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Chapter 15

Plant Pathology and Managing Wildland Plant Disease Systems

Obtaining specific, reliable knowledge on plant diseases is essential in wildland shrub resource management. However, plant disease is one of the most neglected areas of wildland resources experimental research. This section is a discussion of plant pathology and how to use it in managing plant disease systems.

General principles of agricultural plant pathology apply to wildland plant disease. However, unique features limit a general extension of plant disease control management or methods. For example, some fundamental elements of agricultural plant disease management are not applicable, such as annual crop rotation and soil fumigation; and other elements are not feasible, such as protective chemical treatment of low value (per unit area) wildland plants. We have insufficient knowledge of principles of disease epidemics involving uniform homogenic agricultural plants, as opposed to species diversity, such as heterogenic, wildland plant populations. In the latter case, information is more pertinent from wildland forest tree disease epidemiology.

Although diseases of the more treelike shrubs have received some study, most wild-shrubland plant disease systems remain unidentified. Wildland plant disease research suffers from lack of attention, probably because plant diseases are generally less dramatic than other forms of injury such as fire or insect epidemics. Unless there is a disease epidemic of devastating proportions, little action is taken. If revegetation effort is less than successful, plant disease is usually the last explanation given. The effects of plant disease are usually inconspicuous and subtle. The importance of wildland plant pathogens, in a nonecological sense, can only be judged in terms of competition with humans for the plant harvest or other use. The human-use factor constantly changes, and its dominant feature will be to constantly increase on Western United States wildlands. Restoring and managing wildland range resources is a comparatively recent venture, and the intensiveness of the activity promises only to increase. Why not take advantage of existing knowledge of plant pathology as much as possible to avoid experiencing the pitfalls and disasters, especially in the early phases of agronomy and forestry?

What is Plant Disease?

One cannot see a plant disease. Only the symptomatic results of a disease are visible. Plant disease is a physiological process injurious to the host plant. It is a process that interferes with host plant functions and is extended in time. Disease inducers may be biological, physical, or an interaction of these environmental elements.

The more familiar organisms that induce disease are fungi, bacteria, viruses, and nematodes. Less familiar are insects, microplasmas, rickettsias, algae, and lichens. Parasitic flowering plants also induce disease. These are the mistletoes, dodders, and broomrapes. Physical elements of the plant environment that induce disease include certain soil factors, mineral deficiencies or excesses, air temperature extremes, toxic chemicals, and air pollutants. Damage from lightning strikes or freezing is not considered to result in disease because the resulting injurious process is not pathogen induced.

How to Recognize a Plant Disease

Before plant disease management can be planned, the disease must be diagnosed and the causal agent identified. To do this, presence of a pathogen or symptoms of the dysfunction must be determined and characterized. Diagnosis is still primarily an art, and therefore, experience is an important advantage.

If the disease is new or not readily identifiable, the disease symptoms must be reproduced by experimentation. This is usually a time-consuming project of establishing proof following the procedure of Koch's postulates as follows:

1. The inducing agent should be consistently associated with disease.
2. If an organism, it should be isolated, pure cultured, characterized, and identified.
3. The isolated organism, when applied in inoculation tests under the favorable environment for disease development, should reproduce the disease symptoms.
4. The organism should be reisolated, pure cultured, and found to be the same organism.

Koch's postulates cannot be followed precisely in all instances. Cause of diseases that are induced by insect toxins or abiotic factors can be established by characteristic symptoms and by reproducing the disease by withholding and applying the suspected agent in sequence to reproduce the symptoms. Nematodes, viruses, and obligately parasitic fungi require modification of the rules because they are not readily cultured. A further complication exists because more than one agent can be involved in what is then a disease complex. An associated nematode may act only as a vector. An abiotic factor may predispose the potential host to one or more fungal pathogens that may invade in a specific sequence.

The induced dysfunction or disease, once a pathogen is established, results in visible symptoms for which the disease is named and identified. A term describing the symptom, either alone or along with the name of the inducing agent, forms the disease name—aspen leaf blight, stem necrosis, fusarium wilt, canker, bacterial crown gall, witches' broom, chlorosis, tobacco mosaic, root rot, decay, and so forth. Structures of the inducing organism are also used in identifying and naming the disease; for example, spore masses, fruiting structures, and vegetative body—and thus, the signs of the disease such as black stem rust, smuts, blisters, powdery mildews, tar spots, and potato scab.

Identification of wild-shrubland plant diseases suffers immensely from a lack of specific literature, particularly in host-pathogen indices, descriptive keys, monographic treatments, and color illustrations for recognition and verification of diseases.

Disease Occurrence and Development

The occurrence and development of a disease depends on a triad of events: a pathogenic agent, a susceptible host, and a favorable environment interacting to result in a disease. The host and pathogenic organisms are reciprocal environmental elements. Both exist in a soil and air environment and are influenced by moisture, temperature, light, air movement, soil aeration, chemical and physical soil factors, organic soil constituents, microorganisms of the leaf, stem, root zone, and an interaction of combinations of these factors. The pathogenic organism, in addition to the external environment prior to penetration and establishment, is influenced by resistance mechanisms of the host that may be directed either actively or passively or both. The host contends with the external environment and the pathogenic mechanisms of the invading parasite. Both organisms have characteristic environmental limits and optimal zones of function. During periods within the required environmental limits, a pathogen penetrates the host and becomes established. When the established pathogen withstands host defenses, disease development proceeds and the successful pathogen completes its cycle to reproduction.

The occurrence of plant pathogenic organisms and plant disease is a natural, normal phenomenon and part of the evolutionary and ecological systems of all flora. In natural systems, disease incidence fluctuates endemically. During periods of change, either natural or because of human activity, a pathogen may become epidemic. Plant diseases caused by pathogenic organisms are thought of as contagious. Various types of propagules spread or are dispersed in numerous ways: airborne, waterborne, or entirely on their own power (for example, dwarf mistletoe seed). With an unlimiting food source and absence of inhibitors, reproduction is logarithmic, and the amount of propagule or inoculum increase is exponential. Circumstances are ideal for an epidemic or explosive spread of a disease when there is a large host population that is homogenic, nonspecific, in a uniformly susceptible stage of development, and where environmental conditions are optimal for pathogen spread, infection, and rapid regeneration.

Some common wildland management practices that could create ideal circumstances for epidemics are as follows:

1. Introduction of a plant that is susceptible to an endemic pathogen or the reciprocal.
2. Genetic selection of a plant population without regard to disease resistance.
3. Vegetative modification through management practices that tend to reduce heterogeneity both inter- and intraspecifically.
4. Modifications that influence populations of insects that are vectors of plant pathogens.
5. Large scale off-site plantings.

Principles of Plant Disease Management

Managing plant disease deals largely with prevention of infection in plant populations rather than with cure or therapy of diseased individuals. Therefore, it is imperative that action be taken in advance of infection. Essentials for sound management planning include a basic knowledge of the host plant, pathogen life cycle, and environmental factors such as temperature, moisture, and light intensity that influence pathogen disease dynamics. The rationale or justification for disease management and experimental research is found in past disease experience rather than immediate crises.

Methods for preventing, curing, or reducing the severity of disease are directed at the inducing agent following one or more basic principles as follows:

1. Avoiding the pathogenic agent.
2. Exclusion of the pathogen from an area.
3. Eradication of an established pathogen.
4. Protection of the plant by placing a barrier.
5. Curing infected plants.
6. Improving host resistance.

Avoiding the Plant Disease

Site Selection—In vegetative restoration, selection of the site is not usually a basis of avoiding a plant disease organism on the site. However, potential disease problems can be evaluated, based on an analysis of plant pathogens on the site. Species selection criteria should exclude known potential hosts of endemic pathogens and native or exotic species of unknown susceptibility. Another potential danger could be the presence of insect vectors of an endemic pathogen that could spread a virus, for example, to revegetation plants. Selection of seed increase planting sites or species evaluation sites could avoid pathogen infested agricultural land. Evaluation of soil and climatic factors could avoid abiotic diseases.

Pathogen-Free Planting Stock—Use of pathogen-free planting stock should be a routine revegetation requirement. This applies to seed, bare root nursery stock, containerized stock, or in fact, any propagative material. An inspection and certification program is essential to ensure that planting material is pathogen free. Procedures for sanitary packaging, shipment, and protection from contamination during planting need to be developed. Use of native plants for revegetation projects is in its infancy as is the production, sale, and purchase of seed and planting stock by private firms or government agencies. A major portion of native plant seed is collected from wildlands where disease status is unknown. Only recently have private and government concerns begun producing planting stock. Presently there is little or no factual basis for evaluating the disease status of propagative material. Revegetative work in the Western United States is proceeding at great risk in view of this well established principle.

Excluding the Plant Pathogen

Plant pathogens may be excluded from a revegetation site by inspection, pretreatment of propagative material, soil treatment, and eradicating insect vectors.

Treatment of Propagative Material—Propagule treatment to assure pathogen-free planting material is more applicable at the propagule increase certification level than for large rangeland revegetation efforts. Aerated steam, hot water, gases, and radiation are used to eliminate pathogens from planting material. The thermal death point of most pathogens is lower than for most plants and thus pathogens can be eliminated from the host plant by various heat treatment methods. Ultraviolet light, x-ray, gamma-ray, and other electromagnetic radiations are used to kill pathogens in plant material. Meristem culture is used to eliminate fungi, viruses, and bacteria and produce pathogen-free plants.

Quarantine of Diseased Plants—Quarantines are difficult to implement and control. In most instances they are justified even if they only result in delaying entrance of pathogens into a new area. Excluding a virulent pathogen from an area to which it would not likely spread by natural means is the most justifiable basis for quarantine. If there is little or no knowledge of specific pathogens, as is the case with most wildland plants, there is full justification for a complete quarantine. Present interstate or interregional shipment of seed and other planting material should be discontinued until there is a basis for establishing the risks involved.

Eradication of the Plant Pathogen

Eradication, like other control methods, is not usually thought of in absolute terms. The objective is to reduce the pathogen population to a level that permits a suitable return or product. The objective of biological control is to eradicate the pathogen enough from an area to allow an acceptable return.

Sanitation—This is an extremely important method of preventing disease problems although not as directly applicable to wildland revegetation projects such as production of planting material in nurseries, greenhouses, and seed increase plantings. In the production of certified pathogen-free seed and other planting material, roguing of diseased plants, elimination of weeds that may harbor pathogens, or alternate hosts of heteroecious fungi are essential. Alternate hosts and weeds can also serve as spheres for sexual recombination and evolution of new virulent races. Such hosts and weeds should not be permitted near experimental areas where genetic improvement activities are in progress.

Crop Rotation and Soil Treatment—While not applicable eradication methods in solving disease problems in wildland management, crop rotation and soil treatments are of high value in seed garden, nursery, and greenhouse operations.

Benefits from crop rotation depend on a thorough knowledge of the hosts and pathogens involved. The theory is to plant a nonhost or immune crop following a crop that may have increased a specific pathogen population. Soil fumigation should be a routine practice in nurseries and seed increase plantings. To fumigate only when disease problems begin to threaten is an unwise practice. Aerated steam treatment or soil fumigation should be followed rigidly in all greenhouse operations intended to produce healthy containerized planting stock.

Protecting Plants from Pathogens

Application of protective chemicals is a familiar method of plant disease prevention but is of questionable feasibility on wildlands. The principle is to prevent infection by coating seeds or plants with a substance toxic to the pathogen. With cultural methods, for example, plants in greenhouses may also be protected from pathogens by preventing long periods of free moisture that may be required for infection by certain fungi. Seed is dried and then stored at temperatures unfavorable to seed pathogens.

Curing a Diseased Plant

Some diseases can be cured by use of systemic chemicals that are directly toxic to the pathogen. Heat treatment is also used to cure plants infected with systemic viruses or vascular fungi. Localized diseased portions of plants, like mistletoe, witches' brooms, fire blighted branches, or stem galls, for example, can be removed by pruning to rid the plant of the disease. Curing or therapy as a means of control is limited to high value individual plants and the production of pathogen-free propagative material.

Improving Host Resistance

All plants are susceptible to some pathogens, but all plants are also resistant to most pathogens. Evolution of this equilibrium provides the basis for mutual survival of both organisms (pathogen-susceptible and pathogen-resistant plants), and is exploited in pathogen resistance selection and breeding programs. These programs are, however, long-term, expensive, and unwise ventures without a dedicated commitment. In the final analysis, when disease resistance can be improved, it is usually one of the most economical means of managing disease problems.

The host-pathogen-environment interaction must be thoroughly understood before a breeding program can be credible. There are many examples with agricultural crop plants of successfully improving disease resistance, however, improvement is usually a slow process. The success of using improved resistance in agronomy depends on a corresponding cultural control, and both are justifiable because of the high value of the crop. The infeasibility of practices such as fertilization, weed control, insect control, and irrigation in wildland management limits the usefulness of disease management to improving resistance. Nevertheless, improving disease resistance has an important potential for managing wildland plant disease.

Biological Management of Plant Pathogens

The dynamic fluctuation of organism populations in natural systems has evolved from an interaction of associated organisms and their physical environment to the system said to be in biological balance. Humans are disrupters of this balance, and this is the origin of their problems. The stability of biological systems is proportional to their complexity. Management systems in agronomy and forestry tend to create instability by simplifying biological systems. Parasitic organisms react abnormally in human-disrupted systems in agronomy and forestry, and tend to create instability by simplifying biological systems. The premise of biological management is to use the diverse phenomena of natural systems to restore the balance. But to live with this system, humans must agree to share the harvest with microorganisms. In other words, the objective of biological management is to reduce, not eliminate, human loss to plant pathogens. With this system, people are not direct participants (such as is an application of a fungicide), rather they manage the restoration of natural systems through joining a knowledge of biological plant systems. Recent theory and principles of biological management now being directed toward agronomic plant disease, have evolved by following natural systems.

In restoring and managing wildland plant resources, managing plant disease is an important part of the problem. From a scientific basis there is no benefit to proceed without giving attention to plant pathogens. We can successfully use both low cost plant disease management and also natural biological methods. We have before us, in the Western United States shrublands, biological systems more “truthful” and effective in their natural state than exist in agriculture and intensive forestry. Natural microbiological systems are now being modified and threatened by resource management practices that hardly consider their existence. It is an endangered system. An immediate prime effort of wildland resource management and scientific research should be directed to understanding these systems.

Outline for Managing Plant Disease in Wild-Shrubland Plant Improvement and Revegetation Practice

I. Define management needs
II. Review and select potential plant species with them
III. Establish genetic control
   1. Review plant characteristics desirable for human-centered objectives.
   2. Review plant characteristics required for plant survival and evolution.
   3. Define geographic limits of a plant population possessing these characteristics.
   4. Define the variability of all required characteristics within the population.
   5. Based on variability, develop a statistically valid random sampling method for selection of plant propagule collection points.
IV. Preserve gene pool variability
   1. Evaluate seed collection, cleaning, storage, scarification, stratification, germination, planting, establishment techniques for the potential of reducing genetic variability.
   2. Evaluate loss of individual plants because of biological and physical factors during research experimentation for potential of reducing genetic variability.
   3. Base experimental design on population variability. For example, sample size or replication number should be based on preserving plant variability, not on experimental dollar limitations.
V. Attending dangers of narrowing plant gene pools
   1. Planting site location limitations.
   2. Potential for insect and disease epidemics.
   3. Short-term plant survival.
   4. High cost management.
   5. Modifying the nature and direction of plant evolution.
   6. Decertification.