Fire and Disease

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I should clarify that, although I am a plant pathologist, my primary experience has been with diseases affecting grasses grown for seed. During the past year, in preparation for writing a chapter on use of fire and flame in plant disease control for the Annual Review of Phytopathology, I requested help from around the world. Evaluation of this world survey and a study of literature is incomplete, but it is apparent that relatively little has been written on effects of fire on disease (Ahlgren and Ahlgren, 1960; Baxter, 1952; Boyce, 1961; Garren, 1943; Hanson, 1939; Hepting, 1971).

The classic example of the effects of mild surface fires is the often cited control of brown spot needle blight (*Scirrhia acicola* (Dearn.) Siggers) of longleaf pine (*Pinus palustris* Mill.) in the southern United States. A prescribed surface fire generally eliminates sufficient inoculum for the 2 years needed to get longleaf seedlings up out of the "grass" stage, after which this fungus no longer deters

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Cooperative investigations of the Agricultural Research Service, U. S. Department of Agriculture, and the Oregon Agricultural Experiment Station.

Technical Paper No. 3927, Oregon Agricultural Experiment Station.

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growth. Longleaf is very fire-resistant, having a so-called asbestos terminal bud (Baxter, 1952; Boyce, 1961; Siggers, 1944).

Burning reduces the incidence of fusiform rust, *Cronartium fusiforme* Hedgc. & Hunt ex Cummins, the worst disease of southern pines. Burning kills the lower branches of saplings, where most of the rust cankers arise, thus keeping them from ultimately becoming cankers and killing the tree. Fire also suppresses oaks, which harbor the uredo and telial stages of fusiform rust, while promoting growth of the more fire-resistant pine. Without fire, longleaf is lost to the fire-sensitive and rust-susceptible slash pine (*Pinus elliottii* var. *elliottii* Engelm.) and loblolly pine (*P. taeda* L.). Longleaf is highly rust resistant, whereas slash and loblolly are resistant to brown spot (Czabator, 1971).

Mistletoe (*Phoradendron* spp.) and dwarf mistletoe (*Arceuthobium* spp.) in small patches may be eliminated, if infested trees and additional ones on the perimeter of infection patches are felled. The cut trees and mistletoe seeds can be destroyed by bonfires during the safe rainy season. In several areas, undersized infested trees that are not eliminated during logging need to be killed, to prevent the perpetuation and spread of mistletoe to regenerated or transplanted trees. Prescribed slash burning should be effective (Baranyay, 1972).

One effect of catastrophic wildfires that kill or severely damage ponderosa pine forests on some sites is the appearance of mistletoe-resistant lodgepole pine (*Pinus contorta* Dougl.). In being resistant to the ponderosa mistletoe, this pine constitutes a barrier to the spread of mistletoe in the ponderosa (Wicker, 1976).

A unique example of the adverse effect of fire is root rot, caused by a fungus (*Rhizina undulata* Fr. [=*R. inflata* (Schaeff.) Karst.]). In Europe, group dying of pole-size conifers as a result of Rhizina root rot usually occurs around the sites of bonfires built by workers during thinning operations. In North America, the disease has been observed on seedlings planted on clear-cut areas where slash has been burned or in nurseries where brush had been burned. The fungus fruits on the forest floor after a fire, and the optimum temperature for spore germination is high, 35-45° C. The spores may lie dormant in soil for 2 years. Rhizina can severely damage 2-to

4-yr-old Douglas fir seedlings transplanted immediately after a slash burn or fire. The trouble can be avoided by delayed transplanting for 2 years after the fire or burn (Baranyay, 1972; Morgan and Driver, 1972).

Reports on various wood-rotting problems arising from fire-caused wounds far outnumber occasional reports (Froelich and Dell, 1967) of partial control of wood rot by burning. This is logical, because dead wood represents a food supply in locations convenient for exposure to spores and possible invasion by a multitude of fungi. Therefore, the effects of prescribed underburning or surface fires should be distinguished from those of catastrophic wildfires that kill or severely wound trees. Of course, with any kind of fire, damage varies widely with different tree species, according to their inherent tolerances to heat (Brown and Davis, 1973). Although hardwood species are sensitive, fire can be beneficial by killing hardwood stumps and forcing suckers to develop free of butt rot from roots, whereas suckers arising from unburned stumps are invariably infected (Baxter, 1952; Boyce, 1961).

The limited information on fire effects on other forest diseases seems remarkable, in view of the frequency of forest fires of all types that have presented numerous opportunities to study disease control. Burning out understory plants and weed trees, for example, sometimes reduces inoculum and reduces moist chamber conditions that favor infection. Unfortunately, information on the significance of these reductions on forest disease control, other than those mentioned earlier, is hard to find.

The old ponderosa pine stands on the east slope of the Cascade Mountains in Oregon have been studied by Dr. Lewis Roth, Forest Pathologist at Oregon State University. He kindly supplied a few observations. In the past few hundred years, surface fires ran through this forest every 14 years or so. Roth finds evidence from numerous scars where mistletoe was burned out by past fires. Infected branches were killed by heat, and heavily infected and highly flammable trees were selectively destroyed. Several needle diseases, such as *Elytroderma* sp., apparently are becoming more serious with the continued absence of fire. Dr. Roth suggests that understory thickets of weed trees are more readily infected by these needle pathogens, and inoculum that increases on the young weed trees is spread to the large trees. Comandra rust (*Cronartium comandrae* Pk.) has apparently become more serious. Roth suggests that this may result from an increase in the alternate hosts, species of *Comandra,* in absence of surface fires. I think these observations illustrate the need and opportunity for more studies on effects of fire on forest diseases as a part of the total ecosystem. Much more research on forest tree diseases, including antimicrobial effects of smoke (Parmeter, 1976), will be needed to implement the integrated program illustrated in the chart that Bob Martin showed us today, especially as most tree production comes under intensive management.

Burning is prescribed for other plants, in addition to the burning of infected prunings from many different plants and disposing of trees infected with diseases, such as Dutch elm disease. The amount of agricultural acreage burned annually is significant. Sugarcane is commonly burned in many countries before cutting, to aid harvest and afterwards to remove trash. Burning of sugarcane reduces several insects and diseases. In some countries where sugarcane is harvested by hand, burning is necessary to eliminate poisonous snakes before the laborers will enter the fields. Bermudagrass (*Cynodon dactylon* (L.) Pers.) pastures are burned in southern states to remove thatch and to control certain insects and diseases. Spring growth is hastened and forage yield and quality are greatly increased by this practice.

Lowbush blueberries are burned in the Northeast and Canada, primarily to thin and rejuvenate plants, but the practice also controls some diseases. Throughout the world, large acreages of cereals, including rice, are burned to remove stubble and straw. Burning reduces inoculum of a variety of diseases and controls some weeds and insects, but the primary purpose usually is removal of plant refuse.

Use of prescribed burning in agriculture primarily for disease control is limited. Burning of grass seed fields, the single most important cultural practice in the Pacific Northwest, was started originally for disease control 26 years ago (Hardison, 1960, 1963b, 1964, 1969). Postharvest burning had to be recommended on a large scale after the 1948 harvest, to control blind seed disease (*Gloeotinia* *temulenta* (Prill. & Delacr.) Wilson et al.), in an effort to save the perennial ryegrass (*Lolium perenne* L.) seed industry in Oregon. About half the acreage was burned after the 1948 harvest, and nearly all fields have been burned since 1949. Excellent control was immediately obtained. Except for a brief flareup in 1956 and 1957, when straw choppers spoiled straw distribution, the disease has been very well controlled through 1974.

Ergot (*Claviceps purpurea* (Fr.) Tul.), a major disease of most cultivated grasses in north temperate zone countries, was controlled adequately for the first time in grass seed fields when straw and stubble in fields were burned after harvest in western Oregon (Hardison, 1960). Ergot has been well controlled in perennial ryegrass by burning since 1948. When applied, starting in 1949, to fields of tall fescue (*Festuca arundinacea* Schreb.), burning again controlled blind seed disease and ergot. Field fires destroy most of the fungus sclerotia in crop residues. Prevention of fall heading of perennial ryegrass plants is a special need, because autumn inflorescences form abundantly in this grass and are usually heavily infested with ergot. Burning eliminates fall heading and thus prevents the secondary increase of ergot (sclerotia) that is important to the total inoculum.

Grass seed nematode (*Anguina agrostis* (Steinbuch) Filipjev) had caused severe losses in chewings fescue (*Festuca rubra* var. *commutata* Gaud.) seed crops in western Oregon. The incidence of seed nematode dropped sharply after adoption of annual field burning in 1955. In recent years, nematode galls needed for experimental work could not be found in samples of chewings fescue seed crops. Silver top, which caused complete crop losses in chewings fescue and highland bentgrass (*Agrostis tenuis* Sibth.) during 1954 and 1955, in western Oregon, was eliminated by field burning. Silver top had been controlled earlier in Pennsylvania by burning (Keil, 1940). Silver top was thought to be caused by *Fusarium tricinctum* (Cda.) Sacc. emend. Snyd. & Hans. f. *poae* (Pk.) Snyd. & Hans. and the mite (*Siteroptes cerealium*) (Kirchner) [*S. graminum* (Reuter)]. Nevertheless the causal agents appear to be insects, such as *Leptopterna dolabrata* (L.), whose eggs in the lower culm are destroyed when fields are burned (Hardison, 1959).

In subsequent years, burning was adopted on other perennial grasses grown for seed in Oregon, except the fire-sensitive creeping bentgrass (*Agrostis palustris* Huds.) and velvet bentgrass (*A. canina* L.). This burning resulted in excellent control of ergot and silver top in colonial bentgrass (*A. tenuis* Sibth.), red fescue (*Festuca rubra* L.), Kentucky bluegrass (*Poa pratensis* L.), and orchardgrass (*Dactylis glomerata* L.), in western Oregon especially. Application of 1 lb DDT per acre had been the standard recommendation for control of silver top. Control by burning avoided the use of 2 to 3 million pounds of DDT in the Willamette Valley, Oregon.

Burning also partially controlled a number of leaf and stem diseases in several grasses. Burning and flaming helped to control leaf rust, *Puccinia poae-nemoralis* Otth, in Kentucky bluegrass. But later on, we were forced to develop chemicals to control the more serious stripe rust, *P. striiformis* West. (Hardison, 1963a).

Control of these major diseases acquires much more significance when we examine the problem. Grass seed production is inherently trashy farming that unavoidably creates conditions favorable for maximum development of diseases. Diseases inevitably build up when inoculum is allowed to accumulate during several years of continuous grass culture. These unavoidable difficulties are compounded by the impracticality of major methods used for control of diseases of other plants. Breeding for resistance to diseases peculiar to seed production or to the West usually is not possible. Genetic change is not permitted in grass varieties that are developed in consuming areas and sent out for seed production. Crop rotation is not possible in the culture of long-term perennials. Seed treatments have only limited value. Except for chemical control of rust diseases (Hardison, 1963a), chemical control of grass diseases generally has not been feasible. All of these problems are aggravated in most grass crops by low per-acre returns which dictate that control methods must be inexpensive. Under these circumstances, maximum sanitation is imperative, and simple removal of straw and stubble generally is inadequate. Burning fulfills the low-cost requirement and, by the generation of sterilizing heat, furnishes through effective field hygiene the most effective control of diseases probably ever developed in these perennial grass crops.

Excellent disease control is not the only benefit from burning. Postharvest burning immediately increased seed yields from 3- to 10-fold in the older fields of several grass species. Surface fires directly controlled weeds by incinerating seeds and by heat-killing certain weed plants. For control of winter annual weeds in perennial grass fields, field burning leaves a clean soil surface needed for uniform distribution of fall-applied soil-active herbicides. Burning effectively controlled weeds and permitted a no-tillage renewal of annual ryegrass (*Lolium multiflorum* Lam.) fields that were replanted directly with rangeland seeders. Thereby, the energy was saved that would otherwise have been required for plowing and several other farming operations.

Burning grass fields proved equally valuable for increased seed yields and for some pest control in eastern Oregon. The Oregon burning practice adopted in the 1950's in Washington and Idaho has proven highly beneficial to bluegrass seed production, yields exceed several times those of unburned and untreated fields (C. L. Canode and R. D. Ensign, personal communications). Burning grass seed fields in 1974 increased by about $50 million the income of seed growers in Oregon, Washington, and Idaho. In the past 26 years, grass field burning has been worth approximately $750 million in these three northwestern states.

Removal of old plant material is an important consideration in use of grasslands in many areas, because of a possibility of toxin formation by various microorganisms. The saprophytic fungus (*Pithomyces chartarum* (Berk. & Curt.) M. B. Ellis), for example, colonizes plant residues and produces the toxin sporidesmin. This causes liver damage, loss of weight, jaundice, and photosensitivity in sheep and cattle that graze infested ryegrass pastures in New Zealand. Facial eczema describes the inflamation and scabbing of unprotected skin resulting from the photosensitivity (Brooks and White, 1966). Elimination of dead and senescent leaves should be possible with a good field fire, and this sanitation perhaps would be sufficient to minimize or eliminate some of the mycotoxin problems.

Control of ergot avoids potential ergot poisoning in livestock, game animals, and birds. Burning straw and stubble in reasonably dry fields destroys most of the fungus sclerotia in crop residues. In perennial ryegrass, burning eliminates fall heads that are usually severely infested with ergot. Thus, it prevents the possibility of abundant ergot in inflorescences that could be ingested by livestock grazing the fields.

The feeding of chewing fescue seed screenings containing grass seed nematode galls killed numerous cattle and sheep in western Oregon prior to 1955. Burning chewings fescue seed fields beginning in 1955 has virtually eliminated the seed nematode and has thus avoided most of the livestock poisoning. In Australia, wheat stubble was burned regularly until about 25 years ago. The volunteer weed grass Wimmera ryegrass (*Lolium rigidum* Gaud.) was healthy in these wheat fields and furnished grazing for livestock after the wheat harvest. In more recent years after burning was stopped, a seed nematode (*Anguina* sp.) whose galls are highly toxic appeared in this ryegrass. Severe losses of livestock have occurred in South Australia (McIntosh et al., 1967), and more than 4,000 steers recently died after grazing the Wimmera ryegrass infested with the seed nematode in Western Australia (P. H. Berry, personal communication).

During July through September, smoke from burning grass fields, forest slash fires, wild forest fires, and other sources in western Oregon sometimes has reduced visibility and decreased air quality. Complaints resulted in legislation that will prohibit open field burning in Oregon after December 31, 1974, despite a reasonably successful smoke abatement program managed by the Oregon Department of Environmental Quality. The program used a formula, specially devised for this area (Bates, 1974), that kept smoke and fly ash away from major cities and minimized the smoke problem during the last several years.

Grass seed fields are burned by permit under smoke management systems in Washington, Idaho, and Minnesota. Extensive acreages of rice and grain are burned in California under permit. Apparently these four states will continue to allow agricultural field burning until feasible alternatives are available.

To meet the Oregon deadline on field burning, considerable research has been devoted to the development of alternative uses of straw and substitute thermal sanitation. Mobile incinerators have been under development since the first model was built in 1970 by Oregon State University agricultural engineers. None is yet operational or commercially available. The OSU prototype demonstrated that straw and stubble could be burned with very little smoke and very little particulate discharge. This machine was a metal box, open at the top, with transverse slotted pipes (air bars) that directed high-pressure air diagonally forward to the soil surface and supplied low-pressure, high-volume air above the main fire area (Bonlie and Hudson, 1971). Two different models based on the OSU prototype have not performed satisfactorily (Bonlie and Hudson, 1971; Kirk and Bonlie, 1973). Two new models built in 1974, which operate on somewhat different principles, were reasonably successful, and the results indicate that additional design improvements are possible.

The application of hot air, heated with propane burners, charred and killed sagebrush plants without ignition in Montana (Bellusci and Hallman, 1973). Conversion of flame to hot air, however, appears to be an undesirable complication for thermal sanitation in grass seed fields. A clean soil surface derived from field burning is basic to weed control, and the application of super-heated air would not remove the debris. Field flaming with various gas burning machines has been too expensive for low-income crops and is an extravagant use of fossil fuels. Enclosing the flame in a chamber could increase efficiency of combustion and heat transfer.

An apparatus that combines the best designs of mobile incinerators with the best type of flamers, we hope could provide a thermal treatment machine using mainly plant refuse as fuel, with a minimum discharge of smoke and particulate matter. If an improved incinerator-flamer could project the hot gases forward so that the plant material is dried to become part of the fuel train, then such machines might be used to apply thermal sanitation on crops other than grasses. Dormant alfalfa stubble, strawberries, and certain other field crops have plant refuse that is insufficient or too green to carry an open fire. But this limited plant material can sustain an enclosed fire and provide thermal treatment. When functioning only with plant material, the incinerators would thus use a renewable resource, instead of depending on fossil fuel. Thermal sanitation at the soil surface with these field incinerator-flamers or with improved field burning, with the application of newer fungicides, should improve disease control in the production of grass seed and certain other field crops.

SUMMARY

Prescribed surface fire in southern pine forests controls brown spot (*Scirrhia acicola*) of longleaf pine (*Pinus palustris*) and fusiform rust (*Cronartium fusiforme*) of southern pines. Rhizina root rot and many wood rots are favored by fire. Additional research is needed to determine the beneficial or detrimental effects of various types of forest fires on diseases, so that this information can be used in high-intensity tree production.

A large crop acreage is burned annually to remove plant refuse, stimulate regrowth, or both, including cereals and rice, sugarcane, bermudagrass, other grass pastures, and lowbush blueberries. Some diseases and insects are controlled by this agricultural burning, but the main purpose is removal of crop debris. Postharvest burning of grass seed fields in the Pacific Northwest controls ergot, blind seed disease, seed nematode, silver top, and some insects and greatly increases yields. Mobile field incinerators under development show promise for application of needed thermal sanitation at the soil surface with minimal smoke and particulate matter discharge. These machines, perhaps supplemented with flame, may sanitize fields for crops previously not burned, using plant refuse as the main or only fuel. Improved open burning or incinerator-flamer treatment, plus new chemicals, should provide better disease control than has been possible previously.

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