HS1067

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Powdery Mildew of Cucurbits in Florida[1]

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Introduction

Powdery mildew is a common and serious disease of cucurbit crops in Florida. This disease occurs in cucumbers, muskmelons, honeydew, squash, gourds, and pumpkins grown both in field and greenhouse conditions. Previously, powdery mildew was an occasional problem for watermelons, but for the past 5 years the incidence of powdery mildew outbreaks has increased (Roberts and Kucharek 2005). A powdery mildew infection acts as a sink for plant photosynthates causing reductions in plant growth, premature foliage loss, and consequently a reduction in yield. The yield loss is proportional to the severity of the disease and the length of time that plants have been infected (Mossler and Nesheim 2005). For instance, in cucumber there is a negative linear relationship between disease severity and yield (Dik and Albajes, 1999). If this disease is not controlled in a timely manner, symptoms can be severe enough to cause extensive premature defoliation of older leaves and wipe out the crop (Figure 1).

Figure 1. Severe powdery mildew infestation on greenhouse-grown squash (*Cucurbita* spp.).

In muskmelon and honeydew (*Cucumis* melo L.) plants, advanced foliage infection frequently results in decreased fruit sugar content, therefore reducing final fruit quality and marketability. In other cucurbits, such as yellow squash and zucchini, direct damage to the fruit can reduce yield and quality. According to Mossler and Nesheim (2005), powdery mildew occurs to some extent every year and may not be economically damaging in all affected cultivated areas. Powdery mildew infection is present in roughly 70% of the squash acreage in Florida.

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In cucurbits, powdery mildew is caused by three fungal species, *Podosphaera xanthii* (syn. *Sphaerotheca fuliginea auct. p.p.*), *Golovinomyces cucurbitacearum* (syn. *Erysiphe cichoracearum auct. p.p.*), and *Golovinomyces orontii* (syn. *Erysiphe cichoracearum auct. p.p.*) (Jahn et al. 2002). However, *Podosphaera xanthii* (syn. *Sphaerotheca fuliginea auct. p.p.*) is actually more widespread than the other two species (Figure 2). Within each fungal species that causes powdery mildew disease, different races have been described (Jahn et al. 2002). These powdery mildew races have the potential to attack several powdery-mildew-tolerant or -resistant cucurbit crops if specific environmental conditions are favorable for fungal infection and spread.

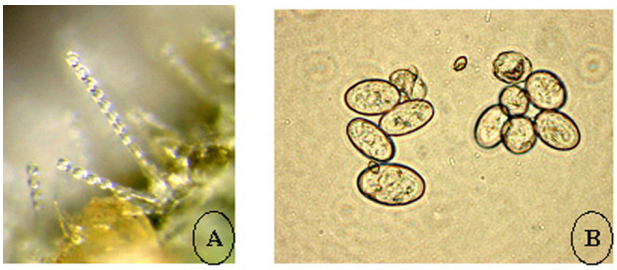

Figure 2. A. Conidiophores of powdery mildew (200X). B. Released conidia in water (400X).

Symptoms and Disease Development

Symptoms of a powdery mildew are often easier to identify than symptoms of any other disease, because powdery mildew forms obvious pads of whitish mycelium on upper and lower leaf surfaces, petioles, and stems. During the crop growing season, the fungus produces hyphae and asexual spores, called conidia, on leaves. This disease can be first noted on older leaves, which develop reddish-brown, small, restrained round spots. At this point, a microscopic examination is necessary in order to discern if typical conidia of powdery mildew are present. Later on, those spots become white as hyphae and spores are produced in abundance (Figure 3. A). Infected areas enlarge and coalesce quickly, forming a white powdery mycelium that resembles talc (Figure 3. B). Severely infected leaves lose their normal dark green color, turn pale yellow and then brown, and finally shrivel, leaving cucurbit fruits exposed to sunburn (Figure 4).

Figure 3. A. Early stages of powdery mildew infection in muskmelon leaf. Notice several whitish and small spots (white arrows) developing on the upper surface. B. Early stages of powdery mildew infection in Beit Alpha cucumber leaf. Notice several whitish and small spots (white arrows) developing on the upper surface. C. Advanced powdery mildew disease in squash, where all small spots have coalesced homogeneously.

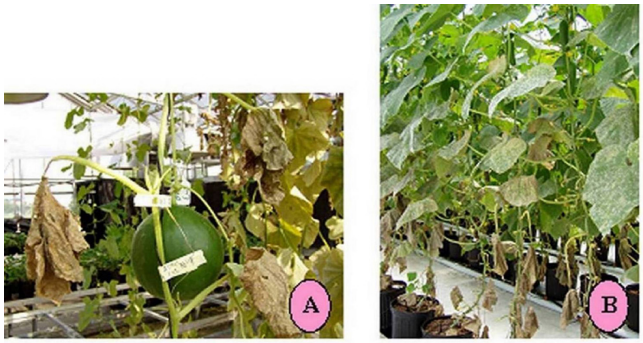

Figure 4. Severely powdery-mildew-infected muskmelon (A) and Beit Alpha cucumber (B) leaves. Fruit exposed to sunburn.

Figure 5. Squash plant infected with powdery mildew. Notice how old leaves are completely covered with talc-white powdery mildew (arrows), whereas new leaves appear to be free of this disease (circle).

Powdery mildew appears first on older leaves and stems of cucurbit plants (Figure 5). Conidia are produced profusely in the white powdery mycelium, and any wind or air movement easily carries those spores to any adjacent leaves or plants, as well as to those at greater distance. This disease spreads quickly and travels over long distances.

Environmental Factors

The powdery mildews are a group of pathogens that can cause disease over a wide range of environmental conditions. However, several environmental factors may directly affect the development of this disease in cucurbits: among them, temperature, relative humidity and light. Temperature and humidity must be examined together since it is the water vapor pressure deficit (VPD) that has the greatest effect on host-parasite interactions (Jarvis et al. 2002). For example, temperatures between 75-85 °F, and elevated levels of relative humidity (80-95%) in the absence of rainfall promote the development of this disease.

During periods of intensive dew on leaf surfaces, the severity of this disease is enhanced, however, excessive water on the leaf surface is often detrimental to the development of powdery mildew disease (Jarvis et al. 2002). On the other hand, the fungi causing powdery mildew can infect under relatively dry conditions if the inoculum level is high enough with spores from nearby infected plants. It can become a severe disease when rainfall is low and conditions are dry, such as during winter and spring in Florida (Mossler and Nesheim 2005).

Powdery mildew is usually more prevalent in shade than in full direct sunlight; therefore, this disease in cucumbers and muskmelons is more profuse under the large overlapping leaves than the new sun-exposed leaves.

Management of Powdery Mildew

A programmed scouting for symptoms in cucurbit plants is always necessary to detect the beginning of a powdery mildew infection, so that a pertinent treatment can be initiated. Strategies for the control of these three different fungal species are very similar, and an integrated approach using a combination of several practices will be most effective in managing this disease. Cultural practices, such as crop rotation, seem to have a slight or no effect on powdery mildew presence and development because conidia are so prevalent and are able to germinate under relatively low RH (Gay et al. 1985). Nevertheless, healthy and vigorous plants grown under a good nutritional program and suitable sanitary conditions are less susceptible to powdery mildew infection than plants under nutritional stress. An effective method for management of powdery mildew should be developed using components from the following strategies: select powdery-mildew-tolerant cucurbit cultivars; use biorational compounds, fungicides, biological agents, and chemical compounds that stimulate systemic acquired resistance (SAR) in cucurbit plants. These control measures will be examined in the following sections.

Genetic Resistance

Cultivating plants with genetic resistance to powdery mildew is the best method of growing disease-free cucurbit crops. Consequently, an appropriate selection of tolerant or resistant cucurbit cultivars is the simplest way to deal with powdery mildew infections. However, because there are several fungal races of powdery mildew, some powdery-mildew-resistant cultivars might be susceptible to a specific fungal race (Zitter et al. 1996). Thus a fungicide or other control agent must be employed to counteract the relentless cycles of a powdery-mildew disease in those tolerant or resistant cultivars. A list of some powdery mildew-tolerant or -resistant cucurbit cultivars (varieties) is depicted in Tables 1-3 (Roberts and Pernezny 2005). It is suggested that growers contact local UF/IFAS County Extension Agents and seed companies for assistance in choosing any resistant or tolerant varieties that grow well under Florida conditions.

Fungicides

For susceptible cucurbit cultivars, fungicide is the most effective means of control. According to Konstantinidou-Doltsinis (1998), the need to control powdery mildew disease is one of the reasons for the increased use of fungicides in cucurbits. Most of the

fungicides to control powdery mildew are primarily preventive; that is, to be effective they must be applied before the fungus infects the plant. In addition, powdery mildew fungi can develop resistance to specific fungicides (Brown 2002).

The following fungicides are approved to control powdery mildew infections under Florida environmental conditions: Flint® (trioxystrobin), Nova® (myclobutanil), Quadris® (azoxystrobin), and Pristine® (boscalid and pyraclostrobin). Strictly follow all label recommendations for handling, application and disposal of these fungicides. The misuse of these fungicides increases the risk of environmental contamination and also increases the possibility that powdery mildew fungi will develop resistance to these chemicals. Contact County Extension Agents for updated registration, recommendations and supplementary assistance.

Other non-systemic fungicides, such as sulfur and copper, have some efficacy to control powdery mildew outbreaks. Sulfur is one of the oldest natural fungicides to control powdery mildews. Sulfur is active against a variety of targets in the fungus and resistance has not developed. Sulfur may be applied as Microthiol Disperss®, which is a micronized, wettable sulfur compound that allows uniform dispersal over the plant surface and increases the antifungal activity. However, according to Mossler and Nesheim (2005), sulfur only provides a moderate level of control in squash, and this lack of control has been confirmed by extension personnel. Moreover, several cucurbit species, mostly muskmelons and honeydews, are very sensitive to sulfur and phytotoxicity as scorch occurs when sulfur is applied to the leaves. In this specific case, melon varieties tolerant to sulfur damage may be chosen (Tables 1-3).

Fungicides based on copper salts are to some extent less phytotoxic than sulfur, but they are not completely unharmful. These copper salts (Kocide® 2000, Microcop, etc) are recommended to be used as a fungicide to control powdery mildew in cucurbits (Zitter et al. 1996).

Biorationals and Non-harmful Chemicals

Biorational materials with low toxicity for plants may have a role in disease management systems (Bélanger and Labbe 2002). These compounds do not cause phytotoxic symptoms; in many cases the mechanism by which disease supression occurs is unknown. Biorational compounds can be used to reduce incidence of infection by powdery mildew in cucurbit crops. Among these biorational materials: natural and mineral oils, peroxigens, cow's milk, silicon, and salts of monovalent cations such as sodium, potassium and ammonium may be used. When considering using these biorationals it is important to contact UF/IFAS Extension for additional information.

Neem oil (Trilogy®, Trilogy90EC™, etc) is a botanical fungicide derived from the seeds of the neem tree (*Azadirachta indica*). This plant oil is a multipurpose insecticide, miticide and fungicide labeled for control of powdery mildew. However, because it has activity towards insects and mites, it might harm bees and beneficial predators as well. Therefore, neem oils should not be used without clear need and plenty of caution. E-RASE™ is another natural product made from jojoba oil (*Buxus chinensis*). It is a contact fungicide that can be applied to control powdery mildew in cucurbits. Cinnamon oil (Cinnamite®, Valero®, etc) has also proved to be effective to control powdery mildew in cucurbits. One possible disadvantage of using natural oils to control powdery mildew outbreaks at extensive commercial level is the cost of management. Most of these natural oils have to be applied several times during the growing season in order to reach a reliable level of control. These oils tend to be expensive compared to other chemicals, and thus may not be economically feasible. Mineral oils, such as JMS Stylet Oil®, have also proved to be effective to avoid a severe powdery mildew outbreak in cucurbits in some cases and are more reasonably priced.

OxiDate is a broad-spectrum fungicide based on hydrogen dioxide as the active ingredient. This compound controls powdery mildew spores by contact. Unfortunately, Oxidate has to be applied

frequently in order to obtain adequate levels of control. Some muskmelon cultivars are sensitive and will develop phytotoxicity.

Cow's milk sprayed onto the leaves of greenhouse-grown zucchini was shown to be effective in controlling *Podosphaera xanthii* (syn. *Sphaerotheca fuliginea auct. p.p.*) (Bettiol 1999). The mechanism by which this occurs is unknown; possibly salts, amino acids, or an antimicrobial agent present in milk might be effective in supressing the disease.

In most Floridia soils, (0.1-.8 mM) silicon is available, but in greenhouse hydroponic systems where clean water may be used, the amounts of this element might be smaller. In hydroponically-grown cucumbers, the addition of 2.3 mM silicon to the nutrient solution can significantly delay and reduce the incidence of *Podosphaera xanthii* (syn. *Sphaerotheca fuliginea auct. p.p.*) (Menzies et al. 1991). Moreover, foliar sprays of chlorite mica clay, which contains silicon, have also demostrated suppression of powdery mildew in cucumber (Ehret et al. 2001).

Different salts of monovalent cations, such as potassium (Armicab100®, Kaligreen®, FirstStep®, Remedy®, Milstop®, etc), sodium and ammonium bicarbonate, as well as mono-potassium phosphate (Nutrol®) are able to control powdery mildew outbreaks in cucurbit crops. Since commercial potassium bicarbonate (Armicab100®, Kaligreen®, FirstStep®, Remedy®, Milstop®, etc) and mono-potassium phosphate (Nutrol®) products may contain as much potassium as 30%, they are also publicized for foliar fertilizer characteristics. In fact, Reuveni and Reuveni (1998) have claimed that the application of a foliar-fertilizer therapy could have a valuable importance in integrated pest management (IPM).

Biological Fungicides

There are several biofungicides which have been registered for the control of powdery mildew in cucurbits. One of these, AQ10 (Ecogen, Inc.) was developed specifically for powdery mildew. Its active ingredient is fungal spores of *Ampelomyces quisqualis* Ces., which act to parasitize and destroy the powdery mildew fungi. Another biological control is Serenade® (AgraQuest, Inc.), which has a bacteria, *Bacillus subtilis*, as an ingredient and prevents the powdery mildew from infecting the cucurbit plant. Recently, a yeast-like fungus *Sporothrix flocculosa* (syn. *Pseudozyma flocculosa*) has been tested for control of powdery mildew in greenhouse-grown cucumbers with promising results. It has been formulated as a wettable powder (Sporodex®) for use against powdery mildew on greenhouse crops (Paulitz and Bélanger 2001). A problem with many biological control agents is that they require higher humidity for survival than do the powdery mildews. Consequently, biological fungicides are not as effective at controlling powdery mildew as the biorationals and non-harmful chemicals or other fungicides.

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Table 1. Some Cucumber Cultivars with Resistance or Tolerance to Powdery Mildew. Modified from Roberts and Pernezny (2005).

Cucurbit Crop	Seed Company	Cultivar (Variety)	Disease Resistance or Tolerance to Powdery Mildew
Cucumbers	Asgrow	Cyclone	Intermediate Resistance
		Discover M	Intermediate Resistance
		Excel M	Intermediate Resistance
		Francipak	Intermediate Resistance
		Lightning	Intermediate Resistance
		Meteor	Tolerant
		Sprint 440	Intermediate Resistance
		Striker	Tolerant
		Thunder	Intermediate Resistance
		Vlaspik M	Intermediate Resistance
		Vlasstar	Tolerant
	Sakata Seeds	Prolific	Tolerant
		SCU 6601	Tolerant
		Slice Max	Tolerant
		Slice King	Tolerant
		Slice More	Tolerant
		Tasty Green	Tolerant

Table 2. Some Melon Cultivars with Resistance or Tolerance to Powdery Mildew. Modified from Roberts and Pernezny (2005).

Cucurbit Crop	Seed Company	Cultivar (Variety)	Disease Resistance or Tolerance to Powdery Mildew
Melons (cantaloupe and others)	Asgrow	Caravelle	Powdery Mildew Races 1 and 2 (intermediately), Tolerant to Sulfur Damage
		Cristobal	Powdery Mildew Race 1, Tolerant to Sulfur Damage
		Don Carlos	Powdery Mildew Races 1 and 2 (intermediately), Tolerant to Sulfur Damage
		Edisto	Powdery Mildew Race 1
		Hiline	Powdery Mildew Race 1, Tolerant to Sulfur Damage
		Honey Dew	Tolerant to Sulfur Damage
		ImPac	Powdery Mildew Races 1 and 2 (intermediately)
		Laguna	Powdery Mildew Races 1 and 2, Tolerant to Sulfur Damage
		Marco Polo	Powdery Mildew Races 1, Tolerant to Sulfur Damage
		Mission	Powdery Mildew Races 1 and 2 (intermediately), Tolerant to Sulfur Damage
		Moonshine	Tolerant to Sulfur Damage

Table 2. Some Melon Cultivars with Resistance or Tolerance to Powdery Mildew. Modified from Roberts and Pernezny (2005).

Cucurbit Crop	Seed Company	Cultivar (Variety)	Disease Resistance or Tolerance to Powdery Mildew
		ToPowdery Mildewark	Powdery Mildew Races 1 and 2 (intermediately), Tolerant to Sulfur Damage
	Harris Moran Seed Company	All Start	Tolerant to Powdery Mildew Races 1 and 2
		Daybreak (Honeydew)	Tolerant to Powdery Mildew Race 1
		Early Dawn	Tolerant to Powdery Mildew Race 1
		Fantasma (Honeydew)	Tolerant to Powdery Mildew Races 1 and 2
		HM 5581	Tolerant to Powdery Mildew Race 1
		HMX 0586	Tolerant to Powdery Mildew Race 1
		HMX 4595 (Honeydew)	Tolerant to Powdery Mildew Race 1
		Honey Gold (Honeydew)	Tolerant to Powdery Mildew Race 1
		Moonbeam (Honeydew)	Tolerant to Powdery Mildew Races 1 and 2
		Morning Ice (Honeydew)	Tolerant to Powdery Mildew Race 1
		Shooting Start	Tolerant to Powdery Mildew Race 1
		Start Fire	Tolerant to Powdery Mildew Races 1 and 2
		Sugar Bowl	Tolerant to Powdery Mildew Races 1 and 2
	Rogers Seeds	Apollo	Tolerant to Powdery Mildew Races 1 and 2
		Athena	Tolerant to Powdery Mildew Races 1 and 2
		Acclaim	Tolerant to Powdery Mildew Race 1
		Galileo (Galia-type)	Tolerant to Powdery Mildew Race 1
		Honey King (Honeydew)	Tolerant to Powdery Mildew Race 1
		Sol Real	Tolerant to Powdery Mildew Races 1 and 2
	Sakata Seeds	Bolero (Crenshaw)	Tolerant
		Honey Brew (Honeydew)	Tolerant
		SME 6121	Tolerant to Powdery Mildew Races 1 and 2
		SME 7123	Tolerant
		SME 7124	Tolerant
		SME 7125	Tolerant
		Temptation#1	Tolerant
		Gold Coast (SME 0164)	Powdery Mildew Races 1 and 2
		Olympic Gold	Powdery Mildew Races 1 and 2
		Oro Duro	Powdery Mildew Races 1 and 2
		Western Gold	Powdery Mildew Races 1 and 2
		Western King	Powdery Mildew Race 1

Table 2. Some Melon Cultivars with Resistance or Tolerance to Powdery Mildew. Modified from Roberts and Pernezny (2005).

Cucurbit Crop	Seed Company	Cultivar (Variety)	Disease Resistance or Tolerance to Powdery Mildew
		Western Sunrise	Powdery Mildew Race 1
	Sunseeds	Creme de Menthe (Honeydew)	Tolerant
		Desert Queen	Tolerant
		Honey Start (Honeydew)	Powdery Mildew Races 1 and 2
		Rocio (Honeydew)	Powdery Mildew Race 1
		Sundew (Honeydew)	Powdery Mildew Race 2
		SXM 7066 (Honeydew)	Powdery Mildew Races 1 and 2
		SXM 7119 (Shipper)	Powdery Mildew Race 2
		Desert Gold	Tolerant
		Iron Horse	Tolerant
		Mainpak	Tolerant
		Voyager	Powdery Mildew Race1
		Odyssey	Powdery Mildew Race 2
		SXM 7057	Powdery Mildew Races 1 and 2
		SXM 7061	Powdery Mildew Races 1 and 2

Table 3. Some Squash Cultivars with Resistance or Tolerance to Powdery Mildew. Modified from Roberts and Pernezny (2005).

Cucurbit Crop	Seed Company	Cultivar (Variety)	Disease Resistance or Tolerance to Powdery Mildew
Squash	Harris Moran Seed Company	Hurakan (Zucchini)	Tolerant
	Rogers Seeds	Sunglo (Yellow Crookneck)	Tolerant