EXPECT AND PREPARE FOR DOWNY MILDEW IN BASIL

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Your help needed for success of our research:

PLEASE Report Observations of Basil Downy Mildew. ***LINK to below***
Monitoring program success depends on participation.
Samples needed for research – PLEASE send. ***LINK to below***

Downy mildew of basil is a new, destructive disease that appears to be here to stay. It was first reported in south FL in October 2007. In 2008 downy mildew was confirmed in both field- and greenhouse-grown basil crops, as well as home gardens, in many states: NC, PA, NJ, NY, MA, NC, KS, and MO. Likely it occurred elsewhere but was not recognized. Growers generally did not realize their basil had a disease because the most noticeable symptom on affected plants was yellowing resembling a nutritional deficiency. The downy-appearing sporulation of the pathogen develops on lower leaf surfaces. And, since downy mildew of basil is so new in the USA, few knew about it. Complete crop loss occurred for some growers because leaves with any injury are unmarketable. This disease was also reported in Canada in 2008 and in greenhouse-grown basil in Argentina in February 2008. In 2009 basil downy mildew was found in the western USA, and early in 2011 it was reported in Hawaii for the first time. Downy mildew has been observed on basil in several states every year since 2008.

Reports of downy mildew began a few years earlier in Europe, where the disease is now considered endemic. It was observed in greenhouses in Switzerland in 2001, Italy in 2003, and Belgium plus France in 2004. Basil downy mildew has also been detected recently for the first time in Israel, New Zealand, Iran and several African countries: Cameroon in 2007, South Africa in 2005, plus Benin and Tanzania.

So where did this new scourge come from? Prior to all these recent outbreaks, basil downy mildew had only been reported in Uganda and that was in 1933. One possibility is that a more aggressive pathogen strain evolved in Uganda that is responsible for the recent outbreaks. The pathogen (*Peronospora belbahrii*) can be seed-borne, as well as dispersed via its air-borne spores. Unknowingly distributing contaminated seed is a plausible way that it has been spread long distances between geographically-separated areas, including in to the USA. Basil growers may recall with frustration a similar situation years ago with another new disease: Fusarium wilt. In just a few years, as the cause of this wilt was being identified, the pathogen became endemic most likely as the result of marketing of contaminated seed. It also is possible that spread of the basil downy mildew pathogen occurred through marketing of infected, basil leaves that were asymptomatic during shipment. Basil in the US has become the leading culinary herb and is available year round. An estimated 20% of the total basil sold is imported from other countries. The pathogen found in FL has been shown to be genetically the same as that in Switzerland (100% homology in their genetic sequences). Once downy mildew has begun to develop in one

crop, the pathogen can readily spread via the easily wind-dispersed spores that it produces abundantly. This is likely the main way it has spread throughout the eastern USA every summer since 2008, similar to its well-known relative, the cucurbit downy mildew fungus.

A monitoring program was started in 2009 to obtain information on where basil downy mildew occurs and to try to determine whether the pathogen could move northward through the eastern USA, now that it is considered established in FL, as occurs with the cucurbit downy mildew pathogen, and whether a monitoring program can assist growers to be prepared for downy mildew occurrence in their basil crop. Each year a spreadsheet accessible by anyone has been set-up in Google Docs. These pages are at:

For 2015: https://docs.google.com/spreadsheets/d/1JgKGmCP-0I2A03J0BG2EafNctvQTiaUUnbqJbYfQhVk/edit#gid=0

For 2014: https://docs.google.com/spreadsheet/ccc?key=0Ak8NCmWCdGPNdGFIUVZuT1ZhVmR1VDBPcUR5WkFtSkE#gid=0

For 2013: https://docs.google.com/spreadsheet/ccc?key=0Ak8NCmWCdGPNdFR6bFBxRERJQjdaYXd5VlZJYWNNX2c#gid=0

For 2012: https://docs.google.com/spreadsheet/ccc?key=0Ak8NCmWCdGPNdEZxSUdxYTNKaUJueU8tTG1Jd2tmTFE#gid=0

For 2011: https://spreadsheets.google.com/ccc?key=tphmBim45_9rRh31XfV7OeA&hl=en#

For 2010: http://spreadsheets.google.com/ccc?key=tpjIzTOV96rlFTVvvYXIa3w&hl=en

For 2009: http://spreadsheets.google.com/ccc?key=pwvp1mHxmowsEd8Sdi4coNQ

A total of 49 reports of basil downy mildew were logged in 2009, 63 reports in 2010, 63 reports in 2011, 75 reports in 2012, 64 reports in 2013, and 284 reports in 2014. These came from 20, 26, 22, 26, 20, and 35 states, respectively, plus the District of Columbus. More reports of downy mildew in 2014 than previous years was associated with affected plants for sale at garden centers in several states and cooler temperatures in the North Carolina to Maryland area where typical high summer temperatures might have limited downy mildew development in other years. Some reports were from outside the USA: Argentina, Australia, Mexico, Baja California, Grand Cayman, Costa Rico, Puerto Rico, Jamaica, Quebec, Ontario, British Columbia, South Africa, and South Korea. Most reports were made by home gardeners, growers and extension specialists of sightings on outdoor plants. Affected plants were also seen in greenhouses. Some reports were not confirmed.

Many more occurrences have been acknowledged but not logged. Another monitoring activity has been sentinel plots with basil conducted as an add-on to the *ipm*PIPE cucurbit downy mildew monitoring program. In 2009, downy mildew was observed in sentinel plots in seven of the 14 states with these plots. There were other reports of downy mildew in these states logged in the web-based monitoring spreadsheet. There were two states with no reports of downy mildew in plots or elsewhere. Thus occurrence of downy mildew in the sentinel plots in a state often reflected disease occurrence in that state.

Success of the monitoring program depends on reports from anyone growing basil; therefore everyone is encouraged to enter observations. Information is needed about the planting and how the diagnosis was made. Reports are also valuable of locations where downy mildew is not found on basil. Monitoring will assist with determining whether seed is becoming a less important source, as expected with the pathogen's ability to be seed-borne becoming well known, and whether movement of the pathogen via its wind-dispersed spores can be predicted based on knowledge of where downy mildew is occurring and forecasts of wind trajectories plus weather, as is done now for cucurbit downy mildew. Even before a forecasting system like that for cucurbit downy mildew can be developed, growers and gardeners alike will be able to look at reports in the spreadsheet to see if basil downy mildew has been observed near by.

Downy mildew also was observed recently on ornamental plants related to basil, in particular coleus and salvia. These plants all belong to the Lamiaceae family, which includes basils (*Ocimum* spp.), mints (*Menta* spp.), sages (*Salvia* spp.) and other culinary herbs.

Fortunately, the coleus and basil downy mildew pathogens have now been demonstrated to be genetically different; therefore, these ornamental plants are no longer considered potential alternative hosts. However, there are many ornamental types of basils that are also hosts to the pathogen affecting basil grown for use as an herb.

The first step in preparing for basil downy mildew is learning the symptoms. Observing spores on the underside of leaves is key to diagnosis. There are other causes of leaf yellowing in basil. Spores are produced during the dark night period, therefore early morning is the best time to inspect basil for downy mildew. Leaves with yellowing resembling downy mildew but lacking spores can be placed upside down on wet paper towel in a closed plastic bag in dark for a day to encourage the pathogen if present to produce spores. Photographs are posted at:
http://www.longislandhort.cornell.edu/vegpath/photos/downymildew_basil.htm
Next become familiar with the monitoring web page to be ready to use it after planting. Finally, develop a management plan.

Management. Using seed not infested with the basil downy mildew pathogen, selecting a less susceptible variety, and applying fungicides are the primary management practices for downy mildew. Minimizing leaf wetness and reducing humidity to obtain conditions unfavorable for disease development may suppress downy mildew, especially in greenhouses.

Seed Tests. Recent efforts to develop a seed test have resulted in a genetic-based procedure specifically for *Peronospora belbahrii* that is now being validated (suspected contaminated seeds are needed for this step, see information about submitting samples below). And Eurofins STA Laboratories in CO (http://www.eurofinsus.com/stalabs/products-services-seed-health.html) now tests basil seed for *Peronospora* spp. It is sufficient to test only at the genus level with this pathogen since it is the only species of *Peronospora* that would be associated with basil seed.

Seed Treatment. Seed companies are starting to steam treat basil seed. It is not amenable to hot-water treatment because while in water the seed produces a gelatinous exudate.

Varieties. Research has been conducted to determine if there are inherent differences in susceptibility among varieties and species of basil, and to identify sources of genetic resistance. Commonly grown sweet basil (*Ocimum basilicum*) has been shown to be more susceptible than some of the other exotic, spice, and ornamental basils such as *Ocimum citriodorum* and *Ocimum americanum*. All sweet basil varieties evaluated before breeding for resistance was started were found to be very susceptible. Other basil varieties with fewer symptoms in evaluations include red types (including 'Red Leaf' and 'Red Rubin'), Thai basil (Queenette'), lemon basil ('Lemon', 'Lemon Mrs. Burns', 'Sweet Dani Lemon Basil'), lime basil ('Lime'), and spice types ('Spice', 'Blue Spice', 'Blue Spice Fil', 'Cinnamon'). An article on one study is available as a PDF. Similar results have been obtained in trials conducted in Illinois and Florida. Fewer symptoms were observed only on those basils that are different from sweet basil being distinct in visual appearance, aroma and flavor, and which have quite limited markets. The challenge in breeding for resistance to basil downy mildew is to develop improved resistant varieties that still look, taste, grow and pack-out as a traditional high quality sweet basil. However, progress is being made. Eleonora is the first commercially available variety with moderate resistance, a level not sufficient to achieve acceptable control without additional management practices, in particular applying fungicides. Researchers at Rutgers have identified excellent source of resistance and produced experimental crosses exhibiting high level of resistance. Results from evaluating these plants at Cornell are available on-line at
http://www.longislandhort.cornell.edu/vegpath/diseases/basil-downy-mildew.html

Fungicides. To control downy mildew effectively with fungicides, it is considered necessary to start before first symptoms and to make applications frequently. Many of the fungicides currently labeled for this new disease, plus others not registered yet, have provided limited suppression in fungicide evaluations, demonstrating the difficulty in controlling this disease, especially in a research setting with applications made with a backpack sprayer, and thus the importance of starting before disease onset. Part of the challenge of controlling downy mildew is the need for blemish-free herbs when marketed as fresh sprigs.

Organic. Actinovate AG (active ingredient is *Streptomyces lydicus*), Double Nickel 55 (*Bacillus amyloliquefaciens*), MilStop (potassium bicarbonate), Regalia (extract of *Reynoutria sachalinensis*), Trilogy (neem oil), and OxiDate (hydrogen dioxide) are OMRI-listed fungicides labeled for use on herbs and for suppressing foliar diseases including downy mildew. MilStop, Regalia, and OxiDate are labeled for use outdoors and in greenhouses. The Actinovate, Double Nickel and Trilogy labels do not have a statement prohibiting use in greenhouses. Double Nickel label has directions for greenhouse use for soil-borne pathogens. OxiDate has limited residual activity and thus if used should be combined with or followed by another product. Results from research conducted at Cornell are available on-line at http://www.longislandhort.cornell.edu/vegpath/diseases/basil-downy-mildew.html

Conventional. Ranman (cyazofamid; FRAC code 21), Revus (mandipropamid; FRAC 40), Ridomil Gold SL (mefenoxam; FRAC 4), Quadris (azoxystrobin; FRAC 11), Armicarb (potassium bicarbonate), and phosphorous acid fungicides (FRAC 33) can be used in conventional production of basil, in addition to the fungicides listed above. Ridomil Gold and Quadris are the only ones of these that are not permitted to be used in a greenhouse. Ranman is the first product labeled with targeted activity for oomycetes, the group of pathogens that includes those causing downy mildews. There are several phosphorous acid (phosphanate) fungicides labeled for this disease, including ProPhyt, Fosphite, Fungi-Phite, Rampart, pHorsepHite, and K-Phite. This chemistry as well as Ranman was documented to be among the most effective in some university fungicide evaluations. Ridomil Gold and Quadris are labeled for use on basil but not specifically for downy mildew; they have been shown to be effective for downy mildew. In states like NY where the target disease is required to be specified on the label, Ridomil Gold and Quadris cannot be used without an approved FIFRA 2(ee) recommendation, which the applicator must possess when using (the one for NY can be downloaded at http://magritte.psur.cornell.edu/pims/current/). These fungicides with targeted activity are prone to resistance development due to their single site mode of action and thus need to be used within a fungicide resistance management program. Resistance to mefenoxam (Ridomil) developed quickly in Israel demonstrating the capacity of this pathogen to develop resistance. Other fungicides are expected to be labeled for basil downy mildew in the future as a result of work by the IR-4 program, which identified this as a top priority and supported fungicide evaluations. Ranman and Revus are the first fungicides registered as a result of IR-4 work. Results from research conducted at Cornell are available on-line at http://www.longislandhort.cornell.edu/vegpath/diseases/basil-downy-mildew.html

There are additional fungicides that can be used in select states under Section 18 or 24(c) registrations. These include Subdue MAXX (mefenoxam; FRAC 4) applied to transplants grown in AL, CA, and MI for re-sale to consumers under a 24(c) Special Local Needs Label. Heritage (azoxystrobin) is similarly labeled in AL, CA, and FL. These labels will expire beginning in 2015.

To determine when to initiate a fungicide program and also when it is warranted to consider harvesting early to avoid losses to downy mildew, growers should not only routinely check the on-line spreadsheet to determine when downy mildew is occurring on basil nearby, but also regularly inspect their crop for symptoms. The cucurbit downy mildew forecasting web site (http://cdm.ipmpipe.org) might be useful for predicting when conditions are favorable for basil

downy mildew since both pathogens likely have similar requirements for successful wind dispersal long distances (e.g. overcast skies) and subsequent infection (e.g. wet leaves or high humidity). Summer is not a time to forget about this disease: unlike most other downy mildew pathogens, e.g. the ones affecting lettuce and cruciferous crops, which stop developing in summer, the basil downy mildew pathogen seems to develop best under moderate to warm temperatures while also tolerating cool temperatures. Don't forget to report occurrence of downy mildew as soon as possible at the monitoring page or via e-mail to mtm3@cornell.edu.

Other Practices. Practices that minimize leaf wetness and reduce humidity can contribute to control. These include planting where there is full sunlight and good air movement with rows parallel to the prevailing wind direction, maximizing plant spacing, and using drip irrigation. Humidity can be lowered in greenhouses by using circulating fans and lights and by increasing temperature. Observations of downy mildew occurrence in field and greenhouse basil plantings suggest that environmental conditions might significantly affect severity of downy mildew.

Illuminating either leaf surface of plants growing under protected conditions during nighttime was shown to effectively suppress downy mildew by inhibiting spore production through a study conducted in Israel. Light was supplied in high tunnel-like structures with 20W Day Light fluorescent bulbs each equipped with a white metal reflector (30 cm diameter), with one bulb per meter row. Spores formed on leaf tissue shaded by other leaves, thus this procedure is most effective when plants are small. Initial experiments were done with illumination throughout night. Recent research has revealed light exposure is most during the first 6 hours of night. Red light was shown to be the most inhibitory under laboratory conditions.

High temperature is detrimental to the pathogen. Maximum temperatures for infection, colonization, and spore production are 80 – 88 F. Spores were killed on plants exposed to 113 F for 2 days.

Basil crops should be disked under or otherwise destroyed as soon as possible after last harvest, or when abandoned because of disease, to eliminate this source of inoculum for other plantings. A sunny day is the best time to physically destroy an affected crop because the disturbed spores will be killed by UV radiation.

Please Note: The specific directions on fungicide labels must be adhered to -- they supersede these recommendations, if there is a conflict. Any reference to commercial products, trade or brand names is for information only; no endorsement is intended.

Basil Downy Mildew Monitoring Program

With basil downy mildew now established in Florida over winter, a monitoring program has been on-going since 2009 to determine whether this pathogen can move northward through the eastern USA as occurs with the cucurbit downy mildew pathogen, and whether a monitoring program can assist growers and gardeners to be prepared for downy mildew occurrence in their basil. The success of this activity depends on reports from anyone growing basil. Reports are also appreciated from outside the USA.

To report your observations and see those of others, go to:

https://docs.google.com/spreadsheets/d/1JgKGmCP-0I2A03J0BG2EafNctvQTiaUUnbqJbYfQhVk/edit#gid=0

Please enter your observations in a line at the bottom of the spreadsheet and send an e-mail to mtm3@cornell.edu. Some column headings have instructions that will appear when the cursor is put over the heading. Include information about the planting and how the diagnosis was made. If you are unable to confirm the diagnosis microscopically, please contact your local diagnosis service for assistance or send an e-mail with close-up image of symptoms to mtm3@cornell.edu.

Consult this site during the growing season to determine where downy mildew is developing in the USA. Data can be sorted by any column by clicking on the letter designation for a column and then selecting Sort under Tool. Re-sort by date when you are done.

Participate in Research by Submitting Sample

Knowledge about strains of the pathogen occurring throughout the USA will help us to refine management practices. For information on shipping samples, please contact Robert Wick by e-mail (rlwick@umass.edu) or phone (413-545-1045). THANK YOU very much!