Impatiens Downy Mildew: Pathogens, Management Options, and Genetic Resistance

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Impatiens (Impatiens walleriana) and New Guinea impatiens (Impatiens hawkeri) (NGI) are very important bedding plants to the floriculture and landscape industries in Florida and many other states in the United States. Downy mildew (DM) has become a devastating disease for impatiens growers and caused significant economic damages to many segments of the floriculture and landscape industries. Three oomycete species could cause DM on impatiens, and Plasmopara obducens has recently caused regional outbreaks of DM in the United States. This pathogen thrives in cool, moist conditions but has a narrow host range. Impatiens plants infected by P. obducens have chlorotic and downward-curving leaves, followed by leaf and flower drops, and eventually complete defoliation and plant collapsing. Several fungicides are effective to control DM when they are applied prior to disease development. Some fungicides have shown a carryover protection on plants installed in the landscape, but such protection generally did not last beyond one month. A number of cultural practices may be used to minimize crop losses due to DM. Impatiens cultivars and their hybrids are susceptible to DM while NGI cultivars are resistant to DM. It has not been possible to transfer the DM resistance from NGI into I. walleriana due to the differences between the two species in chromosome number, size, and morphology. Several genetic strategies are available for introducing DM resistance into impatiens. A better understanding of the resistance mechanisms in NGI will be very valuable for developing DM-resistant impatiens cultivars, which will be critical for the sustainability of impatiens production in Florida and other states in the United States.

Impatiens and New Guinea Impatiens

The genus Impatiens (family Balsaminaceae) has more than 1000 species that grow throughout tropical Africa, Southeast Asia, parts of Europe, and North America (Morgan, 2007). Out of these species, Impatiens walleriana (commonly known as impatiens) is the most commonly cultivated (Morgan, 2007) and has been one of the top floricultural crops in the United States (U.S.). The high popularity of impatiens is attributed to its wide range of flower colors and long flowering season. It was estimated that commercial impatiens plants had a wholesale value of approximately $62.9 million in the U.S. in 2014 (USDA/NASS, 2015).

In recent years, New Guinea impatiens (NGI) (Impatiens hawkeri) has become more popular and widely produced in the U.S. floriculture industry. Compared with I. walleriana, NGI plants are more upright in stature and grow to much larger sizes with attractive flower and leaf colorations (Morgan, 2007). Adaptable to most light conditions and free from most insect pests, NGI has found its way into large containers, window boxes, and hanging baskets since its introduction in 1972 (Morgan, 2007) and had a wholesale value of about $55.7 million in the U.S. in 2014 (USDA/NASS, 2015). Most NGI cultivars are propagated by vegetative cuttings, but several seed-propagated series of NGI cultivars have become available recently.

Impatiens Downy Mildew

Impatiens downy mildew (DM) is a serious disease for Impatiens, either being of potential concerns to impatiens growers, or having already become a devastating disease. So far, there have been three types of DM reported on Impatiens and they are caused by distinct species of oomycetes. The first type of DM is caused by Pseudoperonospora cubensis on the host Impatiens irvingii. This type of DM was first reported in Cameroon in 2007, infected plants showed epiphyllous blood red spots on leaves and plant tissue necrosis, and sporangiophores emerged from stomata on the underneath of infected leaves. Pseudoperonospora cubensis is considered polyphagous since it hosts on species from Balsaminaceae to Cucurbitaceae and Cannabaceae (Voglmayr et al., 2008). The other two parasites causing DM on Impatiens are Plasmopara constantinescui and Plasmopara obducens. These two pathogens share some common hosts and are partly sympatric with each other, thus they are easily confused. Plasmopara constantinescui differs from P. obducens by its dichotomous sporangiophores with flexuose branches, globose sporangia, and associated leaf lesions with well-defined margins (Constantinescu, 1991). Among these three pathogens, DM caused by P. obducens is the one that is causing the greatest economical loss in the U.S. and it is the mostly studied.

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The original isolates of *P. obducens* were first described in 1877 by J. Schroeter, but it was not until the 21st century that this pathogen became active in the United Kingdom (UK) (Lane et al., 2005), Australia (Cunnington et al., 2008), Norway (Toppe et al., 2010), Hungary (Vajna, 2011), Serbia (Bulajic et al., 2011), Italy (Garibaldi et al., 2013), Japan (Satou et al., 2013) and other parts of the world. It is possible that the recent isolates have evolved genetic differences from the original ones (Putnam, 2012). There had been sporadic reports about this disease in the U.S. since 2004 (Wegulo et al., 2004); regional outbreaks have been observed since 2011 in Ohio (Baysal-Gurel et al., 2012), Kentucky (Ward et al., 2013), Florida (Palmateer et al., 2013), Alabama (Conner et al., 2014), Hawaii (Crouch et al., 2014), and other states. These regional outbreaks have made serious impacts on the production and use of impatiens in the U.S. and several other countries.

*Plasmopara obducens* is an oomycete and is obligate biotrophic, thriving under cool, moist conditions. Unlike *P. cubensis*, *P. obducens* only has a narrow host range (including *I. walleriana* hybrids, *Impatiens balsamina*, *Impatiens pallida*, *Impatiens carpensis*, *Impatiens glandulifera*, etc.). NGI and its hybrids appear to be highly resistant to the DM caused by *P. obducens* (Catlin, 2012). This pathogen produces two types of spores, zoospores and oospores. The zoospores, which can be air-borne and swim in water, are produced inside sporangia that are formed inside the leaf tissues and emerge from the underside of the leaves. Under suitable temperature and/or humidity conditions, the zoospores can be released and infect other plants through wind or rain (Warfield, 2011). The oospores are thick-walled and may survive overwinter in plant debris and be released into the soil as the plant decays. Resting oospores can survive in soil for up to several years and infect healthy impatiens plants that are grown in the next growing season. No evidence has shown the DM caused by *P. obducens* is seed-borne (Warfield, 2011).

Downy mildew symptoms on susceptible species of *Impatiens* initially appear as chlorosis on upper leaves and leaves curling downwards. Under cool and humid conditions (about 60 °F to 73 °F), white-colored sporulation can be seen from the underside of leaves (Fig. 1). Sporangia may not be present if the weather is warm and dry. Gradually infected impatiens plants become stunted and the leaves and flowers drop off, leaving the plants bare-stemmed (Fig. 2), and finally the plants collapse and die. Depending on the age of plants, temperature and humidity, it may take about five to 14 days from infection to the appearance of visible symptoms. Young plants, immature leaves, and seedling cotyledons are more susceptible to DM (Catlin, 2012; Hansen et al., 2013; Warfield, 2011).

**Management of Impatiens Downy Mildew**

Since no fungicides have proven to be able to cure DM on infected impatiens, management of DM caused by *P. obducens* has been mainly through applying preventive fungicides and modifying cultural practices.

**Cultural practices.** Since the latent period between infection and visible plant symptoms can be up to two weeks, it is important to ensure that impatiens cuttings and seed-produced plugs are free of DM at production sites. Frequent scouting for early DM symptoms is critical for early detection. Good air circulation, adequate drainage, and appropriate plant spacing should be provided in the greenhouses or nurseries to keep the humidity under 85%. Irrigation should be done early during the daytime, and large temperature swings be avoided to reduce condensations on the foliage. To prevent disease spreading, infected impatiens plants and plants of other *Impatiens* spp. nearby should be removed immediately and should not be composted (Catlin, 2012; Hansen et al., 2013; Warfield, 2011).

![Fig. 1. Impatiens leaf infected by *Plasmopara obducens* and showing white sporangia on the abaxial surface (left) and healthy leaf (right).](image)

![Fig. 2. Healthy impatiens plant (left) and downy mildew-infected impatiens plant completely defoliated and stems dying back (right).](image)
Identification and use of disease-resistant cultivars have been important for managing numerous devastating diseases in crops. For example, breeding and introduction of disease-resistant cultivars have played a significant role in controlling grapevine downy mildew caused by *Plasmopara viticola*, a pathogen in the same genus as the impatiens downy mildew pathogen *P. obducens* (Gessler et al., 2011). Downy mildew-resistant grapevines allowed *P. viticola* to complete its life cycle in leaf tissues, but inhibited its hyphal growth and sporangia formation, resulting in no visible symptoms or sporulation (Bellin et al., 2009; Diez-Navajas et al., 2008). Using conventional breeding techniques, grapevine breeders have produced some DM-resistant interspecific grapevine hybrids, and one of these cultivars ‘Regent’ was once the most popular hybrid grape variety in Germany (Gessler et al., 2011). Another white grape bred in Hungary, ‘Bianca’, also possessed DM resistance (Gessler et al., 2011). Although there were debates regarding their durability of resistance (Kast, 2011; Peressotti et al., 2010), these varieties have served as valuable materials in the grapevine breeding and production. We expect that in the long run, genetic disease resistance could play an important role in managing impatiens downy mildew.

Although downy mildew resistance is widely available in NGI, it has not been possible to transfer such resistance into *I. walleriana* cultivars. This is because the two species have different chromosome numbers (2n = 32 chromosomes in NGI and 2n = 16 in impatiens), morphology, and sizes (Uchneat, 2007), and cross-pollinations between the two species have not succeeded in producing hybrids. Therefore, it is necessary to identify other impatiens species that are resistant to DM and also crossable with *I. walleriana* and can produce viable seeds and offspring when crossed with *I. walleriana*. Such explorations are being conducted at Cornell University (J. Keach, personal communication). Presumably similar explorations are being sought by major impatiens breeding companies. Alternatively artificial mutagenesis may be used to induce DM resistance in *I. walleriana* cultivars. Artificial induction of DM resistance mutations has been reported in a limited number of cases (Van Damme et al., 2005). Conceivably, the gene(s) that confers DM resistance in NGI could be located, mapped, and isolated, and the isolated gene(s) could be introduced into DM-susceptible impatiens cultivars. This strategy has been successful with some DM resistance genes in some horticultural crops (Kuang et al., 2006). In addition, transgenic DM resistance has been reported in a limited number of studies using the *NPRI* gene or other genes (Cao et al., 1998; Nookaraju and Agrawal, 2012). In impatiens, numerous studies have been conducted to understand the DM disease cycle or environmental factors affecting DM incidence or severity, or to evaluate fungicide efficacy or the effectiveness of management programs, but little research has been done to understand the DM resistance mechanisms in NGI or the gene(s) responsible for such DM resistance. More research in these areas should be extremely valuable for developing DM-resistant impatiens cultivars.

### Downy Mildew Resistance

Several studies have shown that all cultivars of impatiens (*I. walleriana*) and interspecific hybrids with *I. walleriana* in parentage are highly susceptible to DM (Warfield, 2011) and NGI cultivars are resistant to DM (Warfield, 2012). Several series of new NGI cultivars have entered the floriculture industry in recent years. In 2014, we evaluated the plant performance and DM resistance of 40 vegetatively propagated NGI cultivars and 17 seed-propagated NGI cultivars as well as 20 cultivars of impatiens in the ground beds at the University of Florida/IFAS’s Gulf Coast Research and Education Center. Plants of all *I. walleriana* cultivars in the evaluation became completely defoliated in 7 weeks after DM symptoms appeared. Minor differences were observed among some impatiens cultivars in DM severity. All the NGI cultivars in the evaluation didn’t show any DM symptoms. Plants of NGI cultivars, in general, grew to larger plant sizes and produced larger flowers than plants of *I. walleriana* cultivars. Strong performers have been selected and put into another replicated trial, which will be completed by the end of 2015. The objectives of our trials are to identify robust NGI cultivars for commercial production and landscape use in Florida.

**Chemical control.** In order to gain maximum efficacy, fungicides should be applied protectively and preventively as a spray or a drench. In order to reduce the disease severity after sparse sporulation becomes visible, many fungicides have to be used at higher levels that are generally not acceptable at production facilities (Warfield, 2011). Fungicides including Adorn (active ingredient flupiciclode), Alude (potassium salts of phosphorous acid), Aliente (fosetyl-Al), Fanstop (fenamidone), Heritage (azoxystrobin), Micora (manipropamid), Orvego (ametoctradin and dimethomorph), Pageant Intrinsic (boscalid and pyraclostrobin), Stature (dimethomorph), and Segway (cyazofamid) have provided very good to excellent control of DM when applied as foliar sprays prior to inoculation in replicated trials (Warfield, 2011). To minimize the development of impatiens downy mildew fungicide resistant populations, Palmateer et al. (2014a) evaluated tank mixes and fungicide rotations with Adorn, Pageant Intrinsic and Daconil Ultrex (chlorothalonil). Hansen et al. (2013) found that an initial drench treatment with Subdue Maxx (mefenoxyam) and Adorn followed by foliar fungicides worked better than applying foliar spray alone. Effective fungicide treatment programs in the greenhouse can have a carryover protection for the plants for up to one month when they are installed in the landscape (Hansen et al., 2013). In terms of application methods, Palmateer et al. (2012b) showed that compared to spray applications, air blast of Pageant and Heritage worked even better. Preventative spray or drench applications of phosphonate containing products can provide excellent control of impatiens downy mildew in the landscape (Palmateer et al., 2014b). As always, fungicide rotations are essential for effective control (Palmateer et al., 2012a). More information on recommended fungicide programs for controlling DM on impatiens are available at the University of Florida, IFAS website <http://edis.ifas.ufl.edu/pp309>, Ball Horticultural Company and Cornell University’s Long Island Horticultural Research and Education Center <http://ballpublishing.com/GrowerTalks/CoverStory.aspx?articleID=18917&highlight=zurko+impatiens+downy+mildew>, and the American Floral Endowment website <http://endowment.org/wp-content/uploads/2012/03/imp%20dm%20program%202.pdf>.

**Literature Cited**
