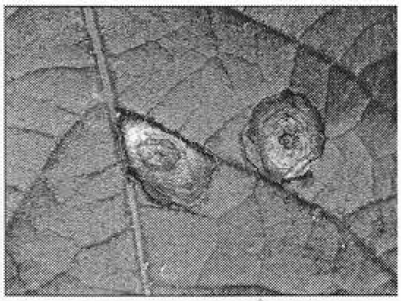
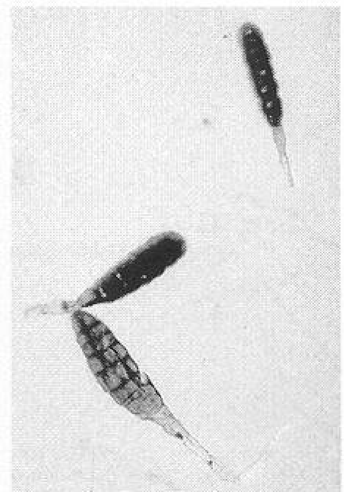
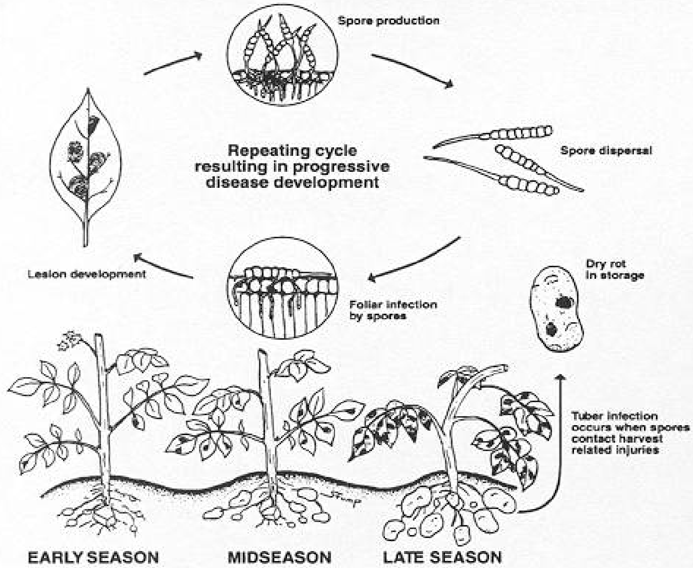
AN INTRODUCTION TO PLANT PATHOLOGY AND PLANT DISEASE MANAGEMENT







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Modified from publication B-1053

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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30,1914, in cooperation with the U.S. Department of Agriculture, Glen Whipple, Director, Cooperative Extension Service, University of Wyoming Laramie, WY. 82071.

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AN INTRODUCTION TO PLANT PATHOLOGY AND PLANT DISEASE MANAGEMENT

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INTRODUCTION

Anyone working as a plant professional will need to determine why plants appear abnormal and what control measures, if any, are appropriate. This manual introduces the reader to the subject of plant pathology and the information it contains will aid in understanding how plant diseases develop as well as the various methods used for control. Terminology important to the study of plant diseases is identified for the reader by printing in ***bold/italics*** and is defined either in the text or in the section on 'Plant Pathology Terminology.'

THE DISEASE TRIANGLE

Plant disease results when a specific agent, such as persistent unfavorable environmental conditions or the activity of a pathogen, disrupts physiological functions causing plants to deviate from normal development. The word 'persistent' is used to distinguish between a ***disease*** which develops over time and an ***injury*** which occurs, more or less, instantaneously.

Noninfectious diseases, perhaps more appropriately called ***disorders***, do not spread from plant to plant. These disorders result from the plant's exposure to such factors as unfavorable weather, mechanical damage, nutrient deficiencies, excess salts or toxic chemicals. Although disorders can ***predispose*** plants to infection by pathogens, disorders are not directly treated using pesticides. The remainder of this manual emphasizes the discussion of infectious plant diseases caused by pathogens.

An infectious disease results when a ***pathogen*** lives in close association with the host plant. The pathogen is functioning as a parasite since this relationship usually benefits the pathogen at the host's expense.

Although relationships resulting in disease are often complex, three critical factors must be present in order for a particular disease to result. The three factors necessary for disease development are (1) the pathogen must be present, (2) a susceptible host must be present and (3) the proper environment must be present, permitting infection of the host. These factors give us the concept of the ***disease triangle*** (Figure 1).

Production practices followed by large growers and home gardeners serve to modify the interaction of these three factors to reduce (or unwittingly increase) the overall impact and severity of plant diseases. Plant professionals use the disease triangle concept to simplify remembering and understanding how a particular disease develops and why various control strategies are used. The pathogen, host and environment are discussed in more detail below.

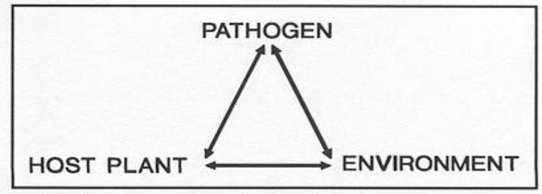

Figure 1. The Disease Triangle. These three factors interact and must be present for disease development to occur.

The Pathogen

Fungi, bacteria, viruses, viroids, nematodes, parasitic plants (dodder and mistletoe), phytoplasmas, and protozoa are examples of various pathogens that cause plant diseases. General descriptions of the most common and economically important classes of pathogens are listed below. It is important to remember that many beneficial microorganisms exist in nature, and that only a small fraction infects plants.

Fungi. Bread molds and mushrooms are examples of fungi familiar to all of us. Most of the 100,000 fungus species identified by scientists are only ***saprophytes*** and not capable of infecting plants. However, more than 8,000 plant pathogenic species have been identified making fungi the most numerous and economically important class of plant pathogens. The great diversity of fungi and the complex and intricate life cycles of some plant pathogenic species make generalizations difficult.

Plant infection by fungi occurs via a great variety of mechanisms. Some species directly penetrate plant surfaces or enter through natural openings, while others require wounds or injury for infection. During disease development, many species of fungi produce spores which are dispersed by wind, water or by other means. Each spore may cause a new infection resulting in a rapid increase in disease incidence and severity. Some fungi form special resting spores which permit survival for long periods of time (several months or years) in soil or plant debris.

Fungi are identified primarily from their morphology, with emphasis placed on their reproductive structures. Laboratory techniques can be used to induce sporulation in many fungi if reproductive structures are not visible on plant tissue.

Bacteria. Bacteria are perhaps the second most economically important class of plant pathogens. Bacteria are considered more primitive than fungi and generally have simpler life cycles. With few exceptions, bacteria exist as single cells and increase in numbers by dividing into two cells during a process called binary fission. Their ability to rapidly reproduce when environmental conditions are favorable give bacteria their potential for causing an explosive increase in disease.

Some species are able to survive on healthy-appearing plant surfaces as epiphytes, and only cause disease when environmental conditions are favorable or when injuries, such as those caused by hail, occur. Overwintering weed hosts, infected seedstocks or contaminated crop debris may serve as the initial source of bacterial inoculum. The presence of certain bacterial species on plant surfaces increases frost sensitivity while other species are able to move long distances in aerosols or irrigation water.

Bacterial ooze on plant surfaces or bacterial streaming can aid in the identification of bacterial diseases when working in the field. However, laboratory methods are usually required for identification.

Nematodes. Nematodes are microscopic round worms that reside in the soil. Disease induced by nematodes usually results in poor plant growth and may be overlooked when there are no healthy plants available for comparison. Roots of poorly growing plants should be examined carefully for evidence of nematode feeding. Symptoms may be deformed roots or galls.

Feeding by plant-pathogenic species can cause disease by direct interference with normal plant development, by interacting with other disease causing organisms or by acting as a vector for pathogens. Although most plant pathogenic species affect only roots, some species infect stem, foliar and bud tissues.

Viruses and Viroids. Viruses and viroids are extremely tiny particles consisting of protein and genetic material (viruses) or genetic material with no associated protein (viroids). Biologists disagree on whether viruses and viroids should be classified as 'living' since they are true obligate parasites incapable of carrying out any physiological processes in the absence of a host.

In order for disease to spread, these particles must be physically inserted into a living host cell by vectors including insects or man, or they may be transmitted through seeds, tubers, grafts or merely by physical contact between healthy and infected plants. The method(s) of transmission for a specific virus or viroid is a characteristic of that pathogen and the disease it causes. Once inserted into a host, the physiological processes of the cell are redirected into the manufacture of more particles. Chemical controls usually target insect vectors and some disinfectants inactivate viruses, rendering them noninfectious.

Most virus diseases are identified by characteristic symptoms coupled with electron microscopy and/or serological tests. Viroid identification requires even more specialized detection methods.

The Host

Levels of ***resistance*** or susceptibility of the host plant will affect disease development. Plants with high levels of resistance are essentially immune or not susceptible and do not allow the pathogen to become established, even if present. Plants with lower levels of resistance may become infected but only allow the pathogen to develop slowly, limiting the economic impact of the disease to acceptable levels. Stress, such as that brought on by an unfavorable environment, poor fertility or irrigation will affect a host plant's ability to resist infection and, therefore, also effects disease development.

In some cases, resistance in the host is overcome by the pathogen, resulting in rapid and devastating disease development. This risk is increased if large production areas are planted to a monoculture of identical hosts. Therefore, genetic diversity of host plants will decrease the risk of catastrophic losses.

The Environment

Environmental conditions play a large role in disease development and disease severity. However, broad generalizations about environmental effects have many exceptions. The disease triangle shows that the environment influences disease development by interacting with both the host and pathogen. Furthermore, environmental stress can predispose plants to infectious disease. Several important environmental factors are given below.

Temperature. Temperature greatly influences disease development. Temperatures that are not ideal for the host plant induce stress and predispose plants to disease by lowering host resistance. This may occur for hosts determined to be resistant under normal growing conditions.

Temperature also affects the amount of inoculum available. Cold winters interrupt the disease cycle by killing pathogens or vectors that otherwise may persist until the next growing season. During the growing season, temperature will directly influence the pathogen’s ability to reproduce and infect the host. This will directly affect the rate of disease development, disease severity or even if diseased plants will appear in the first place.

Moisture. Abundant, prolonged or repeated moisture is the predominant factor in the development of most epidemics caused by fungi, bacteria and nematodes. Although relationships can be complex, rain, greater relative humidity or prolonged dew periods will increase the likelihood of many, but not all, diseases.

Moisture affects the host by inducing new growth that may be more susceptible, or resistant, to infection. Moisture also induces sporulation of fungi, replication of bacteria and mobility of nematodes, thus, increasing the amount and dispersal of available inoculum. For other pathogens, rain may suppress movement of insects acting as vectors of pathogens, thus reducing disease spread.

Wind. Fungal spores, vectors, and, to a lessor extent, bacteria and nematodes, can be dispersed by the action of wind. This will enable pathogens to move from infected plants to healthy plants. Wind can also injure hosts, thus providing an avenue for infection and/or increasing susceptibility to some pathogens.

Other Factors. There are many factors including light intensity, light quality, soil pH, fertility and soil type that influence disease development. Relationships can be complex with environmental influences being exerted on the host and the pathogen. Each disease must be studied carefully to determine what interactions are important for its development.

DISEASE DIAGNOSIS

Diagnosis requires knowledge of what is normal for the host plant as well as knowledge of problems that occurred in the past. Accurate diagnosis is critical for deciding if a disease is present and if effective control measures are available or justified. An accurate diagnosis is based upon recognition of specific signs of the pathogen on the host as well as the presence of symptoms on the host.

Signs are defined as the visible presence of the pathogen or products of the pathogen on the host plant. Fungal spores, fruiting structures that bear spores and bacterial ooze are all examples of signs. In contrast, ***symptoms*** are the external and internal reactions or alterations of a plant as a result of disease. For example, dead spots in leaves or bark, rotten spots in fruits or tubers, swellings on roots or branches, clustered branches, unnatural color or shape and vascular discoloration in stems are all symptoms that may aid in diagnosis of a plant disease.

Because most diseases encountered have previously been described, it is usually possible to diagnose a specimen by comparison with the symptoms and signs of pathogens already described for diseases of that particular host. Books, manuals and pictures are very useful aids in diagnosis of many plant diseases. Experienced diagnosticians recognize many diseases on sight or are able to quickly narrow down possibilities to several choices. Although experience is the best teacher, the general guidelines listed below will help focus attention on information needed for accurate diagnosis.

1. Carefully describe the characteristics that make the plant appear abnormal (symptoms).

2. Determine the distribution of symptoms in the host by looking at the entire plant.

3. Determine if evidence of the pathogen (signs) exist.

4. Determine the distribution of affected plants in the field.

If diagnosis is still not possible, contact fieldmen or your local Cooperative Extension Educator for assistance. Specimens can be mailed by your Extension Educator to the University of Wyoming, when additional assistance is required.

DISEASE DEVELOPMENT

Every infectious disease requires a series of sequential events in order for disease to develop. This series of events is called the ***disease cycle***. Although the specific characteristics are unique for each disease, the general events in the disease cycle are; (1) dispersal of the pathogen to the host, (2) penetration and infection of the host, (3) invasion and colonization of the host, (4) reproduction of the pathogen, (5) pathogen dispersal (6) pathogen survival between growing seasons and/or in the absence of a host.

Completion of events #1-5 is one ***generation*** of the pathogen and, depending on the pathogen, can be repeated before the growing season ends at event #6. The generation time and the number of generations a pathogen completes during one season determines the dynamics of disease development and the potential for plant or crop loss. Graphic representations of disease severity over time are called ***disease progress curves*** and are discussed below for Figures 2, 3 and 4.

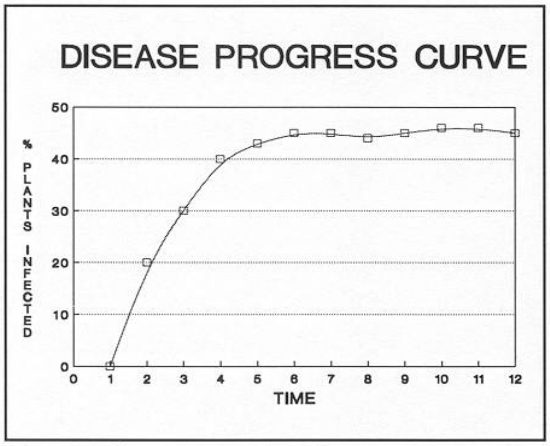

Figure 2. Monocyclic disease progression within a plant population. Time can be days, weeks or months.

Monocyclic pathogens have a maximum of one generation per growing season and possess a characteristic disease progress curve (Figure 2). Pathogens are monocyclic because environmental conditions or other physical factors prevent repeating events #1-5 until the next growing season; examples are *Verticillium* wilt and some other soil-borne diseases. Other pathogens are monocyclic because their life cycle requires at least one season to complete; examples are cedar-apple rust and corn smut.

Polycyclic pathogens complete more than one generation per growing season and, therefore, are able to reproduce and infect additional healthy plants during the current growing season (Figure 3). As the potential for the number of generations increases (i.e., the generation time decreases), so does the potential for devastating losses. Some fungi have such short generation times that steps in the cycle of pathogenesis completely overlap resulting in a continuous series of new infections giving the appearance of explosive disease development. Examples of polycyclic pathogens can be found in virtually all classes of pathogens including fungi, bacteria, nematodes and viruses. Several examples are early and late blight of potatoes, and wheat and bean rust.

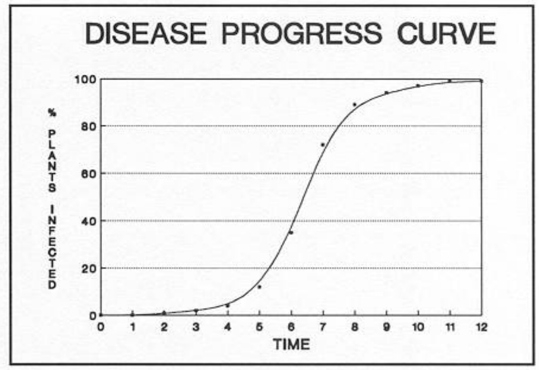

Figure 3. Polycyclic disease progression within a plant population. Time can be days, weeks or months.

The time over which disease develops in a production area or region for both monocyclic and polycyclic diseases can vary from days to years and is a characteristic of the specific disease involved. Severe losses can occur regardless of the speed at which disease develops and can result from both monocyclic and polycyclic pathogens.

PLANT DISEASE CONTROL

Control measures are used to interrupt or weaken at least one of the six sequential events in the disease cycle (see above). In general, monocyclic diseases are most efficiently suppressed by reducing the amount of the initial inoculum at events #1 and/or 6. Polycyclic diseases are most efficiently suppressed by reducing the initial inoculum and/or by reducing the rate of disease increase that occurs when events #1-5 are repeated. Various control methods commonly used to reduce or eliminate disease are categorized below; much overlap exists between categories.

Exclusion. The disease triangle illustrates that if the pathogen and host remain separated, no disease will develop. Disease control methods that maintain separation can be very effective. However, this approach to disease control is largely regulatory in nature and includes quarantines, inspections, use of pathogen-free plant materials, certification of seed stocks, and by other means.

Evasion. The use of healthy seed, planting and growing plants under environmental conditions unfavorable for disease development, selecting early (or late) planting and harvest dates and maintaining the proper distance between rows and fields are all examples of methods for evading disease. These practices increase the chance that the host will remain healthy or go through its susceptible stage before the pathogen reaches the host.

Eradication. Eradication is the elimination or destruction of the pathogen. Methods of eradication include temporary removal and destruction of host plants, chemical treatment of soil or seeds to kill the pathogen, and sanitation of equipment and storages. Growers routinely practice crop rotation to reduce the amount of inoculum present to acceptable levels, by growing a non-host plant.

Resistance. Resistance is the growing of plants not susceptible to the disease. Resistant cultivars are usually developed through special breeding and selection programs. Immunity or total resistance is often unobtainable and many varieties have partial resistance that allows the plant to grow in spite of contact with a pathogen.

Environmental Modification. Creating conditions unfavorable for the pathogen is a practical disease control method used by some growers. Proper spacing of the plants in the field or greenhouse will aid in reducing humidity that favors development of some diseases. Good soil drainage and proper irrigation practices are also important. Flooding fields during the fallow period may also reduce the incidence of some disease caused by soil borne organisms. Environmental modification by drying and/or refrigeration of harvested products is one of the most common methods used to slow growth of pathogens and reduce disease.

Protection. Infection of plants may be reduced through ***prophylaxis*** or protection. Although biological control agents are used in some instances to protect plants from infection, the most common method to directly or indirectly protect plants from pathogens is through the careful use of chemicals.

Chemical Controls

Chemicals or ***pesticides*** are often used to help control plant diseases. The correct timing of chemical applications as well as choosing the proper chemical is essential for good control. Labels provide application information and the directions must be followed.

Fumigants and Sterilants. These chemicals generally have a broad range of activity but are not applied to growing plants. Soil fumigation is commonly used to reduce nematode populations as well as other soil-borne pathogens and pests. Total eradication of pathogens and pests is generally not possible. Fumigants are typically expensive, difficult to apply, highly toxic and nonselective in their activity. Therefore, beneficial microorganisms and insects are affected, as well. Proper soil preparation, soil moisture (approximately 70% field capacity) and soil temperature (55-85 F) is critical for achieving uniform chemical distribution and effective disease control. Methyl bromide and chloropicrin are highly volatile fumigants, and plastic sheeting is required to seal the soil surface during their application. In contrast, metham sodium is less volatile and water can be used to seal the soil surface. Label directions will give precise directions on the soil conditions required and suitable application methods.

Nematicides. Fumigants are considered nematicides. However, other liquid and granular chemical formulations are available for nematode control, in addition to fumigants. These products have low volatility and can be applied before and after planting many, particularly non-food, crops. Nematicides kill nematodes that come in contact with the chemical and may kill some insects, as well. Nematicides are generally highly toxic and may contaminate ground water when not used properly.

Seed Treatments. Seed treatments are typically fungicides that protect the seed and germinating seedling from infection and/or decay. Pathogens can be seed-borne or soil-borne. Some advantages of seed treatments are that small amounts of chemical are required and that seedlings are able to get off to a strong start. Because treated seed is not to be used for feed, food or processing, dyes are used to color treated seed and treated seed should be properly labeled. An exception is the treatment of high moisture grains with acetic or propionic acid. Acid-treated grain is commonly used for livestock feed.

Protectants. These chemicals are usually applied to the seed or foliage of the growing crop so that a protective chemical barrier over the host surface prevents the initial infection. These products must not be toxic to the host.

Systemics. These are applied to the seed or growing crop and are often absorbed and transmitted systemically within the plant. These substances may kill or suppress the pathogen growing within host tissue and, therefore, may have a curative or therapeutic effect. Some systemics have very selective activity and, through repeated use, become ineffective due to selection for insensitive fungal isolates.

Integrated Methods

Frequently, a number of control methods are ***integrated*** or used simultaneously to reduce the economic loss of plant diseases. Relying on a single method for disease control frequently results in failure. Integrated methods can reduce costs associated with more expensive control methods and decrease the risk associated with dependence on a single method of control. Added benefits of integrated methods are that disease control is generally greater than for each method used individually (Figure 4).

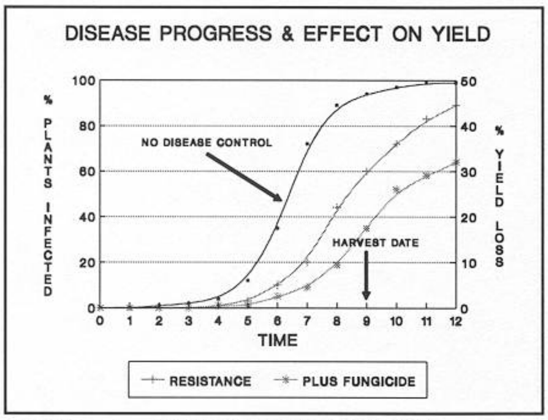

Figure 4. Integrated control methods (resistance plus fungicide curve) are often more effective for disease control than relying on a single method (resistance).

ADDITIONAL INFORMATION

Numerous reference books and publications are available that provide summaries of specific plant diseases, their control, and photographs to aid diagnosis. The professional society of plant pathologists, *The American Phytopathological Society*, offers many of these publications for sale at reasonable prices (approximately $35.00). Contact *APS* at (800) 328-7560, <http://www.scisoc.org> or write; 3340 Pilot Knob Road, St. Paul, MN 55121-2097. Some of the publications listed in the section "ADDITIONAL READING" are readily available through *APS*.

PLANT PATHOLOGY TERMINOLOGY

Atrophy - A lack of development of certain plant parts or tissues.
Bactericide - A compound toxic to bacteria.
Canker - A diseased or dead area in the bark and wood of trees or shrubs characterized by a drying out of the tissues.
Cell - The smallest unit that makes up a plant and consists of the cellular contents (protoplasm) surrounded by a cell wall.
Damping-off - A type of seedling disease in which the stem decays in the vicinity of or below the soil line.
Disease Cycle - The chain of events involved in disease development, including the stages of development of the pathogen and the effect of disease on the host.
Ecology - The study which deals with the effect of environmental factors, such as soil, climate, and culture on the occurrence, severity, and distribution of plant diseases.
Environment - The external conditions and influences that surround living organisms.
Epidermis - The superficial layer of cells occurring on all plant parts.
Exudate - Material that has been forced out.
Fungal - Relating to fungi.
Fungicide - A compound toxic to fungi.
Gall - An unusual enlargement on some portion of a plant.
Host - The plant upon which a parasite lives.
Hyperplasia - A symptom due to an abnormal increase in the number of individual cells.
Hypertrophy - An symptom due to an abnormal increase in the size of individual cells.
Hyphae - Fungal filaments which collectively form the mycelium of a fungus.
Immune - Cannot be infected by a given pathogen.
Incubation period - The period between the time the inoculum is introduced onto the host and the time when the diseased condition becomes evident.
Infection - The process of the pathogen gaining entrance to the host and becoming established as a parasite.
Infection court - Specific area on a plant where a pathogen gains entrance to the host.
Infest - To overrun or contaminate.
Inoculum - The pathogen, or its parts, that can cause infection.
Inoculation - The process of transferring inoculum to host.
Lesion - A diseased region of the host.
Local invasion - That involving only a portion of the plant.
Mummy - A dried, diseased fruit.
Mycelium - The group of hyphae that form the fungal body.
Necrosis - A symptom marked by rapid death of the host or parts of the host.
Nematicide - A compound toxic to nematodes.
Obligate - Necessary or essential.
Obligate parasite - Organisms that live only as parasites.
Pathogen - A disease-producing agent.
Pathogenicity - Ability of an organism to produce disease.
Pathology - The study of disease.
Pesticide - A compound toxic to a specific pest(s).
Physiology - The study of metabolic processes, activities and phenomena related to life.
Predispose - Make favorable for.
Primary infection - The first infection of a host by the overwintering or over summering inoculum.

Primary inoculum - The overwintering or over summering inoculum.
Prophylaxis - Methods used to preserve health and prevent spread of disease.
Pustule - Blister like elevation of the epidermis created as spores form underneath and push outward.
Resistance - The ability of a host to exclude or overcome the effect of a pathogen or other damaging factor.
Rogue - To remove or pull out.
Rust - Used to describe a particular fungus, any of its stages or the disease caused by any of the stages.
Saprophyte - An organism that uses dead organic matter for food; not functioning as a parasite.
Sclerotia - A hard, dense, compact mass of hyphae that serves as a resting body.
Secondary infections - New infections caused by inoculum produced during the same growing season.
Sign - The structure of the pathogen itself.
Spore - A fungal reproductive unit or seed that serves as an agent of dispersal and propagation.
Stomate - A small pore or opening in the epidermis of leaves and stems through which gases pass.
Symptom - Something that indicates a diseased condition.
Tumor - A swelling or protuberance.

Virulent - Designates the ability to function as a pathogen.
Vector - An animal able to transmit a pathogen.

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