PP-193

Integrated Disease Management for Vegetable Crops in Florida[1]

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Introduction

A successful disease control program depends on a crop production system which is closely aligned with the goals of pest management. One must start with the selection of appropriate varieties, an irrigation system that minimizes leaf wetness, a fertilizer program that results in optimum plant growth, bed preparation, plant density, and canopy management that affords optimum air circulation and pesticide coverage when needed, a transplant program which minimizes transplant shock, a clean seedling production program, effective pest monitoring during the season, and finally, a harvest and shipping procedure which maximizes shelf life and produce quality. Integrated pest management (IPM) as applied to diseases of vegetables means using all the tactics available to the grower (cultural, biological, host-plant resistance, chemical) that provides acceptable yield and quality at the least cost and is compatible with the tenets of environmental stewardship.

The five components of an IPM program are prevention, monitoring, correct disease and pest diagnosis, development and use of acceptable thresholds, and optimum selection of management tools. The management strategies available include genetic control, cultural control, biological control, and chemical control. What management strategy is most relevant depends in part on the particular pest. In general, weeds are most effectively controlled with cultural and chemical practices. Diseases are controlled most by host-plant resistance, cultural practices, and chemicals. Insects and nematodes are controlled with all four strategies.

For disease management, it is important to understand the potential of a pathogen to infest and spread in the crop. The three parameters of disease progress are 1) the initial amount of inoculum, 2) the rate of disease increase, and 3) the time the crop is grown. These parameters interact in ways to produce a rapid pathogen population increase, manifested as exponential growth in many production systems (Figure 1).

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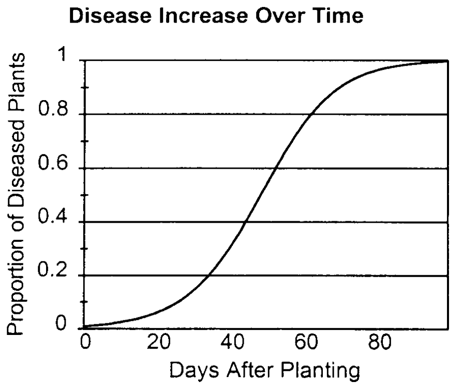

Figure 1. Typical progress curve for polycyclic diseases.

The rate of disease increase over time is dependent upon the interactions of the pathogen, plant host, and the environment. For disease management purposes, we are most concerned with the interactions of the pathogen and host at the population level of organization. However, environmental conditions play a critical role in determining the nature of plant disease epidemics. In plant pathology, this set of interactions is known as the disease triangle (Figure 2).

Understanding the biology of the pathogen, host-pathogen interactions, and the effect of environmental factors on this dynamic process in time and space (disease epidemiology), is critical for planning and implementing effective and efficient management strategies. These strategies can affect particular aspects of the growth of the pathogen population. Host-plant resistance can affect all three parameters by 1) reducing the amount of inoculum via resistance to particular strains of the pest, 2) by slowing the rate of pathogen buildup by reducing its reproductive capacity, and 3) by reducing the total period of exposure in short-season varieties.

Cultural control is aimed at reducing the primary inoculum (sanitation) or reducing the rate of disease increase by modifying the crop environment. A good example of the latter is the use of drip irrigation rather than overhead to reduce free water on foliage. The total time that a crop is exposed to a pathogen may be minimized by optimizing plant growth, thus reducing the time to harvest. Biological control usually affects the rate of pathogen buildup. Finally, chemical control can affect the amount of inoculum available at the beginning of the season (i.e. soil fumigation) and/or reduce the rate of disease development by killing a portion of the pathogen involved in later stages of the epidemics.

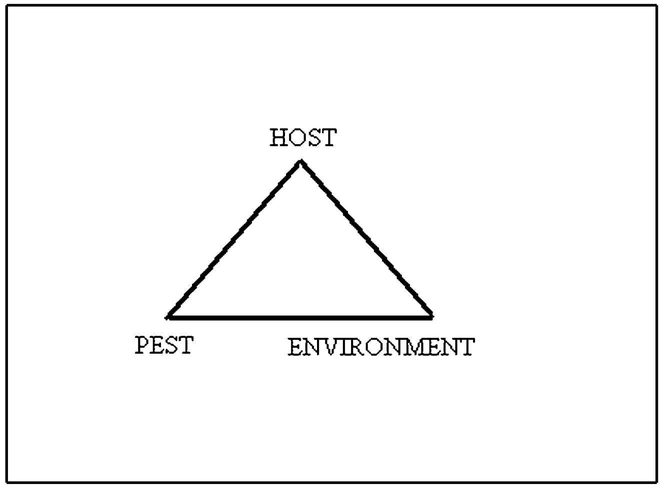

Figure 2. Disease triangle.

Accurate Diagnosis of Diseases

Proper disease identification is critical for making correct disease management decisions. This will save time, money, and the environment. Effective use of fungicides and other pesticides depends on correct identification of the problem.

The accuracy of any diagnosis depends upon the information supplied, the specimen material selected, and the condition of the specimen when it arrives at a clinic. Digital images of the fresh specimen with symptoms and field-view images of the problem might be useful in some cases. The Distance Diagnostics and Identification System (DDIS), available through the Florida Cooperative Extension Service, may be used for this purpose in many counties.

In order to apply disease management practices, there should be knowledge of which pathogens are present or are likely to appear in a particular field or season. Descriptive and pictorial manuals are helpful for identification of diseases commonly found in Florida. It is important to know the common diseases of a given crop specific to your area. Professional scouting firms and the University of Florida Extension Faculty can provide assistance in disease diagnosis. Diagnosis can also be provided by sending samples to the Plant Disease Clinics of the University of Florida located at Gainesville, Homestead, Immokalee, and Quincy.

Monitoring Pathogens

As mentioned, monitoring is a critical component of an effective IPM program. Monitoring can be direct (looking for the pathogen or disease) or indirect (recording environmental conditions which affect disease development). Financial considerations weigh heavily in the choice of monitoring practice.

Direct monitoring of diseases can be based on symptoms or signs of the pathogen. Identification of pathogens is generally difficult, because pathogens usually are microscopic and can be detected typically after the disease process has begun. Most monitoring is actually for disease symptoms, with the control strategy aimed at reducing further spread. Even when visible symptoms are evident, levels of disease may be so low as to make detection very difficult. To optimize the chances of detection, one should concentrate on those areas where disease is most likely to occur, for example in low areas or areas of lush growth. If this is not possible, an array of sampling designs may be used, such as a diagonal across the field, a random walk, a stratified design where each subsection of the field is sampled, or a stratified random design where a random sample is taken in each subsection of the field (see UF/IFAS Extension publication No. SP22 "Florida Tomato Scouting Guide”). The appropriate sampling design will depend on the level of disease expected, the distribution of the disease and sampling schemes already in place for other pests.

Disease distribution within a field is dependent, in large part, on the source of inoculum for the pathogen. If the disease is seedborne, in many cases the first diseased plants will be more uniformly distributed in the field. If the disease is soilborne, it may often be found in clusters in the field. If it is transmitted by insects, the distribution may be more random, or a field edge effect may be apparent. Thus, it is important to understand the biology of the disease when developing an appropriate sampling strategy for it.

Indirect monitoring of disease most often involves stand-alone, turn-key computer systems with probes or whole units in the field. Data commonly gathered include temperature, relative humidity, and leaf wetness. Data are typically recorded every 15 minutes, with data being used to update real time indices of the likelihood of disease at a given time. The algorithms for the models are often developed from controlled environmental chamber experiments where the minimum, maximum, and optimum temperatures and relative humidity for fungal growth, germination, and/or disease development are identified. Leaf wetness, either monitored directly or by prediction of dew point based on the relative humidity and temperature conditions, is used if the pathogen requires free water for germination. The prediction of disease events through environmental monitoring has been very successful in a few cases and is used widely for those crops and diseases where sufficient research exists.

For further information on scouting tomato diseases, see UF/IFAS Extension publication No. SP22, “Florida Tomato Scouting Guide”. In addition to identification keys, disease symptoms and disease seasonality chart, mode of pathogen spread and conditions that favor most diseases in Florida can be found in this publication.

Control Action Guidelines for Diseases

There are three major types of models used for determining when a disease (or vector insect) may exceed its economic threshold and a control action is justified. The simplest is the critical point model, where one parameter is monitored to determine if a disease problem is likely to occur. Perhaps the best known is the model of the corn flea beetle, which transmits the bacterium that causes Stewart's wilt of corn. In this pathosystem, the epidemic is dependent upon the ability of the flea beetle vector to survive the winter in the soil. This occurs in the northern U.S. only during mild winters. By adding together the average temperatures for December, January and February, it is possible to predict beetle survival. If the sum of the averages is less than 90, the threat of Stewart's wilt is negligible. Between 90 and 95, the threat is light to moderate. For values between 95 and

100, the threat is moderate to severe. Above 100, the threat is severe.

Although easy to apply, critical point models often are inappropriate due to the complex nature of many epidemics. The multiple point model is used to address more complex pathosystems. These models typically consider a number of parameters and assign severity points to each, with the sum of severity points indicating the potential need for control action. These models are simple to use and do an excellent job of helping to organize what is critical in the development of the disease. An example is the one used by peanut growers in the southeastern U.S. for *Tomato Spotted Wilt Virus* (TSWV), a virus vectored by thrips that affects a wide range of crops. Severity points are assigned based upon plant cultivar (more susceptible, higher the number), planting date, population density, insecticide use, row pattern (1 or 2 row), and tillage (conventional or strip). The sum of the risk values indicates a low, moderate, or high chance of loss to TSWV. Multiple point models can be used in more complex systems but also can be calculated before planting; thus action can be taken to change the field to a less dangerous situation. For example, if some fields must be planted at a time for optimum disease development, then a more resistant cultivar could be used in those fields.

The most complex type of model is the simulation model. These models often consider environmental conditions in real time analysis, thus determining when plants are most susceptible to an epidemic. As mentioned above, these models usually require environmental monitoring equipment that record data daily every 15 minutes. The data are input into an algorithm which determines the risk and length of the conditions for disease development. An inch of rain that occured over five hours will have different effects than an inch of rain that occurred over 20 minutes and quickly dried up. These models usually monitor temperature, moisture and dew point, and sometimes solar radiation, wind speed, and evaporation potential. The output is similar to simpler models, usually a range of low, moderate to severe. This information will lead to better timing of treatments, preventing crop damage and saving of sprays. Although simulation models can handle the complexities of a rapidly changing environment, they are usually not fine tuned enough to account for varieties, planting dates, etc. as the multipoint models.

Ideally, a single or multiple point model could be applied before the season begins in order to develop the best strategy for that particular growing season. The simulation model can be used to add real time inputs during the growing season. Such hybrid models are becoming more common, as we continue to gain a better understanding of what drives an epidemic.

After the methyl bromide era, a truly integrated approach to management of soilborne pathogens will be needed. For example, combinations of effective nematicides, herbicides, and fungicides will be necessary based on the pest population history of a field or expected soilborne pest problems of the region. Management decisions usually need to be based on samples taken prior to planting (available for nematodes). Records of diseases in previous crops, chemical treatments, and weather will no doubt have to be used in disease management decisions. Weather data might be consulted to predict if and when disease outbreaks will occur, providing good experimental data exist to predict likely outbreaks.

Prevention and Management Methods

Site Selection and Preparation

Soilborne diseases remain a major limiting factor for the production of vegetables in Florida. It is important to start with clean soil and proper sites for crops. Plowing and disking will reduce pathogen carryover in old crop refuse. The longer the fallow period, the more pathogen populations are reduced. It is also essential to follow the latest recommendations for soil fumigation, cultural practices, and biological control options to eliminate or reduce initial inoculum of soilborne pathogens. It is important that soil compaction is avoided, since this interferes with root growth, encourages soil moisture retention and promotes root diseases. Preparation of raised beds generally allows for better drainage. Prior to planting, soil should be tested for nutrient levels and nematode populations (and other pathogens if tests are available). Histories of soilborne disease outbreaks are important in prediction of possible future problems. Planting times can be altered to avoid or reduce development of certain diseases.

Host Resistance

It is very important to choose cultivars with multiple pathogen and nematode resistance whenever possible. In Florida, practical control of many diseases of vegetables (Fusarium wilt, Verticillium wilt, and gray leaf spot for tomato) is achieved primarily by this method. Recently, varieties resistant to *Tomato Yellow Leaf Curl Virus* (TYLCV) and *Tomato Spotted Wilt Virus* (TSWV) have been identified. Firm-fruited, crack-resistant tomato fruit can escape infection of some pathogens.

Irrigation Management

High soil moisture enhances the development of soilborne pathogens including *Phytophthora*, *Pythium* and the bacterial wilt pathogen. Excess water damages roots by depriving them of oxygen and creates conditions that favor infection by certain soilborne pathogens.

Irrigation management, based on plant needs, will help to create an environment unfavorable for pathogen survival and disease development. Use of tensiometers or other devices for irrigation scheduling and avoidance of low areas can help in disease management. For irrigation management recommendations of University of Florida/IFAS, see "Irrigation Management” recommendations (http://edis.ifas.ufl.edu/TOPIC_Vegetable_Irrigation).

Soil and Fertilizer Management

Plant nutrition and soil pH can also impact some diseases. Fertilizers with a higher proportion of nitrate nitrogen (NO_3) than ammoniacal nitrogen (NH_4) will help to reduce the incidence of Fusarium wilt on tomato. Increasing soil pH by liming is a good management strategy to reduce Fusarium wilt incidence as well as Botryis gray mold severity. Optimum calcium nutrition and higher soil pH may reduce the incidence of bacterial wilt in the field. Adequate calcium is necessary to minimize blossom end rot and to provide for overall healthy growth. Avoiding excessive nitrogen leads to less dense canopies, thus improving air movement in the canopy. For University of Florida/IFAS recommendations, see EDIS publication HS-711 "Soil and Fertilizer Management for Vegetable Production in Florida” (http://edis.ifas.ufl.edu/CV101).

Cultural Practices

Cultural practices serve an important role in prevention and management of plant diseases. The benefits of cultural control begin with the establishment of a growing environment that favors the crop over the pathogen. Reducing plant stress through environmental modification promotes good plant health and aids in reducing damage from some plant diseases

Sanitation practices aimed at excluding, reducing, or eliminating pathogen populations are critical for management of infectious plant diseases. It is important to use only pathogen-free transplants, especially for late blight, bacterial spot, viral diseases, and early blight.

In order to reduce dispersal of soilborne pathogens between fields, stakes and farm equipment should be decontaminated before moving from one field to the next. Reduction of pathogen survival from one season to another may be achieved by destruction of volunteer plants and crop rotation. Removal of cull piles and prompt destruction of crops should be applied as a general practice.

Avoid movement of soil from one site to another to reduce the risk of moving pathogens. For example, sclerotia of *Sclerotinia sclerotiorum* and *Sclerotium rolfsii*, are transported primarily in contaminated soil. Minimizing wounds during harvest and packing will reduce post-harvest disease problems. Depending on crops and other factors, sanitation of soil can be achieved to some degree by solarization.

Crop rotation is a very important practice, especially for soilborne disease control. For many soilborne diseases, at least a 3-year-rotation using a non-host crop will greatly reduce pathogen populations. This practice is beneficial for Phytophthora blight of pepper and Fusarium wilt of watermelon, but longer rotation periods (up to 5-7 years) may be needed. Land previously cropped to alternate and reservoir hosts should be avoided whenever possible. Vegetable fields should be located as far as away as possible from inoculum and insect vector sources.

Weed control is important for the management of viral diseases. Weeds may be alternate hosts for several important vegetable viruses and their vectors. Elimination of weeds might reduce primary inoculum. Cover crops help to reduce weed populations that may harbor pathogens between seasons. For this purpose use cover crops that grow fast and provide maximum biomass. Non-host cover crops will help to reduce weed populations and primary inoculum for soilborne pathogens.

Excessive handling of plants such as in thinning, pruning and tying may be involved in spread of pathogens, particularly bacteria. It is advisable to handle plants in the field when plants are driest. Because some pathogens can only enter the host through wounds, situations which promote plant injury should be avoided. During pruning process and harvest, workers should periodically clean their hands and tools with a disinfectant, such as isopropyl alcohol.

If applicable, plants can be staked and tied for improved air movement in the foliar canopy. A more open canopy results in less wetness, discouraging growth of most pathogens.

Soil aeration and drying can be enhanced through incorporation of composted organic amendments in the soil. Build up of inoculum can be reduced by removing all plant materials (infected and apparently healthy) after harvest. Between-row cover crops reduce plant injury from blowing sand.

Polyethylene mulch can be used as a physical barrier between soil and above-ground parts of plants. This is an important practice for fruit rot control in the field. Highly UV-reflective (metalized) mulches repel some insects. It is beneficial to use metalized mulch during certain times of the year when insect vectors of some viral diseases are prevalent. *Tomato spotted wilt virus* (TSWV) incidence and associated vector thrips populations have been demonstrated to be effectively reduced by using metalized mulches on tomatoes. Metalized (UV-refelctive) mulches can not be used during winter in southern Florida and early spring in northern Florida, because soil temperatures do not reach desirable levels.

Biological Control

Biocontrol agents for use in vegetable disease management are increasing in use especially among organic growers. These products are considered safer for the environment and the applicator, than conventional chemicals and are mainly used against soilborne diseases. Examples of commercially available biocontrol agents include the fungi *Trichoderma harzianum* and *Gliocladium virens*, an actinomycete *Streptomyces griseoviridis,* and a bacterium *Bacillus subtilis*. Bacteriophages (phages) have been found as an effective biocontrol agent for the management of bacterial spot on tomato. Phages are viruses that infect bacteria. It is best to run small trials on ones own farm to fully evaluate the applicability of biocontrol to particular farming operations.

Chemical Control

Fungicides and bactericides are an important component of many disease management programs. It is important to remember that chemical use should be integrated with all other appropriate tactics mentioned in this chapter.

Information regarding physical mode of action of a fungicide will help producers improve timing of fungicide applications. Physical modes of action of fungicides can be classified into four categories: protective, after infection, pre-symptom, and anti-sporulant (post-symptom). Protectant fungicides include the bulk of the foliar spray materials available to producers. In order to be effective, protectant fungicides, such as copper compounds, mancozeb etc., need to be on the leaf (or plant) surface prior to arrival of the pathogen. Systemic (therapeutic) fungicides, based on their level of systemicity [true systemic (i.e. Aliette), translaminar (i.e. Quadris), meso-systemic (i.e. Flint)], are active inside of the leaf (can penetrate at different rates through the cuticle). Systemic fungicides may stop an infection after it starts and prevent further disease development. If necessary fungicides must be used based on recommended fungicide resistance management strategies.

A new strategy to chemically manage plant diseases without direct interference with the pathogen is the triggering of plant defense reaction. Acibenzolar-S-methyl (Actigard), a chemical in this category, was registered for the control of bacterial spot and speck on tomatoes.

Chemicals must be used at recommended rates and application frequencies. Besides selection of the most efficacious material, equipment must be properly calibrated and attention paid to the appropriate application technique. As always, the key to effective disease management is correct diagnosis of the problem.

Follow the latest fungicide recommendations given by the University of Florida, Cooperative Extension Service publications (See current version of Extension Plant Pathology Report No.6 by Tom Kucharek). Always read the pesticide labels and follow the instructions carefully. Remember, the label is the law. Fumigants can be used to manage soilborne pathogens. Before applying, it is important to review the disease history of the specific site when choosing fumigant materials.

Effective management of whiteflies, thrips, and aphids should be practiced to reduce the incidence and secondary infections of viral diseases vectored by these insects. Apply University of Florida/IFAS recommendations for insect management (http://edis.ifas.ufl.edu/TOPIC_GUIDE_Insect_Management_Guide).