FORECASTING PLANT DISEASE EPIDEMICS

Being able to forecast plant disease epidemics is intellectually stimulating and also an indication of the success of modeling or computer simulation of particular diseases. Foremost, however, it is extremely useful to farmers in the practical management of crop disease.

Disease forecasting allows the prediction of probable outbreaks or increases in intensity of disease and, therefore, allows us to determine whether, when, and where a particular management practice should be applied. In managing the diseases of their crops, growers must always weigh the risks, costs, and benefits of each of numerous decisions. For example, they must decide whether or not to plant a certain crop in a particular field. Growers must also decide whether to buy more expensive propagating stock free of virus and other pathogens or whether they can “get by” with untested stock. Quite often, growers must decide whether to plant seed of a more expensive or less-yielding but resistant variety rather than seed of a high-yielding but susceptible variety that needs to be protected by chemical sprays. Most frequently, farmers need forecasts that will help them determine whether a plant infection is likely to occur so they can decide whether to spray a crop right away or to wait for several more days before they spray.

If disease forecasting allows them to wait, they can reduce the amounts of chemicals and labor used without increasing the risk of losing their crop. To develop a plant disease forecast, one must take into account several characteristics of the particular pathogen, host, and, of course, environment. In general, for most monocyclic diseases (such as root rot of peas and Stewart’s wilt of corn) and for a few polycyclic diseases that may have a large amount of initial inoculums (such as apple scab), disease development may be predicted by assessing the amount of the initial inoculum.

For polycyclic diseases (such as late blight of potato) that have a small amount of initial inoculum but many infection cycles, disease development can best be predicted by assessing the rate of occurrence of the infection cycles. For diseases in which both the amount of initial inoculum and the number of disease cycles are large, e.g., beet yellows, both factors must be assessed for the accurate prediction of disease epidemics. Such assessments, however, are often difficult or impossible, and, despite considerable improvements in equipment and methods, assessments of initial inoculum or rapidity of infection cycles are seldom accurate.

**Disease Diagnosis: The Key to Forecasting of any**

**Plant Disease Epidemic**

Plants in a field are rarely attacked by a single kind of pathogen. More often than not, leaf spots and blotches caused by abiotic factors or bacteria may be present along with spots and blotches caused by fungi. Such symptoms may be confused with those caused by the pathogen in question and may be difficult to diagnose accurately. Such difficulty is especially likely early in the development of a disease when accurate diagnosis is needed most for determining if a threshold for development of an epidemic has been reached and appropriate instructions for its management must be issued. Inaccurate diagnosis of the pathogen in question as being present in the crop early, while in reality it is not, will lead to premature recommendation to spray and therefore to additional and unnecessary fungicide applications.

However, misdiagnosis of the real pathogen as something else of lesser importance is likely to miss the opportunity to take appropriate management measures early in the development of the epidemic and to make it much more difficult and expensive to prevent the epidemic from developing and causing serious losses.

**Evaluation of Epidemic Thresholds**

It is always desirable for the grower to have flexibility in timing fungicide applications according to the progress of an epidemic. In diseases characterized by numerous localized infections (foliar diseases), epidemics are generally characterized by three parameters: disease incidence in individual plants, disease incidence in individual organs (usually leaves), and disease severity (percentage infected leaf area) in leaves. These parameters mark different phases of disease development.

In the early stages of disease, disease incidence in plants may increase rapidly but disease severity on individual plants is low. In the second phase of the epidemic, i.e., disease incidence in leaves, there is a small increase in disease severity along with an increase in disease incidence in leaves. Depending on the specific disease, when a percentage (e.g., 1–50%) of plants and a percentage (e.g., 1–25%) of leaves show disease incidence, these are taken as the epidemic threshold in the first two phases of the epidemic for the application of fungicides to stop or slow the development of the epidemic.

During the third phase of a disease, disease severity is likely to increase rapidly (up to 2–50% per week). During this phase, fungicides are applied according to disease severity assessment, the dictates of weather conditions (rainfall, relative humidity, temperature measured daily, and providing a daily infection value), and continue as long as there is healthy tissue on the plants

that needs to be protected while the crop is not yet ready for harvest.

**Evaluation of Economic Damage Threshold**

Although it is fairly easy to determine the epidemic threshold, in many plant diseases the threshold for a fungicide application is reached late in the season, which results in disease severity remaining low and yield not being affected. Therefore, in order to apply fungicides only when needed, one must evaluate the tolerance level of disease severity at harvest. This tolerance level, known as economic damage threshold, is the highest disease severity level that does not decrease economic profits. The economic damage threshold is obtained by studying a disease–loss relationship of disease severity at harvest and the final value of the produce and then determining the point beyond which disease severity at harvest decreases economic profits.

**Assessment of Initial Inoculum and of Disease**

It is often difficult or impossible, in the absence of the host, to detect small populations of most pathogens. Inoculum propagules of soilborne pathogens, such as fungi and nematodes, are estimated after extraction or trapping from soil. Airborne fungal spores and insect vectors are estimated by trapping them in various devices.

Usually it is easier to assess the amount of inoculums present by measuring the number of infections produced on a host within a certain period of time. Even in the presence of a host, however, it is often difficult to find and measure a small amount of disease. Furthermore, in many diseases there is an incubation period during which the host is infected but shows no symptoms.

Aerial photography, using films sensitive to nearinfrared radiation, has made possible both earlier detection and sharper delineation of diseased areas in crop fields (due to the reduced reflectance of diseased foliage tissues that are occupied by water or pathogen cells). However, for many diseases, by the time aerial photography detects diseased areas in fields, yield loss has already occurred.

**Monitoring Weather Factors That Affect**

**Disease Development**

Monitoring weather factors during a plant disease epidemic presents enormous difficulties. Difficulties arise from the need for the continuous monitoring of several different factors (temperature, relative humidity, leaf wetness, rain, wind, and cloudiness) at various locations in the crop canopy or on plant surfaces in one or more fields. In the past, measurements were made with mechanical instruments that measured these environmental variables roughly or infrequently and recorded data inconveniently as ink traces on chart paper. Since the 1970s, however, several types of electronic sensors have been developed that produce electrical outputs recorded easily by computerized data loggers. Such computerized sensors are now prevalent in parts of the United States and of other countries and have improved studies of weather in relation to disease greatly and have facilitated the acceptance and use of predictive systems for disease control on the farm.

In most parts of the world, however, several types of traditional and battery-operated electrical instruments are used to measure various weather factors. Temperature measurements are made with various types of thermometers, hygrothermographs, thermocouples, and especially with thermistors (the latter are semiconductors whose electrical resistance changes considerably with temperature). Relative humidity measurements are made with a hygrothermograph (which depends on the contraction and expansion of human hair in relation to relative humidity changes), with a ventilated psychrometer (consisting of a wet and dry bulb thermometer or a wet and dry thermistor), or with an electrode-bonding sulfonated polystyrene plate (whose resistance changes logarithmically with relative humidity). Leaf wetness is monitored with string-type sensors that constrict when moistened or slacken when dry and either leave an ink trace in the process or close or break an electrical circuit.

Several types of electrical wetness sensors are available that can be either clipped onto leaves or placed among the leaves; they detect and measure the duration of rain or dew because either of the latter helps close the circuit between two pairs of electrodes. Rain, wind, and cloudiness (irradiance) are still measured by traditional instruments (rain funnels and tipping-bucket gauges for rain, cups and thermal anemometers for wind speed, vanes for wind direction, and pyranometers for irradiance).

Several of these instruments, however, have become adapted for electronic monitoring. In modern weather-monitoring systems, the weather sensors are connected to data-logging devices. Data may be read on a digital display or be transmitted to a cassette tape recorder or a printer. From the cassette, data may be transferred to a microcomputer. There they may be viewed, processed in several computer languages, organized into separate matrices for each weather variable, plotted, and analyzed. Depending on the particular disease model used, accurate weather information provides the most useful basis to predict sporulation and infection and therefore provides the best warning to time disease management practices, such as the application of fungicides.

The cost of purchase of automated weather systems (AWS) and the required time for operation and maintenance discourage their use by individual farmers, leading to the development of low-cost, automated weather instruments or stand-alone packages or to the creation and sharing of regional automated weather systems.