DISTRIBUTION & CHARACTER OF CUCURBIT DOWNY MILDEW AND POTATO AND TOMATO LATE BLIGHT IN 2013

Amanda J. Gevens[1]
{with contributions from Anna Seidl[2] and Amilcar Sanchez Perez[3]}

Introduction

On vegetable and potato crops, the water molds, or fungus-like, oomycetous plant pathogens, which threaten the greatest crop losses include *Pseudoperonospora cubensis* (causal agent of downy mildew on cucumbers), and *Phytophthora infestans* (causal agent of late blight on potatoes and tomatoes). Downy mildew and late blight can both be aerially dispersed over long distances and genotypes identified in the region are not known to be soilborne at this time (1, 2). Initial inoculum and infection occurs as the result of movement of spores in the air from diseased fields to healthy, infected seed or transplants, or by overwintering plant tissues harboring the pathogen from the previous year (e.g. volunteers, cull piles, compost piles). In Wisconsin in 2013, both diseases were detected in vegetable crops.

Results and Discussion

Cucurbit downy mildew caused by the fungus-like pathogen *Pseudoperonospora cubensis* has become more prevalent in the Midwestern & Great Lakes states and throughout the U.S. over the past 8 years. Growers of cucurbits (cucumber, squash, melon, pumpkin) in the Midwestern U.S. states, may recall rare occurrences of late season downy mildew on squash or watermelon crops over the last four decades. Whether there has been a change in the pathogen population by way of a genetic mutation or sexual recombinations, or introduction of an invasive and aggressive cucumber strain, or if changes in environmental conditions have promoted increased virulence is unknown. North Carolina State University researchers determined that recent eastern U.S. populations of cucurbit downy mildew were much more diverse in host range and pathogenicity than was previously known, with *Cucumis* species (cucumber, melon) having greater susceptibility to most pathogen isolates than *Cucurbita* species (squash, pumpkin). Recent identification of the presence of mating pairs in U.S. cucurbit downy mildew populations strongly suggests a source of genotypic and phenotypic variation.

Since 2005, the Midwestern U.S. has seen cucumber as the first cucurbit crop infected with downy mildew with symptoms detected as early as mid-June. Here in Wisconsin, we have seen sporadic and low incidence of downy mildew on cucumber, in particular, in recent years. Few other cucurbits have been noted with downy mildew symptoms. In mid-August 2013, melon and squash cultivars were diagnosed with downy mildew on just a single farm in Jefferson County. The disease did not decimate all of their cucurbit crops, but rather was evident through profuse sporulation on leaf undersides and some necrosis of leaves. No noted progress or spread occurred from this single site. Typically, when environmental conditions favor downy mildews, the disease can be a continual challenge until harvest or frost.

Cucurbit crops in the Midwest have typically not needed routine application of fungicides for downy mildew control. For ~40 years, varietal resistance in commercial cucumber and some melon varieties, conferred by the recessive *dm1* downy mildew resistance gene, was effective in controlling disease.

---

[1]Assistant Professor and Extension Plant Pathologist, University of Wisconsin-Madison
[2]Former Post-doctoral Research Associate, Plant Pathology, University of Wisconsin-Madison
[3]Graduate Research Assistant, Plant Pathology Department, University of Wisconsin-Madison

Pumpkin, squash, and watermelon crops were without this resistance and would sporadically become infected with downy mildew late in the production season. It had been standard recommendation that pumpkins in northern states were to be planted and harvested early to avoid risk of downy mildew because the pathogen could make its way north on late season air currents. The strain(s) of the downy mildew pathogen that have recently made their way to our region are not adequately controlled by *dm1* resistance that held up for decades.

Downy mildew, like other members of the water molds, is favored by warm temperatures (65-85°F) and wet field conditions. In 2010, areas of Wisconsin received over 30 inches of rainfall from May to October, the highest quantity of precipitation recorded over the production season since 1895. Conducive weather coupled with presence of the pathogen resulted in downy mildew in multiple cucumber producing areas of the state.

While downy mildew does not cause fruit infection on cucurbits, the pathogen can defoliate plants leaving fruit at risk for sunscald and secondary infection. Foliar symptoms include pale green-yellow angular (squared off within veins) lesions on leaf surfaces with corresponding and distinctive fuzzy brown growth on leaf undersides (Figure 1). The fuzzy growth is the pathogen producing thousands of new sporangia (spores) which can become airborne and further spread the pathogen within field and beyond at a rate of approximately 6 miles/day. Early infections can be tricky to identify, as they may mimic a nitrogen deficiency, angular leaf spot, or even virus symptoms. The pathogen is an obligate parasite, requiring living plants to remain viable. The pathogen cannot overwinter in the soil on its own, as production of persistent soilborne spores (oospores) have not been found here in Wisconsin.

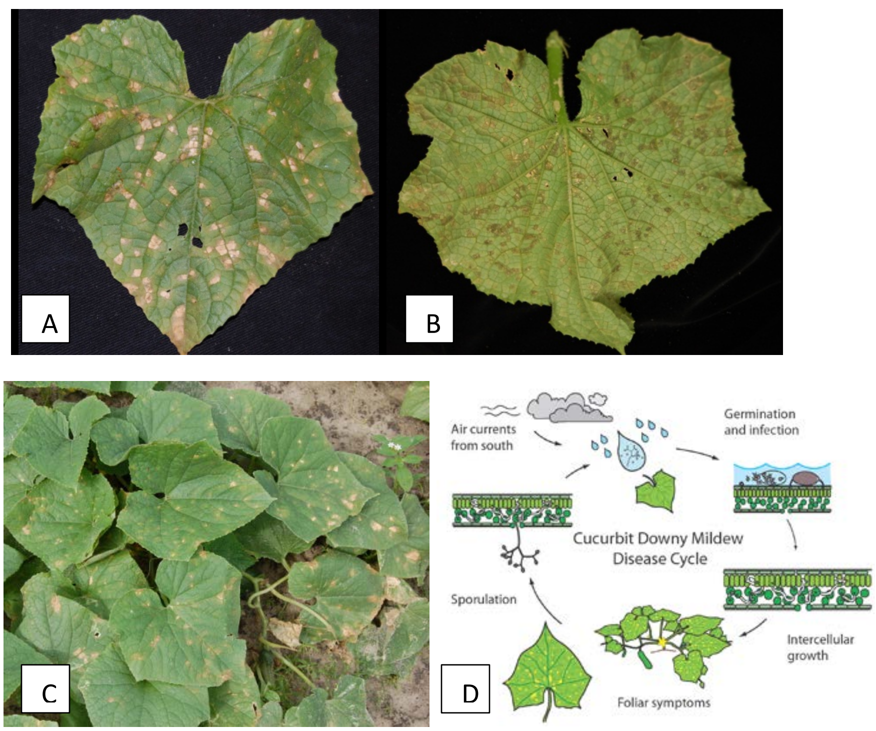

Figure 1. Symptoms of downy mildew on cucumber. A) Mature, angular, necrotic downy mildew lesions on cucumber leaf surface. B) Fuzzy, brown, pathogen sporulation on leaf underside. C) Cucumber downy mildew in the field. D) Cucurbit downy mildew diseaes cycle.

Management Currently, with mid-season risk of spore movement and lack of commercially available and durable varietal resistance in cucurbits, fungicide applications are essential for protection of yield and quality. The selection of fungicides, timing of application, and thoroughness of application are critical for effective disease control. Fungicides should be applied prior to or at first sign of infection to best control cucurbit downy mildew. Based on field research in multiple states including Michigan and North Carolina, effective fungicides for downy mildew control include zoxamide+mancozeb, fluopicolide, propamocarb hydrochloride, cyazofamid, famoxadone+cymoxanil, and ametoctradin+dimethomorph. The effective control program for cucumber established at Michigan State University by Dr. Mary Hausbeck, which I recommend to producers in Wisconsin, specifies a 7-day spray interval of the previously listed materials tank-mixed with either mancozeb or chlorothalonil when initiated **before** downy mildew is found in the field. Fungicides should be alternated so as to manage the potential development of fungicide resistance. Sprays are tightened up to a 5-day interval when initiated **after** disease is found in the field. For cucurbits other than cucumber, the program above is modified to expand the spray intervals from 7 to 10-day **before** disease, and 7-day **after** disease is found in the field. Downy mildew can be well controlled in cucurbit crops with use of effective fungicides, however, this adds a significant increase to the cost of production and success is contingent upon careful attention to regional extension vegetable disease reports and careful field scouting to appropriately time fungicide application.

To aid in tracking cucurbit downy mildew in your county and beyond, the website: http://cdm.ipmpipe.org/ offers forecasting of the disease based on confirmed reports across the U.S. The ipmPIPE (or **i**ntegrated **p**est **m**anagement **P**est **I**nformation **P**latform for **E**xtension and Education) cucurbit downy mildew website provides a publicly accessible site for sharing of cucurbit downy mildew detections, as well as symptom descriptions and management recommendations by region. The site is maintained by researchers at North Carolina State University with collaboration from researchers across the U.S., including Wisconsin. With the multitude of tasks that growers have to manage in the field, office, and marketplace, I recommend use of the CDM ipmPIPE Alert System (link on left side bar of website) which sends you an email or text message when downy mildew is reported within a selected geographic radius around your farm. Also, consider e-mail list serve membership to the University of Wisconsin Extension Vegetable Crop Update newsletter each week through the growing season for downy mildew status reports. Newsletters may be sent out by your grower association or can be directly accessed each week at our UW-Vegetable Pathology website: http://www.plantpath.wisc.edu/wivegdis/.

Research is ongoing in the U.S. and worldwide to better understand the pathogenicity, host resistance, and spread of cucurbit downy mildew. Advances in resistance breeding will greatly aid in improved disease control and sustainability of cucurbit production in Midwestern states and worldwide.

Tomato and potato late blight was confirmed in 15 Wisconsin counties in 2013 from both tomato and/or potato. For all but 2 samples (that were US-8), the pathogen genotype was US-23 (Table 1 & Figure 2). Nationally, the US-23 genotype predominated disease outbreaks, with few determinations of US-7, US-8, and at least one novel type. By production season's end, most of the late blight samples coming in through our lab from Wisconsin were from home garden tomatoes (Table 1). Given the understood nature of the pathogen in state at this time, the early hard frosts should have aided in our late season late blight control as dead plants=dead pathogen.

Late blight is the most limiting disease to potato production worldwide and has been recognized as a significant agricultural concern since the Irish potato famine in the late 1840s (2,3). In addition, recent strains or genotypes of the pathogen have also been problematic on tomato – a crop with less significant acreage in Wisconsin than potato – but a crop with great distribution around the state. Two mating types are needed to produce sexual, persistent soil-borne oospores. The population is largely clonal outside its center of origin in the Toluca Valley of Mexico, relying on production of asexual sporangia for persistence. Nationally, US-1 (A1) was the predominant clonal lineage until the late 1980s-early 1990s, when US-8 appeared. US-8 was the opposite mating type (A2) and was insensitive to mefenoxam, a fungicide with exceptional activity against oomycetes, but with a specific mode of action that effectively selects for insensitivity.

Table 1. Characterization of late blight from Wisconsin in 2013.

County	Host	Genotype	Date of 1st Confirmation in County
Adams	Potato	US-23	28 Jun
Juneau	Potato	US-23	29 Jun
Sauk	Tomato	US-23	2 Jul
Dunn	Potato	US-23	29 Jul
Portage	Potato	US-8/US-23	29 Jul/6 Aug
Brown	Potato+Tomato	US-23	6 Aug
Langlade	Potato	US-23	6 Aug
Racine	Tomato	US-23	8 Aug
Waushara	Potato	US-23	8 Aug
Milwaukee	Tomato	US-23	22 Aug
Forest	Tomato	US-23	28 Aug
Marinette	Tomato	US-23	10 Sep
Oconto	Tomato	US-23	10 Sep
Walworth	Tomato	US-23	10 Sep
Waukesha	Tomato	US-23	20 Sep
Polk	Tomato	US-23	3 Oct

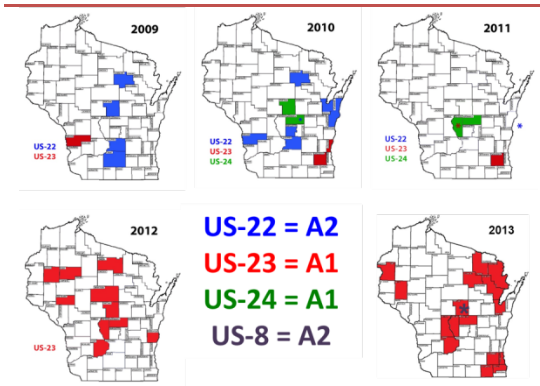

Figure 2. Distribution and character of late blight detected in Wisconsin during production seasons of 2009 to 2013.

Leaf symptoms appear as pale green, water-soaked spots that often begin at the leaf edges or tips where water from rain and dew accumulates. Lesions can be circular or irregular and bordered by pale yellow to green blending into healthy tissue. They enlarge rapidly (expanding ¼ to ½ inch per day) turning brown to black over time. When relative humidity is in excess of 90% leaf lesions are often surrounded by cottony white mold on the lower leaf surface (Figure 3). This white, cottony growth distinguishes late blight from several other foliar diseases of potatoes and tomatoes. Infected stems and petioles turn brown to black and may also be covered with white masses of sporangia. Stem lesions frequently appear first at the junction between the stem and leaf, or at the cluster of leaves at the top of the stem. Entire vines may be killed very rapidly. A characteristic odor similar to that produced by green tissue after a severe frost can be detected. Visit the UW-Vegetable Pathology website http://www.plantpath.wisc.edu/wivegdis/ for additional late blight photos and links to other late blight information and identification resources.

After 2002, Wisconsin growers enjoyed a 6-year respite from this disease, until it appeared in 2009, and in each of the subsequent years including 2013. In these years, isolates were collected from potato and tomato from across the state. Allozyme genotype was resolved using cellulose acetate electrophoresis (3). This revealed 3 banding patterns which profiled US-22, US-23, and US-24. All isolates of US-22 and US-23 were sensitive to mefenoxam, while isolates of US-24 showed partial insensitivity. US-22 isolates were of the A2 mating type, and US-23 and US-24 isolates were of the A1 mating type. In 2013, we also detected US-8, an older genotype with resistance to mefenoxam and an A2 mating type status.

While possible under laboratory conditions, to date, opposite mating types have not been identified in the same field within the same production year in Wisconsin. Oospores have not been identified in late blight infected plant tissues in samples submitted for diagnostic services. Ongoing studies are designed to better understand the overwintering and germination potential of oospore. Constant monitoring and managing of late blight through use of varietal resistance and well-timed and –selected fungicides is essential in order to efficiently and effectively control late blight and maintain geographical separation of mating types.

***Management Considerations for fungicide programs to manage late blight*:** There is not one recommended fungicide program for all late blight susceptible potato fields in Wisconsin. Fungicide selections may vary based on type of inoculum introduction, proximity to infected fields, crop stage, late blight strain, and other diseases that may be in need of management. This article provides general guidance to assist in development of your fungicide program.

Under high late blight pressure, fungicide programs with Revus Top, Forum, Curzate 60DF, Ranman, Tanos, Gavel, Previcur Flex, or Omega should be used. Mefenoxam containing fungicides such as Ridomil Gold SL can also be highly effective in controlling late blight caused by the pathogen strain US-23. This strain was identified in most WI cases in 2013. Zampro is a newly registered late blight fungicide offering a novel mode of action fungicide in an effective pre-mix for late blight control. Brief comments on each of these fungicides are listed below.

Revus Top contains mandipropamid (Group 40) for late blight and difenoconazole (Group 3) for early blight; excellent protectant on leaf blight; rainfast; translaminar and contact activity.

Forum contains dimethomorph (Group 40) for late blight; can be applied after vine kill; good protectant on leaf blight; good antisporulant; rainfast; translaminar activity.

Curzate 60DF contains cymoxanil (Group 27) for late blight; locally systemic; excellent curative activity; good protectant on leaf blight; rainfast in 2 hours.

Ranman contains cyazofamid (Group 21) for late blight; excellent protectant for leaf and tuber blight; rainfast; contact activity.

Tanos contains cymoxanil (Group 27) for late blight and famoxadone (Group 11) for early blight; excellent curative activity; good protectant on leaf blight; rainfast; translaminar and contact activity.

Gavel (zoxamide, Group 22+mancozeb, Group M3) is best used as a protectant and has been reported to reduce tuber blight; excellent protectant on leaf blight; rainfast; contact activity.

Previcur Flex contains propamocarb hydrochloride (Group 28); good protectant on leaf, new growth, and stem blight; good curative and antisporulant activity; excellent rainfast activity; systemic and contact activity.

Omega is a broad spectrum fungicide (fluazinam, Group 29) and especially effective at controlling the tuber phase of late blight (with added benefit of white mold control); excellent protectant on leaf blight; good protection against tuber blight; rainfast; contact activity. Has special label for powdery scab in WI as of 2011.

Ridomil Gold SL contain mefenoxam (Group 4); excellent systemic movement in plant; curative activity; excellent control of stem, leaf, and tuber late blight; rainfast; can only be effective if you are controlling a sensitive strain such as US-23, US-22.

Zampro contains ametoctradin (Group 45) and dimethomorph (Group 40) both with activity on late blight; good preventative disease control; systemic and protective activity.

In Wisconsin, the QoI inhibitors Headline (pyraclostrobin, Group 11), Quadris (azoxystrobin, 11), and Reason (fenamidone, 11) have offered good late blight control at high label rates under moderate late blight pressure and should be used in a manner which mitigates pathogen resistance development - in tank-mix with protectant fungicides such as mancozeb or chlorothalonil-based products and do not apply in consecutive applications.

Headline, Quadris, Reason, Revus Top, and Tanos, also provide good control of early blight in most potato fields in Wisconsin. There are fields/areas where the early blight pathogen population may have some resistance to the QoI fungicide group (11), but generally, this group of fungicides is still effective.

Phosphorous acid formulations such as Crop-phite, Fosphite, Phostrol, Prophyt, and Rampart can increase tuber protection to late blight and pink rot. However, rates must be high and multiple applications must be made for significant tuber protection. Post-harvest treatments can aid in storage late blight development and progress.

Mancozeb used as a tank-mix partner in the final fungicide applications can provide some additional tuber late blight production. Research conducted in Washington and published in 2006 by Porter, Cummings, and Johnson indicated that soil application of mancozeb greatly reduced the incidence of tuber blight when compared to other fungicides. Additionally, in our early blight fungicide trial work at the Hancock Research Station we have often seen yield increases when we use mancozeb as the base protectant tank-mix partner in our final 2 applications.

In years when weather conditions do not favor severe late blight, programs based on chlorothalonil formulations and EBDCs can be adequate to reduce risk of late blight. The addition of TPTH 80WP to any of the protectant programs can enhance disease control particularly towards the end of the growing season. Our current weather conditions, while very hot, can promote disease development due to periods of rainfall, high humidity, and moderate overnight temperatures.

Timing and frequency of fungicide applications are critical elements in an effective disease control program. As in previous years, our program offers Blitecast information which indicates timing for initial preventative fungicide applications for late blight control. Blitecast uses accumulated environmental conditions from crop emergence to determine risk thresholds and has been very reliable in recent years in pre-empting late blight epidemics. Five to seven day applications are needed to protect the crop under conditions of rapid growth and high disease pressure. Once late blight has been detected in WI, protectant programs should be maintained in areas near affected fields until the end of the growing season to limit late season infection and the tuber phase of the disease.

In fields with late blight 'hot spots,' crop destruction is recommended to limit disease development and production of inoculum. A conservative approach to reducing spread from a hot spot includes destruction of 30 rows on either side of the newest lesions at the border of the late blight locus and 100 feet along the row (either side) are killed with Reglone or with Gramoxone (generic). Although harsh, trials at MSU have shown that the latent period between infection and symptom development is about seven days and although not visible, plants within this area are already infected. Fields with very few lesions across a broad acreage, must be intensively managed and consideration for early vine kill and harvest should be made to reduce overall risk.

Listing of 2013 WI potato late blight fungicides:
http://www.plantpath.wisc.edu/wivegdis/pdf/2013/Potato%20Late%20Blight%20Fungicides%202013.pdf

The 2013 A3422 Commercial Vegetable Production in Wisconsin guide is available for purchase or download through the UW Extension Learning Store website (updated annually):
http://learningstore.uwex.edu/Commercial-Vegetable-Production-in-Wisconsin2013-P540.aspx

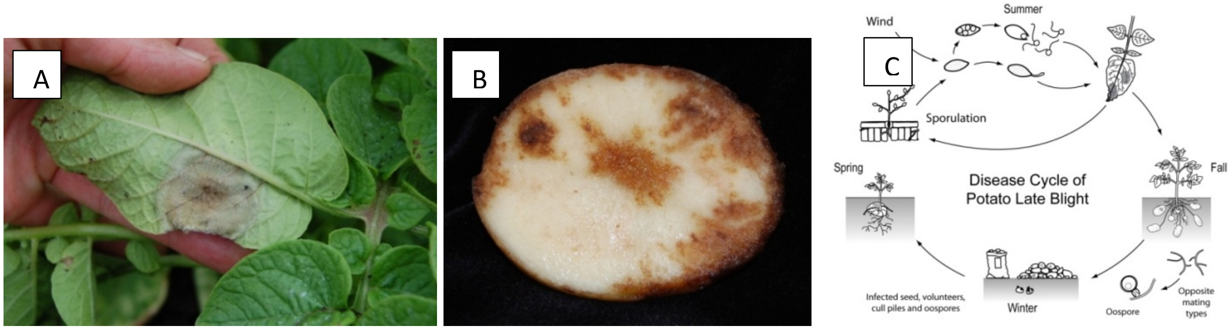

Figure 3. Potato late blight symptoms and disease cycle. A) Lesion on potato leaf displaying pathogen sporulation on underside. B) Internal late blight symptoms on potato tuber. C) Potato late blight disease cycle.

References

1. Colucci, S.J. and G.J. Holmes. 2010. Downy Mildew of Cucurbits. *The Plant Health Instructor*. DOI: 10.1094/PHI-I-2010-0825-01
2. Fry, William E. and Niklaus J. Grünwald. 2010. Introduction to Oomycetes. *The Plant Health Instructor.* DOI:10.1094/PHI-I-2010-1207-01
3. Legard, Daniel E. and William E. Fry. 1996. Evaluation of field experiments by direct allozyme analysis of late blight lesions caused by *Phytophthora infestans*. Mycologia 88(4) 608-612.