UF IFAS Extension UNIVERSITY of FLORIDA

PP325

# Management of Cucurbit Downy Mildew in Florida[1]

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## Introduction

Cucurbit downy mildew is a major disease that affects all cucurbits. Commercially important species of cucurbits include watermelon (*Citrullus lanatus*), muskmelon (*Cucumis melo*), cucumber (*Cucumis sativa*), squash (*Cucurbita pepo*, *Cucurbita moschata*), and pumpkin (*Cucurbita maxima*). The causal agent is the fungal-like organism (oomycete), *Pseudoperonospora cubensis* (Sitterly 1992).

## Symptoms and Signs

The classic sign of the disease is the presence of dark sporangia on the underside of infected leaves (Figures 1 and 5). Symptoms of cucurbit downy mildew are characterized by foliar lesions, which first appear as small chlorotic patches on the upper side of the leaves (Figures 2 and 3). Lesions may appear water-soaked, especially during periods of prolonged leaf wetness caused by rainfall, dew, or irrigation. As the disease progresses, these lesions may coalesce into large necrotic areas and result in defoliation and a reduction of yield and marketable fruit (McGrath et al 2008) (Figure 4).

**What is a sporangia?**
A sporangium (pl. sporangia) is a structure that holds spores as they are being developed. This is the main source of inoculum into a new field. It is common to see several sporangia on a structure called a sporangiophore.

**What is a sporangiophore?**
A sporangiophore is a specialized hyphal structure that holds multiple sporangia.

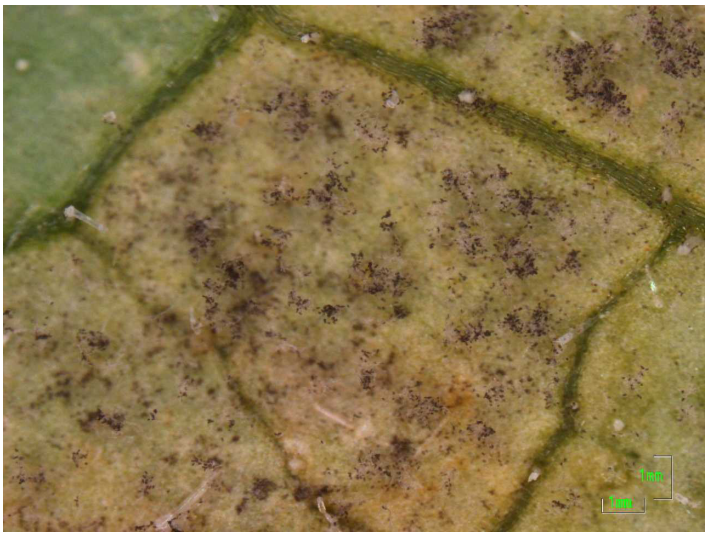

Figure 1. Sporangia present on the underside of a cucumber leaf. Credits: M. Paret

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Figure 2. Early symptoms on squash characterized by chlorotic angular lesions—circled in red.
Credits: M. Paret

Figure 3. Early sumptoms on cucumber leaf.
Credits: M. Paret

Figure 4. Older lesions will coalesce and create large necrotic patches as seen on this cantaloupe.
Credits: M. Paret

## Epidemiology and Disease Cycle

Cucurbit downy mildew is caused by a biotrophic organism or obligate parasite, which means it needs a living host to survive. The overwintering structure, the oospore, has not been observed in the United States, and the pathogen does not survive on crop debris between seasons. *P. cubensis* must be reintroduced each year. The sporangia are dispersed by wind and serve as the primary source of inoculum (Figure 5). They require free water for germination, which occurs rapidly at 15 to 20 °C (59–68 °F). Secondary inoculum within an infected field is dispersed by rain-splash and/or wind dispersion.

**What are primary and secondary inoculum?**
Primary Inoculum: The first spores or infectious units, which cause infection. This is what begins the disease.
Secondary Inoculum: The next generation of the pathogen population. This is often produced in the field. This is what escalates the disease.

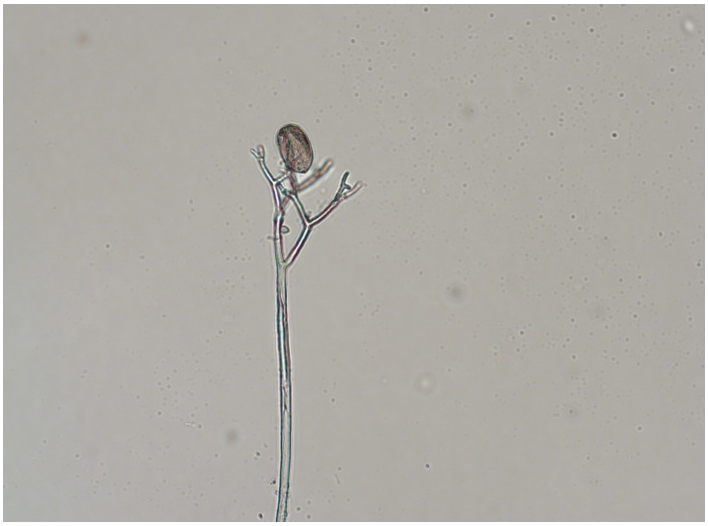

Figure 5. Microscopic image of sporangiophore with sporangia attached.
Credits: N. Dufault

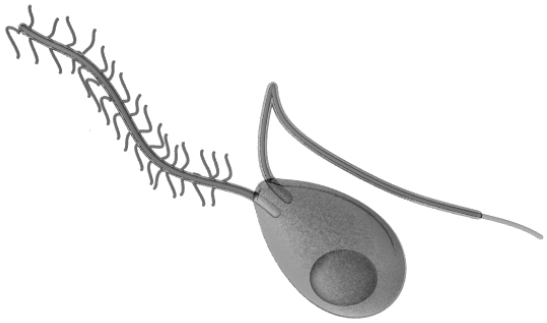

Figure 6. Artist rendering of a zoospore.
Credits: http://www.cronodon.com

Upon landing on the leaf surface, each sporangia can release 5–15 zoospores, the main spore type responsible for infecting the plant. Zoospores are biflagellate spores, containing an anterior and a posterior flagellum (Figure 6) that allows them to move in water on the leaf surface. Once a spore locates a stomate on the leaf, the spore will stop moving (encyst) and produce a germ tube. The ideal temperature for encystment is 25 °C (77 °F). This germ tube is responsible for penetrating the stomate and infecting the host cells.

After infection, mycelium will grow between and within the host cells. This mycelium acts as a network for absorbing and transporting nutrients and acts as an infrastructure for other structures later in the infection cycle. Under a microscope, the mycelia are transparent (hyaline) and lack cross-walls (aseptate). The mycelium will eventually develop a haustorium, an anchor-like structure, which facilitates absorption of nutrients from the host.

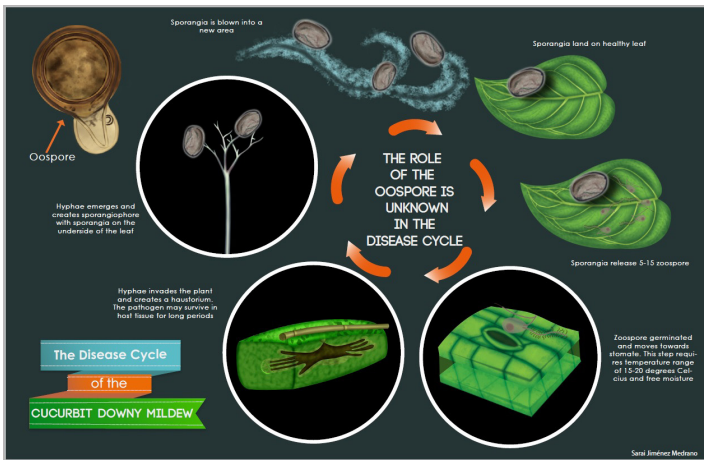


Figure 7. The disease cycle of cucurbit downy mildew. Note: not drawn to scale.
Credits: S. J. Medrano

What is a zoospore?
A zoospore is a mobile spore with two tails (flagella).
What is mycelium?
Mycelium (pl: mycelia) is a vegetative tissue that absorbs nutrients and acts as an anchor for other structures.
What is encystment?
Encystment is when a spore is entering a phase of suspended animation. During this time, the spore is immobile and is no longer searching for a stomate.
What is a stomate?
A stomate (pl: stomata) is an opening in the leaf used for gas exchange. These are often common routes of entry for pathogens within a plant.

## Host Range and Pathotypes

Cucurbit downy mildew can affect over 40 species of cucurbits. Host specialization has been observed. The pathogen can be broken down into five pathotypes based on their host range and compatibility. For example, pathotype 1 can infect cucumber and cantaloupe and is incompatible with a watermelon host. Below is a table from work published in 1987 designating pathotypes based on host compatibility (Thomas et al. 1987).

## Management of Downy Mildew for the Three Production Regions of Florida

Managing cucurbit downy mildew requires an integrated approach and should include avoidance, monitoring, resistance, cultural practices, and the application of protective fungicides. For management, the state is divided into three regions. The north region includes the panhandle. The central region is defined as below the I-10 corridor and above the I-4 interstate. The south region is defined as below the I-4 interstate. Each management approach is recommended for the regions in parentheses.

### Early Planting (North and Central Florida)

Early season plantings may be less impacted by downy mildew. Downy mildew prevalence increases during summer and fall production. By planting when the disease is less prevalent, growers can reduce disease pressure and reduce the need for fungicides. This is an important strategy for the northern and central regions. Given the constant presence and reintroduction of downy mildew in the southern region, this strategy is not effective for that region.

### Monitoring (North and Central Florida)

A nationwide monitoring system (IPM PIPE) has been developed at North Carolina State University and should be used closely while planting susceptible hosts in your region. The forecast homepage can be found at http://cdm.ipmpipe.org/ (Figure 8).

The IPM PIPE should be used in addition to field scouting, which should be done frequently and regularly to detect the disease as early as possible. Both of these practices will help you decide when to start applying fungicides. Good control is achieved by early detection and timely fungicide application. Note that the forecasting only tracks disease development from the airborne movement of spores. Other

means of transmission, such as infected transplants, may not be detected.

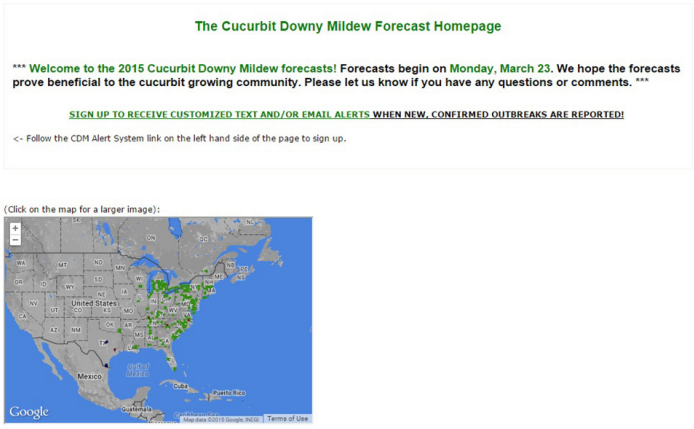


Figure 8. Homepage of the IPM PIPE. This site is good for monitoring outbreaks in the eastern United States and can aid growers in deciding when to spray and what to spray.
Credits: http://cdm.ipmpipe.org/

Growers should also monitor weather conditions and apply protective sprays when conditions are conducive to disease development, particularly when plants have grown sufficiently and begin touch each other or cover the top of the beds. Once the disease is reported in your county or is scouted in your own field, the addition of a "systemic" or penetrant fungicide (such as Quadris®, Ridomil®, or Previcur Flex®) is recommended. Follow the label for appropriate rates and resistance management guidelines.

## Resistant Varieties (North, Central, and South Florida)

The use of resistant varieties is a very efficient management strategy. Table 2 contains a list of tolerant and resistant varieties has been provided. When possible, a resistant variety should be chosen, especially if downy mildew historically has been reported during the growing season. This is recommended for all three regions in Florida.

Note: This is not a complete list as new varieties are constantly being developed and many names can change. Consult your local Extension office or seed supplier for more information.

## Chemical Control (North, Central, and South Florida)

Protective fungicides should be considered for use once downy mildew is reported in the area. Common recommended protective products include chlorothalonil, mancozeb, and copper. These products are designed to prevent infection from occurring, but have limited control once the disease is established inside the plant. Once downy mildew has been discovered in your field, it is necessary to add penetrant/"systemic" fungicides to your disease management program in order to achieve the best possible control. A spray program applied weekly or biweekly, depending on disease pressure, is recommended. A watermelon spray guide can be found at http://programs.ifas.ufl.edu/u-scout/Tutor_files/UF_Watermelon_Spray_Guide_2014_15.pdf (Dufault and Paret 2014) while a more general plan for cucurbit downy mildew can be found at http://www.clemson.edu/psapublishing/PAGES/PLNTPATH/IL90.pdf (Keinath 2015). Begin preventative sprays at transplanting or seedling emergence. To improve downy mildew control, a "systemic" product should be added once the disease is reported in your county or is observed in your field..

Below is a table from the *2015–2016 Vegetable Production Handbook of Florida* with a list of labeled products for control of cucurbit downy mildew (Dittmar, Freeman, and Vallad 2015). This list is continually changing based on product labels and new product releases. Always consult with your local Extension agent, consultant, or agricultural chemical representative for more information on products available in your area.

## Organic Production

The most important downy mildew disease management strategy for organic production is to use resistant varieties (see Table 2). Other management strategies include early plantings, limiting optimal environments, and the use of biopesticides. In general, the efficacy of biopesticides is limited to use as a preventative product, which means disease monitoring is critical to the success of these products. Organic producers are highly encouraged to scout their fields regularly for the disease and to use disease monitoring tools (e.g., IPM PIPE). Producers with a high risk for downy mildew are encouraged to use an OMRI-listed fixed copper product to prevent infection. Other products are available, but their efficacy is often variable. Table 4 contains a list of OMRI-listed fungicides labeled for use in organic cucurbit production.

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Table 1. Pathotype designations based on *Pseudoperonospora cubensis* and host compatibility (Thomas et al. 1987).

| **Host** ***Scientific name*** **(common name)** | **Pathotype** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| ***Cucumis sativus*** **(cucumber)** | + | + | + | + | + |
| ***C. melo*** **var.** ***reticulatus*** **(muskmelon)** | + | + | + | + | + |
| ***C. melo*** **var.** ***conomon*** **(oriental pickling melon)** | – | + | + | + | + |
| ***C. melo*** **var.** ***acidulous*** **(bitter melon)** | – | – | + | + | + |
| ***Citrullus lanatus*** **(watermelon)** | – | – | – | + | + |
| ***Cucurbita moschata*** **(butternut squash)** | – | – | – | – | + |

+ highly compatible host interaction
– incompatible or very slightly compatible host-pathogen interaction

Table 2. Tolerant and resistant varieties.

| Tolerant and Resistant Varieties |
|---|
| **Cucumber (Slicing)** |
| 'SV3462CS'*** |
| 'SV4719CS'*** |
| 'Cortez' |
| 'Darlington' |
| 'Dasher II' |
| 'Daytona' |
| 'Diomede' |
| 'Dominator' |
| 'General Lee F1' |
| 'Green Slam F1' |
| 'Indy F1' |
| 'Intimidator F1' |
| 'Lider' |
| 'Lisboa' |
| 'Marketmore 76' |
| 'Marketmore 97' |
| 'Olympian F1' |
| 'Poinsett' |
| 'Rockingham' |
| 'Senor' |
| 'Shantung Suhyo Cross F1'* |
| 'Slice more' |
| 'Soarer F1'* |
| 'Speedway F1' |
| 'Stonewall' |
| 'Summer Top F1'* |
| 'Talladega' |
| 'Tasty Green'* |
| 'Thunder F1' |
| 'Turbo' |
| * Specialty Asian type<br>*** Improved Downy Mildew Resistance |
| **Cucumber (Pickling)** |
| 'Calypso' |
| 'Cross Country F1' |
| 'Diamant' |
| 'Eclipse' |
| 'Eureka F1' |
| 'Excursion' |
| 'Expedition' |
| 'Fancipak M' |
| 'Jackson' |
| 'Lafayette' |
| 'Little Leaf H-19' |

| Tolerant and Resistant Varieties |
|---|
| **Cucumber (Pickling) Continued** |
| 'Max Pack' |
| 'Sassy F1' |
| 'Supremo' |
| 'Vlasstar' |
| 'Wautoma' |
| 'Zapata' |
| **Muskmelon** |
| 'Ambrosia F1' |
| 'Hannah's Choice F1' |
| 'Primo'* |
| 'Sun Jewel'** |
| *Western Type<br>**Asian Type |
| **Melon (specialty)** |
| 'Crème de Menthe'* |
| 'Crete'* |
| *Honeydew melon |

Table 3. Cucurbit fungicides ordered by FRAC group according to their mode of action. This table was copied from the *Florida Vegetable Production Handbook 2015–2016* (Dittmar, Freeman, and Vallad 2015).

| Fungicide Group[1] | Chemical (active ingredients) | Max. Rate/Acre | |
|---|---|---|---|
| | | Applic. | Season |
| **M1** | (copper compounds) **Many brands available:** Badge SC, Badge X2, Basic Copper 53, Champ DP Dry Prill, Champ Formula 2 FL, Champ WG, Champion ++, Copper-Count-N, Cueva, Cuprofix Ultra 40 Disperss, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, Koverall, MasterCop, Nordox, Nordox 75WG, Nu-Cop 3L, Nu-Cop 50DF, Nu-Cop HB | SEE INDIVIDUAL LABELS | |
| **M1 & M3** | ManKocide (copper hydroxide + mancozeb) | 3 lb | 24 lb |
| **M3** | (mancozeb) **Many brands available:** Dithane F45 Rainshield, Dithane M45, Koverall, Manzate Flowable, Manzate Max, Manzate Pro-Stick, Penncozeb 75DF, Penncozeb 80WP, Roper DF Rainshield | SEE INDIVIDUAL LABELS | |
| **M5** | (chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo ZN, Choloronil 720, Chlorothalonil 720SC, Echo 720, Echo 90DF, Echo ZN, Equus 500 ZN, Equus DF, Equus 720 SST, Initiate 720, Initiate ZN | SEE INDIVIDUAL LABELS | |
| **4 & M1** | Ridomil Gold/Copper 64.8 W (mefenoxam + copper hydroxide) | 2 lb | 8 lb |
| **4 & M3** | Ridomil Gold MZ WG (mancozeb + mefenoxam) | 2.5 lb | 10lb |
| **4 & M5** | Ridomil Gold Bravo SC (mefenoxam + chlorothalonil) | 2.5 pt | See label |
| **7 & 11** | Pristine 38WG (boscalid + pyraclostrobin) | 18.5 oz | 74 oz |
| **7 & 11** | Merivon (fluxapyroxad + pyraclostrobin) | 5.5 fl oz | 16.5 fl oz |
| **11** | Cabrio 20EG (pyraclostrobin) | 12 fl oz | 64 fl oz |
| **11** | Flint 50WP (trifloxystrobin) | 4 oz | 8 oz |
| **11** | Quadris 2.08FL Satori (azoxystrobin) | 15.5 fl oz | 92.3 fl oz |
| **11** | Reason 500SC (fenamidone) | 5.5 fl oz | 22 oz |
| **11 & M5** | Quadris Opti (azoxystrobin + chlorothalonil) | 3.2 pt | See label |
| **11 & 3** | Quadris Top (azoxystrobin + difenoconazole) | 14 fl oz | 56 fl oz |
| **21** | Ranman (cyazofamid) | 2.75 fl oz | 16.5 fl oz |
| **22 & M3** | Gavel 75DF (zoxamide & mancozeb) | 2 lb | 16 lb |
| **27** | Curzate 60DF (cymoxanil) | 3.2 oz | See remarks |
| **27 & 11** | Tanos 50DF (cymoxanil + famoxadone) | 8 oz | See label |

| | | | |
|---|---|---|---|
| **28** | Previcur Flex<br>Promess<br>(propamocarb hydrochloride) | 1.2 pt | 6 pt |
| **29** | Omega 500 F (fluazinam) | 1.5 pts | 9 pts |
| **33** | Aliette 80WDG<br>Linebacter WDG<br>(fosetyl-Al) | 5 lb | 35 lb |
| **40** | Forum<br>(dimethomorph) | 6 oz | 30 oz |
| **40** | Revus<br>(mandipropamid) | 8 fl oz | 32 fl oz |
| **43** | Presidio<br>(fluopicolide) | 4 fl oz | 12 fl oz |
| **45 & 40** | Zampro<br>(ametoctradin + dimethomorph) | 14 fl oz | 42 fl oz |
| **21** | Actigard 50WG<br>(acibenzolar-S-methyl) | 1 oz | 8 oz |

1 FRAC code (fungicide group): Number (1 through 46) and letter U is used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. U=unknown, or a mode of action that has not been classified yet.
Source: FRAC Code List, 2014; http://www.frac.info/ (FRAC= Fungicide Resistance Action Committee)

Table 4. OMRI-listed fungicides labeled for use in organic cucurbit production. *Note:* There is limited data on the efficacy of the various biopesticides. This is not a complete list; new products are constantly being developed and released. For an up-to-date list of products approved for organic production, visit **http://www.omri.org/omri-lists**, or contact your local Extension office.

| Product | Active ingredient | Rate (per acre) | Maximum rate per season |
|---|---|---|---|
| **Serenade ASO** | QST 713 Strain of *Bacillus subtilus* | 2–6 quarts | N/A |
| **Actinovate** | *Streptomyces lydicus* WYEC 108 | 3–12 oz | N/A |
| **Champ WG** | Copper Hydroxide | 1.5 lbs | 10.5 lbs |
| **Cueva** | Copper Octanoate | 2.0 gal | 33 gal |
| **Badge X2** | Copper Oxychloride and Copper Hydroxide | 0.5–2.5 lbs | 18.8 lbs |