SLIDE 1:
This is Steve Johnson, University of Maine Cooperative Extension, bringing you information on Plant Pathology. It is possible to receive a Maine Board of Pesticides Control recertification credit for this presentation. As this presentation is approximately a half hour, another presentation would also have to be viewed. Additionally, a test must be passed with a minimum of 80 percent correct answers on each presentation. While there is no charge for viewing this information, there is charge for taking each test, whether the tests are passed or not.

SLIDE 2:
"Plant Pathology is the study of the living entities and the environmental conditions that cause disease in plants; the mechanisms by which these factors produce disease in plants; the interactions between the disease-causing agents and the diseased plant; and the methods of preventing or controlling disease and alleviating the damage it causes." (G.N. Agrios)

This definition says nothing about production issues nor does it consider the esthetic value of a plant or plants. Plant pathology is about plants and the organisms that cause diseases on them. While the economic value of plants is important, it is plant health rather than plant production that is the focus of plant pathology.

SLIDE 3:
What is health?
The ability to carry out normal physiological functions at an acceptable level consistent to genetic potential. Normal physiological functions include:

Normal cell division, differentiation, and development,
Absorption of water and minerals from the soil and translocation;
Photosynthesis and translocation of photosynthates;
Utilization and storage of photosynthates;
Metabolism of metabolites and synthates;
Reproduction;
Storage of reserves for overwintering or reproduction.

The primary causes of disease are either biotic or abiotic. Biotic causes are living organisms (pathogens) while abiotic causes are nonliving and usually involve the environment. Organisms may kill plants directly or they may so severely debilitate them that they die of starvation or the effects of secondary infections.

SLIDE 4:

So, what is disease? Disease is "a malfunctioning process that is caused by continuous irritation. Of course, this process must result in some suffering, and produce symptoms." (Horsfall and Cowling)

"The term plant disease is properly applied to any deviation from normal growth or structure of plants that is sufficiently pronounced and permanent to produce visible symptoms or to impair quality and economic value." (Stakman and Harrar)

Any disturbance of a plant that interferes with its normal growth and development, economic value, or aesthetic quality; a continuously, often progressively affected condition in contrast to injury, which results from momentary damage." (Schumann)

Any disturbance brought about by a pathogen or a consistent environmental factor which interferes with manufacture, translocation, or utilization of nutrients would be considered a disease.

Failure to reach full genetic potential due to the activities of another organism or environmental factor would be a disease.

Plant disease is any disturbance brought about by a living entity or environmental factor which interferes with the manufacture, translocation, or utilization of food, mineral nutrients, and water in such a way that the affected plants changes in appearance or yields less than a normal healthy plant of the same variety.

SLIDE 5:

Plant pathogens may cause disease in plants in a number of ways:
1 - consuming the contents of the host cells upon contact
2 - killing or disturbing the metabolism of host cells through toxins, enzymes, or growth-regulating substances they secrete
3 - weakening the host by continually absorbing food from the host cells for their own use
4 - blocking the transportation of food, mineral nutrients and water through the conductive tissues. (environmental factors -- like extreme

temperature, light and extremes in chemicals absorbed - mineral toxicity)

Plant disease is the sum of all the biochemical reactions taking place at the point of contact of the pathogen and the host cells or at the points of reaction of the enzymes, toxins, etc., secreted by the pathogen, with the host cells. Diseases are not symptoms or conditions, nor are they instigators of the symptoms or the conditions, but rather are the interactions between the host and the pathogen or adverse environmental conditions.

SLIDE 6:
The pathogen is not the disease; it is the cause of the disease. Disease is the sum of the normal chemical reactions that are inhibited and of the abnormal chemical reactions induced inside the cells and in the tissues of the plant as a result of the irritation brought about by the causal agent, or the pathogen.

SLIDE 7:
Diseases are expressed in a number of different ways:

There are pathogens that interfere with the roots of plant
root rots are examples of these
There are pathogens that interfere with the translocation of water and minerals to the crown of the plant.
wilts are examples of these
There are pathogens that interfere with photosynthesis
leaf spotters and blights are examples of these

SLIDE 8:
There are pathogens that interfere with the downward translocation of photosynthate
viruses in the phloem are examples of these
There are pathogens that interfere with reproduction
smuts are an example of these
With tuber propagation, these are not as important except for plant breeders
There are pathogens which interfere with the storage of reserve foods
tuber rotters are examples of these

SLIDE 9:
In addition, pathogens can cause cellular disruption in the order of cell division.

Hyperplasia is the increased cell division associated with galls.

Hypertrophy is the increase cells size associated with some smuts (like common ear smut on corn)

Slide 10:

Disease is not a condition:

A condition is a symptom complex. A disease is "deeper" than the symptom. A disease is the totality of the biological activity of all interactants--both overt and covert.

Diseases are not symptoms or conditions, nor are they the instigators of the symptoms or the conditions, but rather are the interactions between the host and the pathogen or adverse environmental conditions.

Disease is not the pathogen:

Pathogens are the causal agents of disease. Imprecise usage of terms has lead to careless application. One hears "*Phytophthora infestans* is late blight of potatoes." This misstatement fails to recognize that the organism is not the disease and that disease cannot occur in the absence of a host. Disease is not infectious. Following the above logic, since disease is the result of host and parasite interaction; only the parasite/pathogenic partner is infectious. Disease is not mobile, it is not disseminated. Propagules and inoculum are disseminated and the disease host may be transported; but it is incorrect to equate disease and inoculum when speaking of epidemiology or dissemination. Only inoculum is disseminated.

Disease and injury are not the same. Mowing a lawn may remove as much as 60 percent of the biomass of the grass and may cause wounding by the mower; but it is a single non-recurring event that does not cause constant irritation. As such, disease is not the result of tissue removal. However, one should not ignore the tremendous wound sites produced by tissue removal and their potential for entry sites for opportunistic parasites that may lead to disease.

Slide 11:

What is seen in the photograph is wind damage. This is not a disease.

SLIDE 12:

What is Plant Pathology?

From the Greeks - Pathos (suffering) + Logos (study) = The study of the suffering plants.

SLIDE 13:
Plant Pathology has two parts:

Science - the theoretical consideration of the suffering plant.

How do plants defend themselves?
How do pathogens invade?
What causes symptoms?
Why don't all plants die?

SLIDE 14:
Art - The application of the Science (*i.e.* Diagnosis)

Differentiating symptoms caused by disease organisms from symptoms that might be due to environmental influences or production practices requires a good understanding of crop growth and production. For example, individual plants of some potato cultivars emerge uniformly at the beginning of a growing period. However, other cultivars emerge nonuniformly. Thus, an uneven emergence of a uniform cultivar might be a symptom of *Fusarium* tuber rot in one case; however, an uneven stand of a nonuniform cultivar would be considered normal.

In the same way, normal production practices might stimulate symptoms of plant disease. For example, rolling of potato foliage along the edge of a field in a regular repeating pattern may be due to uneven distribution of fertilizer rather than a pathogen.

Plant disease diagnosis is most accurate when the grower has a broad knowledge of possible problems that might affect that particular crop. In most cases, the grower will be familiar with the diseases that affect his crops, i.e. powdery mildew on grapes. In this case, identification is routine. When the disease is unknown, answers to some or all of the following questions may help in diagnosing the problem:

What are the symptoms on the plant? (leaf spot, wilt, rot, chlorosis, size, shape, etc.)

Are there any signs of the pathogen? (mycelium, spores)
Is disease localized or systemic in the plant?

Are symptoms widespread in the field or only on a few plants close together?

When were the symptoms first observed?

Has there been any history of disease in the field?

What is the crop variety?

What disease resistance or tolerance genes are built into the variety?

Disease Identification:
Effective disease management depends on early identification or diagnosis of the disease and/or the pathogen that caused it. In countless situations, disease control has been unsuccessful because of incorrect diagnosis.

Plant disease diagnosis is easier and more accurate if the following are well understood:

crop growth and development
crop production practices
diseases and other problems affecting a crop

SLIDE 15:
Disease theory / spontaneous generation

SLIDE 16:
There are many ways to classify plant diseases. One of the simplest is:

Living - Biotic
Non-living - Abiotic
Non-Diseased Plant death

Programmed Cell Death - Apoptosis

SLIDE 17:
In order to substantiate that an organism, group of organisms, or combination of organisms and environmental factors are causal agents for a disease, one must fulfill Koch's postulates. While this principle and concept are universally accepted by all pathologists, it is too often overlooked and there are diseases with putative causal agents that have never been demonstrated by Koch's Postulates. Years of research may have been spent on organisms never proven to cause particular diseases. Whenever one speaks about, or hears about, a disease, one should always seek to find out if Koch's Postulates were performed or have been performed. In effect, Koch's Postulates are the scientific method applied to pathology. As such, without them, pathology becomes an art and not a science.

The pathogen must ALWAYS be **associated** with the disease in ALL diseased plants. There are no exceptions allowed.

The pathogen must be **isolated** and established in PURE culture. This may be difficult with obligate parasites, but methodologies have been developed to fulfill this requirement even with obligate parasites.

Inoculation of a healthy plant of the same variety must reproduce EXACTLY the same symptom(s). Inoculation must be of a healthy plant of the same cultivar and species. This may be difficult if one isolates from a plant of unknown cultivar. The symptoms must be reproduced essentially identical to the initial diseased plant, taking into account differences between the initial plant's environment and the health of the inoculated plant.

The pathogen must be **reisolated** from the inoculated plant and its identity confirmed as the same as the original isolate. The organism recovered must be the identical to the original isolate. There are no exceptions.

SLIDE 18:
A few definitions may be helpful:
Host: A living organism on or in which a parasite is living and from which the parasite obtains its sustenance.

SLIDE 19:

Pathogen: The causal agent of disease in a plant. It may be biotic (infectious) or abiotic (non-infectious).

SLIDE 20:
Disease: An injurious physiological process. It involves an alteration or one or more of the ordered, sequential series of physiological processes essential for plant growth, development, or reproduction. It is the result of continuous irritation due to the presence or absence of some factor or causal agent. The causal agent may be biotic or abiotic, infectious, or non-infectious, transmissible or non-transmissible. A host condition is the result of the activities of a causal agent. NOTE: Causal agents are mobile and "infect." Diseases can neither be mobile nor infectious.

SLIDE 21:
Sign: The physical manifestation of the causal agent. Characteristic structures of the causal agent appearing on or in the diseased plant are signs. It may be in the form of spores, mycelia, thallus, nematode, bacterial ooze (when the bacterium is present), or something like that.

SLIDE 22:
Symptom: The physical manifestation of the host's response to the causal agent. Symptoms may be localized (confined to a small area of the plant) or systemic (spread through out the entire plant). It is any reaction of a plant to a disease causal agent and usually refers to visible reactions.

SLIDE 23:
Primary symptom: symptoms proximal to the infection site produced as a direct result to the causal agent. A common primary symptom is a lesion; a well-defined localized diseased area.

Secondary symptom: symptoms that result from indirect or "chain of events" interactions and occur some distance from the infection point and in many cases distal to the causal agent. Whether primary or secondary symptoms, tissue may be greener than normal, chlorotic (yellower than normal), or necrotic (dead, tan or brown).

SLIDE 24: The "Disease Triangle" is a central concept of plant pathology. It is based on the principle that disease is the result of an interaction between a host, a potential pathogen, and the environment. If any one of these factors is missing, then the disease will not occur. It is important to remember that all

three components are necessary pre- and post- infection. Too often the importance of environment is forgotten once the host-parasite interaction is established. To do so is to limit potential disease management approaches. In order to fully understand this concept, one needs develop definitions and "working definitions" of: what is a host, a pathogen, and environment? Definitions are not just carefully worded phrases. They are concepts that imply meaning by usage; therefore, one needs to be thoroughly familiar with the terms, concept(s) and usages implied by the term.

For a disease to occur, there needs to be certain conditions present. There has to be susceptible host, virulent pathogen, and suitable environment for the virulent pathogen to infect, colonize, and reproduce on the susceptible host.

SLIDE 25:
Parameters:

The study of plant disease is not exactly like the study of insects or weeds. Diseases, or more specifically plant pathogens, have an infection period, an infection site, a latent period, an infectious period, all of which may explain why there appears to be more disease after the application of a protective fungicide.

SLIDE 26:
Infection site:

This is the area of the infection, specifically the part of the host that the pathogen will actually infect. This may be a natural opening such as a leaf stomate, a stem lenticel, or a wound such as those caused by wind-blown sand or a damaged area as a result of an insect feeding. The infection site may be internal as a result of an insect or nematode directly penetrating into the host. The pathogen may not need a specific site for infection, as it may have the chemical arsenal to directly penetrate the host tissue. This chemical penetration of the host is completed by an orderly set of enzymes which dissolve the cuticle of the host, break down the epidermal cells, and proceed to chemically disrupt the host cells in such a way that their contents are consumed by the pathogen.

SLIDE 27:
Infection period:

The infection period is the time in which the pathogen infects the host. Specific environmental conditions must exist for this to occur. Temperature, humidity, and even light have to be within certain ranges for a successful infection to occur. These parameters are not the same across all pathogens.

SLIDE 28:
Latent period:

This is the time between the successful infection and the appearance of a symptom, or lesion, or the disease, this may be hours, days or months. Once the infection has occurred, the pathogen has to reproduce to the point that the host cells are disrupted and die, causing a visible lesion. There is not a difference between this and human sickness where coming down with a cold come after picking up the infection, This is one of the most important concepts in the study of plant diseases. This is where the science diverges from the study of insects or weeds. A grasp of this may help in the proper control of plant pathogens.

SLIDE 29:
Infectious period:

This is the period when the lesion is actually infectious, or able to spread the pathogen, causing more disease on other hosts or other locations on the same host. There is a time when the reproduction on the host will cease. This will end the infectious period, but the original lesion still will be present, unless it senesced off the host. This infectious period can be very long, but usually is less than two weeks. This is a response of the pathogen to no food available, as the host has been killed, or at least the portion of the host under immediate attack has been killed.

SLIDE 30:
Going through this with Phytophthora infestans, the late blight pathogen, may help explain some of this a little better. The infection site for the late blight pathogen is direct penetration through the leaves, tubers, petioles, peduncles, stems, or other potato plant parts. It can directly penetrate the tissue.

SLIDE 31:

The infection period takes between 9 to 15 hours, perhaps a little longer, and this is dependent on temperature. Again, with the host/pathogen environment triangle, there has to be high relative humidity, possibly free water, a susceptible host, and a virulent pathogen. We have the pathogen and we have the host, what we need is the environmental conditions. At this point, the warmer the environment is to a point, the faster the infection takes place.

SLIDE 32:
The latent period is about 7 days in the field. About 7 days after the infection, the lesions will appear on the potato leaves. It has possibly been reported as fast as 5 days under some conditions and may be even faster under some very highly controlled laboratory conditions. For the most part, when you see a lesion appearing on Monday or Tuesday, it was likely the infection the previous Monday or so.

SLIDE 33:
The infectious period or the period at which the late blight lesion will be able to spread the pathogen is 3 to 5 days, sometimes longer, sometimes less, but it has tremendous capability to produce a lot of spores. It may continue to grow and expand and produce more spores for another 3 to 5 days as well.

SLIDE 34:
Using late blight as an example of the stage and development of the fungal disease, the late blight pathogen, *Phytophthora infestans*, spores have to be deposited onto a susceptible unprotected potato plant. These spores have to germinate. The environmental conditions have to be such that they will. They have to penetrate the host, and the Phytophthora infestans it makes an aspersorium and a penetration peg to actually go into the host, infects the host, establishes itself in the host and will reproduce in and on the host. It will go through the tissue and sporulate on the bottom. This inoculum this new spores that is actually sporulating and the white mycelia will be spread to other plants so these spores will continue the cycle going through.

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