Effects of Smoke on Pathogens and Other Fungi

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ACCUMULATING evidence indicates that western wildlands burned frequently before the advent of fire control (Biswell, 1961, 1967, 1972; Kilgore, 1972; Mutch, 1970; Stewart, 1954, 1955). Indians, and later settlers, deliberately burned wildlands, and lightning has caused numerous fires each year. Many direct effects of fire on plant communities are known, but secondary effects such as those associated with exposure to smoke have received little attention. Since fires were frequent and smoke may drift for many miles, smoke undoubtedly was a normal feature of the environment (Biswell, 1972).

Preservative and antimicrobial effects of smoke have been known since antiquity. Numerous compounds with known or suspected antimicrobial properties have been identified in wood smoke (Frazier, 1967; Kramlich et al., 1973). Recently, Melching et al. (1974) demonstrated that tobacco smoke inhibited spore germination of several pathogenic fungi and protected wheat from infection by a rust fungus. Frequent fumigation of wildland plant communities by antimicrobial materials in smoke might be expected to have important ecological implications.

In 1971 at the University of California, Berkeley, exploratory studies were initiated on ways in which smoke might affect microorganisms, especially those causing diseases in wildland plant communities. In all studies, air-dried pine needles or grass were burned in a ventilated garbage can and the smoke was piped several feet to

a chamber containing test materials. Piping the smoke promoted cooling, so that the temperatures within the chamber did not exceed ambient air temperatures by more than 2°C. Details of methods and results have been published (Parmeter and Uhrenholdt, 1975). The following is a brief summary of results and possible ecological implications.

EFFECTS OF SMOKE ON SPORE GERMINATION

Germination was tested by exposing cellophane, water agar, or glass slides to smoke for various time intervals ranging from 0-16 minutes. Spores of selected fungi then were deposited on the smoked substrates, incubated in a moist chamber, and counts in random microscope fields were made. In each test, at least 100-250 spores were counted. Each test was repeated at least twice. Of eight fungi tested, the spores of five failed to germinate on substrates exposed to smoke for 1-16 minutes. These included aeciospores of *Peridermium harknessii* (a forest tree rust), teliospores of *Teletia caries* and *T. foetida* (cereal smuts), conidia of *Fusarium lateritium* (a stem pathogen of forest trees), and conidia of *Botrytis gemella* (a common mold). Germination of conidia of *Penicillium expansum* (a fruit decay fungus) and *Fomes annosus* (a forest tree root pathogen) was reduced by more than half with 4 minutes of smoke, but some spores germinated on substrates exposed to smoke for as much as 16 minutes. A *Trichoderma* sp. showed increased spore germination on substrates smoked for 1-4 minutes and germination on substrates smoked for 16 minutes was comparable to that of unsmoked controls.

In one unrepeated field test, spores from six stem galls (*P. harknessii*) on Monterey pine were tested before and after a prescribed burn. Galls ranges from 4-62 inches above ground. Germination of spores collected after the burn was reduced by 25-79 percent. Although the fire was of low intensity, heat effects were not ruled out by this test. Whether by heat or smoke, these data suggest that ground fires may reduce the effectiveness of inoculum of some pathogenic fungi.

MYCELIAL GROWTH

Effects of smoke on mycelial growth were tested by growing fungi on cellophane previously exposed to smoke for various periods.

The growth of two forest-tree root-disease fungi (*F. annosus, Verticicladiella wagenerii*), a bark beetle symbiont (*Trichosporium symbioticum*), and a heartrot fungus (*Pholiota adiposa*) declined as exposure of the substrate to smoke increased. All but *T. symbioticum* were completely inhibited on substrate exposed to 16 minutes of smoke.

Effects of smoke on actively growing mycelia were tested with *Thanatephorus cucumeris* (a damping-off fungus commonly called *Rhizoctonia solani*). Hyphae of the fungus were transfered to plates of potato-dextrose agar and then exposed to smoke either immediately or after the mycelium had grown for a day. In either case, growth was greatly reduced in plates exposed to 4 minutes of smoke and no growth occurred on plates exposed for 8, 16 or 32 minutes of smoke, even after 10-12 days incubation following exposure.

COLONIZATION OR INFECTION

Prior exposure of plants to smoke reduced infection of bean plants by the rust fungus *Uromyces phaseoli* and of Monterey pine seedlings by *P. harknessii.* With beans, numbers of rust lesions per unit area of leaf were progressively reduced as exposure to smoke was increased from 0-640 seconds. With unsmoked Monterey pine, 12 galls developed on 5 trees and 19 galls developed on 10 trees in separate tests. Only one gall appeared on a tree smoked for 4 minutes. No galls appeared on 34 trees smoked for 4, 5, 8, 16, 25 or 32 minutes prior to inoculation.

Preliminary studies have been made with cotton seeds smoked for 32 minutes and then planted in soil infested with *T. cucumeris.* In three tests, emergence from smoked seed was 66, 28, and 71 percent. Emergence from unsmoked seed was 43, 14, and 45 percent, respectively. These observations need further confirmation but taken with the demonstrated reduction in growth of *T. cucumeris*

by smoke, they suggest that smoke may impede this fungus and thus reduce seedling mortality.

In addition to the quantitative studies outlined above, two qualitative studies have been made. One involved exposing oak leaves to various periods of smoke, washing the leaf surfaces with sterile water, and preparing dilution plates from the resulting suspensions. The numbers of fungal and bacterial colonies decreased as exposure to smoke increased. No counts were made, but differences in numbers and kinds of surface microorganisms were obvious.

A qualitative study of the colonization of pine stem discs by *F. annosus* and other microorganisms was made by exposing freshly cut discs to smoke for various periods, spraying them with a conidial suspension of *F. annosus*, and incubating them in moist chambers. Differences in the amount of *F. annosus* and other fungi on disc surfaces were obvious but did not follow a discernible pattern in relation to the amount of smoke.

DISCUSSION AND SUMMARY

The data and observations presented here are fragmentary and are not adequate to establish that smoke from wildfires or prescribed burns markedly affects microbial activity in wildland plant communities. They suggest, however, that such effects are likely.

Fires produce large quantities of smoke that often accumulate under inversions or drift for long periods through forest stands. Surfaces exposed to smoke were found unsuitable for the germination of spores of several kinds of fungi. Mycelial growth of fungi was inhibited on surfaces previously exposed to smoke, and direct exposure of mycelium to smoke arrested growth. Smoked leaf surfaces and pine-disc surfaces showed marked changes in numbers and kinds of microorganisms present. Bean plants and pine seedlings exposed to smoke were protected from infection by certain rust fungi. Cotton seeds exposed to smoke appeared to be less susceptible to damping-off.

These data and observations suggest that smoke may have important effects on microbial activities in plant communities. Microbial activities include initiation of disease, deterioration and recycling

of dead plant materials, transformation of soil nutrients, mycorrhizal formation, inhibition of pathogens by antibiosis and competition, and numerous other processes that critically influence the development of plant communities. If we are to understand and utilize the capacity of fire to modify plant communities and ecological processes, we should know how fire and smoke affect these microbial activities.

The few data and observations outlined here lead to numerous unanswered questions for which data are needed:

1. What are the materials in smoke that modify microbial activities?
2. How are these materials related to fuel type, moisture content, weather, and speed of burning?
3. How persistent are these materials in nature?
4. In what ways does exposure to smoke significantly modify microbial processes in nature and how do these modifications affect the development of plant communities?
5. How might information on effects of smoke contribute to decisions on how and when to use prescribed burns?

These are a few of the numerous questions involving smoke and its probable influences on microbial activities. If, as available evidence indicates, smoke was a normal feature of many environments, then our present concepts of microbial activities derived from studies in relatively smoke-free ecosystems may not reflect "normal" conditions. Clearly, further study is desirable.

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