and pre-fire microsite differences in quantity of plant litter and soil organic matter (sagebrush subcanopies are nutrient islands).

Soil enzyme activities have become important indicators of ecosystem health for they are positively correlated to nutrient release from organic matter. Recent research has shown that fire greatly reduces enzyme activity because enzymes, being proteins, are denatured at temperatures greater than about 60C. The prescribed burns in central Nevada significantly reduced

enzyme activities of urease and phosphatase as shown in the following graph. Surprisingly, enzyme activities decreased at depths of 10-20 cm where temperatures are not appreciably affected by fire.

Germination Cues

In fire prone ecosystems, such as the chaparral of coastal California, the germination of many species is cued synchronous to wildfires. Recent research has shown that, for certain seeds, this cueing is due to particular chemical compound(s) in the smoke and charred wood. The chemical(s) cause an impermeable membrane in the seed coat to become permeable and signal the embryo to germinate. We have experimented with the effect of smoke and previously heated soil on the germination of several range grasses. Soil was heated in the muffle furnace at various temperatures to mimic fire and various seeds were planted in the soil. Many species exhibited mildly elevated germination as shown below. Thurber's needlegrass had far higher germination when planted in previously heated soil, but almost no germination when exposed to sagebrush smoke. We have not explored the effect of smoke and heated soil on any forb as of yet. The observation that particular forbs significantly increase after wildfire in the sagebrush steppe suggests the possibility of germination cueing.

Negative Cueing

Litter from particular species can retard or prevent the germination of many seeds. Sagebrush litter has been shown to elicit this response and thus has been tagged allelopathic. Recent research, however, suggests that in certain cases, allelopathy may in fact be negative cueing. Apparently certain seeds have evolved a two-way fail-safe dormancy system. In order to germinate both



positive cueing (smoke) and destruction of negative cues (some unknown compound in shrub litter) are required.

Sagebrush Smoke and Heated Soil Extract: Effect of Plant Growth

We studied the influence of seeds treated with either sagebrush smoke or an aqueous extract of soil heated to 350C on plant growth. Compared to the control, an aqueous extract of heated soil did not have a stimulatory effect on aboveground or below ground mass. To our surprise, however, plants from seeds of particular species exposed to sagebrush smoke, grew faster, grew taller, and gained more total mass than control plants as shown in the following figures. We are not sure of the mechanism. Perhaps smoke acts as a microbiocide. Possibly smoke attenuates certain enzyme systems affecting plant growth. We have for the last three years attempted to duplicate these greenhouse results in the field, but establishment trials have failed either due to lack of timely precipitation or below normal spring temperatures.

Effect of Smoke Type

We are presently conducting experiments to test the effect of sagebrush smoke and cheatgrass smoke on seed germination and seedling growth. These are preliminary results, but the growth of Basin Wildrye seems to be suppressed when pre-exposed to cheatgrass smoke as shown in the following figure. Although somewhat premature, these experiments suggest that there may be different seed/fire interactions between sagebrush dominated burns versus cheatgrass

dominated burns. If this is the case, which ongoing experiments will clarify, it suggests that the ecological consequences of cheatgrass invasion will be more pernicious and convoluted than previously appreciated.

Conclusion

Prescribed burning will elicit a host of ecological interactions potentially important in restoration, including release from plant competition, greater access to light and water, nutrient enrichment, germination cueing, destruction of germination retardants, and effects of smoke on plant growth. Seeds in the soil seed-bank not exposed to lethal heat and seeds sown after the fire will be influenced by these interactions. Restoration will be further influenced by timing of prescribed burn and preburn conditions such as fuel load and heterogeneity of fuel load, species composition, soil water content and the nature of the soil seed-bank and the time of the burn. With such inexorable complexity can predictions be made regarding the potential success of restoration following prescribed burning? Small-scale experiments such as we have undertaken in central Nevada will greatly assist in the planning of future large-scale restoration.

Citations

Baldwin, Ian T.; Staszak_Kozinski, Lynn; Davidson, Robert. 1994. Up in Smoke: Smoke-derived germination cues for post-fire annual, *Nicotiana attenuata* Torr Ex. Watson. J. of Chem. Ecol. 20(9):2345-2371.

Blank, RR and Young, JA. 1998. Heated substrate and smoke: Influence on seed emergence and plant growth J. Range Manage. 51:577-583.

Keeley, J. E.; Fotheringham, C. J. 1997. Trace gas emissions and smoke induced seed germination. Science, 276(5316):1248-1250.

Rundel, P W; Parsons, D J, 1980. Nutrient Changes in 2 Chaparral Shrubs along a fire induced age gradient, Amer. J. Bot. 67 (1) pp. 51-58.

Preston, CS and Baldwin, IT. 1999. Positive and negative signals regulate germination in the post-fire annual, *Nicotiana attenuata*. Ecol. 80:481 494.

Zackrisson, O.; Nilsson, M._C.; Wardle, D.A. 1996. Key ecological function of charcoal from wildfire in the Boreal forest. Oikos, 77(1):10-19.

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