HOW DISEASE IS MANAGED

PHILOSOPHIES OF DISEASE CONTROL

Dr. Ron Pitblado

RIDGETOWN COLLEGE, University of Guelph

In the long gone days of the Old Testament, ignorance of plant disease was profound and mysticism was rampant. When Amos (4:9) was writing his book in the Bible (about 750 BC), he was so steeped in mysticism that he could explain plant disease only as a punishment meted out by Jehovah to encourage the people to repent their sins: "I have smitten you with blasting and mildew ... yet you have not returned to me said the Lord." With this understanding of cause and effect, the only option for disease management in Amos' day was to quit sinning.

The Romans did many things more thoroughly than most. Having many different gods they created two gods for the dreaded rust of their grain - "Robigo" and Robigus", male and female. Never in the 2000 years since Roman times has plant pathology enjoyed so high a status as to have two recognized gods. But praying to Robigo and Robigus apparently had very little influence on the amount of rust in Roman wheat.

In 1667, Robert Hooke used a fairly new gadget, a compound microscope, to see the spores of the rust fungus for the first time. Hooke had at last, associated a fungus with a disease for the first time. Despite the significance of his major discovery, Hooke was still in the grip of mysticism. Dropping the idea that God caused disease, Hooke embraced the equally mystical notion that diseases were generated spontaneous. The prevalent thinking retrogressed from having a cause for disease to having no cause. Hooke set in motion a new form of mysticism that was to dominate man's thinking for 200 years.

Even as Hooke was writing his famous book in England, however, wheat seed salvaged from a ship that sank in the sea grew free of smut. From that time forward, farmers in England decreased the amount of smut in their wheat by brining wheat seed in salt water. They were simply ignored by the scientific community of their day - ignored by those who knew where babies came from, but proclaimed that parasites on diseased plants originated without parents.

Around 1802 a French scientist observed under the microscope the germination of a black spore and when a droplet containing copper sulphate was added the spore did not grow - the first chemical control experiment.

Throughout history mankind has suffered from his ignorance of plant disease and its management. The discovery that copper sulphate controlled plant diseases was followed by the chemical revolution as the most effective management tool for controlling diseases.
THE THEORY OF DISEASE MANAGEMENT

The philosophy and approach of the crop protection sciences have been influenced significantly during the past decade by the evolution of an integrated pest management (IPM) concept. Although developed originally by entomologists as an integrated control approach for insects, this concept has evolved into a multidisciplinary, management system that integrates control methods, on the basis of ecological and economic principles, for pests of all classes.

The term disease control has been transformed into disease management. Both ancient and modern history have demonstrated that absolute control of disease is not only ecologically impossible but also economically impractical. For example the continuous application of a fungicide for tomato disease control, without an understanding of both fungal growth and the economics of the practice is certainly unwise. Certainly a better understanding of disease development, including the effect that weather has on the development of disease is essential in the development of disease management.

The plant disease triangle has been used to better understand plant disease management strategies. The 3 sides to the triangle represent:

1. the **PATHOGEN** eg. the organism that causes Early Blight *Alternaria solani*

2. the **HOST** or plant, eg a tomato plant

3. the **ENVIRONMENT**

One philosophy is to assume that the disease organism is present and that the tomato plant cultivar is susceptible to the disease. Later we can modify our plant disease strategy if we are able to determine when and if the disease organism is present and the relative resistance of the tomato cultivar. If the first two parts of the triangle are given, ie a susceptible host plant and the presence of the disease organism, then the triggering action determining the onset and severity of the disease focuses on the weather.
This concept that disease spores and mycelium can be present on a susceptible plant WITHOUT the development of disease and only under certain moisture or weather parameters is the basis of weather-timed spray programs such as TOMCAST. We will be discussing the application of these concepts later, but first we must appreciate another important concept of COMPENSATION.

**COMPENSATION**

The fact that one observes disease in plants does not mean that the plants will suffer yield losses. There are levels of damage that a plant can COMPENSATE for depending on the type of disease and which plant part it attacks.

Those organisms that require extended periods of time to develop (Early Blight and Septoria Leaf Blight), we manage differently than those that progress very fast (Late Blight). Those diseases that we consider as direct pests (Anthracnose) versus those that cause a foliar "burn or blight", we also need to develop control programs to address their differences. The concept of ECONOMIC THRESHOLD is important.

**THE ECONOMIC THRESHOLD CONCEPT**

The impact of disease losses in vegetable production cannot be assessed in isolation from an understanding of the biology of the crop and economic principles. The relationship between plant injury and the resulting damage is seldom linear.

The following graph depicts a hypothetical representation of a simplified economic threshold. Crop income (solid line) decreases at an increasing rate as the plant disease severity increases above some crop tolerance level (CROP DAMAGE THRESHOLD). The economic threshold is defined as the plant disease severity (or amount of plant damage) at which incremental costs of control just equals incremental crop returns. If controls are initiated successfully at the crop damage threshold, zero damage would occur, however the costs of controlling the disease would not be justified.
The crop tolerance level, or damage threshold, can vary depending upon the stage of crop development when attacked, crop management practices, geographic location and the climatic conditions. These factors, together with changing commodity prices, type of product being produced for sale, affect the economic threshold via the crop tolerance level or crop damage threshold.

In the production of processing tomatoes the crop damage threshold levels will change from crops used for whole pack to those grown for paste. For example, having speck or even bacterial canker lesions on tomato fruit destined for paste is not nearly the concern than if the crop was destined for whole packing, where the disease lesions on the fruit significantly down grade the product with removal costs incurred in the factory.

Another way of developing a philosophical strategy for disease control is to view the progress of plant disease on a graph. If over a period of time during the season the amount of, say foliar disease, begins to build up, there comes a point when the reduced photosynthetic capacity of the plant caused by the plant disease reaches a level of crop damage. If a successful control measure was put into place, that point of crop damage would be delayed - the onset of disease loss is delayed. By shifting the DISEASE PROGRESS CURVE, the amount of disease will be considerably reduced at time of harvest.

There are two plant disease strategies available to growers:

1. **Reduce the initial inoculum**
   - Seed treatments
   - Crop rotation
   - Host eradication
   - Sanitation

2. **Reduce the infection rate**
   - Chemicals - spray programs
   - Plant breeding - single vs multi gene resistance
   - Plant vigour
   - Creating conditions unfavourable for disease

![Disease Progress Curve](image-url)
Where philosophical differences arise or where differences in opinion in disease control strategies are made is often the result of how each weighs the relative importance of the components of either of these two methods of disease control.

**CRISIS MANAGEMENT vs FORECASTING SYSTEMS**

There was a time when few fungicides were applied to vegetable crops. Once these products became available, they became an important tool used by the vegetable industry. At this time, let us reflect back to my first statement in this article, "In the long gone days of the Old Testament, ignorance of plant disease was profound and mysticism was rampant." Prior to the introduction of TOMCAST in Ontario, we relied on a fungicide spray philosophy of over-kill. It was a very conservative understanding of fungicides and disease development that by continuously covering the new foliage growth you could "protect" the plant from plant diseases. In fact, that strategy was by in large fairly accurate. It was an avoidance of CRISIS MANAGEMENT. The recommendations for field tomatoes was to, "Apply a fungicide 2-3 weeks after the first cluster bloom, when the first fruits are about the size of golf balls. If plants are grown on soils frequently cropped to tomatoes, begin spraying a week after plants are set in the field and repeat every 10 days throughout the season." (Ag. Canada publication 1479 TOMATO DISEASES written in 1974). This was known as the "Fixed Scheduled or Calendar" method of timing fungicides (A Protectant Spray Program).
However, many growers began to realize that massively spraying their vegetable crops was not always needed or sometimes they found that it was not even effective under certain weather conditions. The key was the development of a better understanding of "THE WEATHER" and its impact on vegetable plant diseases.

WEATHER-BASED DISEASE PREDICTION SYSTEMS:

A. HOW DO THEY WORK?

Lord Kelvin's famous dictum says that our ability to understand a phenomenon is proportional to our ability to measure it. Why it has taken us so long to develop weather-based disease prediction systems, reflects this dictum. We have not had the instrumentation to monitor the pertinent weather parameters. This shortcoming has only recently been corrected, although further efforts in instrumentation need to continue. It is of interest that the science of Agrometeorology has produced considerably more sophisticated weather instruments than we can possibly use to-day to operate a real time weather based spray program. From our highs of sophistication, we need to address the practical problems with instruments that reflect what is happening within the crop canopy - where the fungi and bacteria reside.

In developing a weather-based prediction system one must reflect the often unique characteristics of the disease organisms themselves. Early Blight in tomatoes is caused by *Alternaria solani*. The spores will only germinate under conditions of free water. If tomato leaves are dry the spores will not germinate. Also fungal spores germinate over a wide range of temperatures.

The course of germination of *Helminthosporium* spores at 15C and 23C and of *Alternaria* at 25C, show distinct germination profiles. As often is the case, as the temperature rises the greater the number of spores will germinate over a shorter period of time. A weather-based spray model must reflect these temperature differences.

**Fungal Spore Germination**

*Helminthosporium*

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 C</td>
<td></td>
</tr>
<tr>
<td>23 C</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing fungal spore germination at different temperatures](image)
Alternaria solani is the causal organism for Early Blight in tomatoes. It has a unique "break through" germination pattern, with an initial lag phase that initially slows down the germination of these spores. Once a series of activities inside the spore has occurred, the fungal spore will germinate. This lag phase is of practical importance as often quick isolated showers during the day or irrigation during the day, where plant leaf surfaces dry off quickly, do not give the fungal spores a chance to germinate and thus are not often included in a predictive spray program, yet these occurrences are unnecessarily worrisome to many vegetable growers. In Ontario conditions, foliar diseases are driven not by rainfall but by evening and morning dews. Eight-five percent of the leaf wetness that is recorded is caused by dew.

**Fungal Spore Germination**

![Fungal Spore Germination Graph](image)

### B. HOW EFFECTIVE ARE THEY?

There are more Weather-based disease predictive systems around today than are being used. This is because some are not very effective, while more often, they are either misunderstood and/or difficult to manage on a real-time basis.

Initially the term FORECASTING was used. A forecaster is a prophet and a prophet has his troubles - What's the weather going to be tomorrow? "Forecasting is a difficult business, especially forecasting the future". The more effective weather-based predictive systems do not attempt to forecast but rather monitor what is happening, while the most effective programs are able to provide "what is happening" in a real-time basis. So the effectiveness of these models is not only based on good science but on rapid communications.

The more effective models also allow for modifications to their programs that growers can quickly use. If a crop has various levels of disease resistance, then the model should be able to accommodate this information. If a grower or processor wishes to have varying levels of insurance (how much disease are you willing to accept), then too, the model should be able to accommodate this as well.

### CONCLUSIONS

The philosophies of disease control have come a long way from placing a frog in a vase and walking around a field to ward off the wicked gods of plant disease. We now have new tools to combat plant disease. These new tools are knowledge.