Celery

Wednesday afternoon 2:00 pm

Where: Grand Gallery (main level) Room D
MI Recertification credits: 2 (1B, COMM CORE, PRIV CORE)
OH Recertification credits: 1.5 (presentations as marked)
CCA Credits: PM(1.5) CM(0.5)
Moderator: Mark Cnossen, Cnossen Farms, Wayland, MI

2:00 pm	Fungicides and Varietal Resistance for Celery Leaf Curl / Anthracnose Management (OH: 2B, 0.5 hr) • Beth Gugino, Vegetable Pathology, Penn State Univ.
2:30 pm	Managing Pythium Root Rot on Celery Seedlings (OH: 2B, 0.5 hr) • Mary Hausbeck, Plant, Soil and Microbial Sciences Dept., MSU
3:00 pm	Postharvest Handling for Celery • Steve Sargent, Horticultural Sciences Dept., Univ. of Florida
3:30 pm	Insect Pest Management in Celery (OH: 2B, 0.5 hr) • Zsofia Szendrei, Entomology Dept., MSU
4:00 pm	Session Ends

FUNGICIDES AND VARIETAL RESISTANCE FOR CELERY LEAF CURL / ANTHRACNOSE MANAGEMENT

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In 2010, the Penn State Plant Disease Clinic received a celery sample with unusual symptoms of curled, distorted leaves, and brownish to black lesions on the stems and petioles (Figure 1). The disease was identified as celery leaf curl, caused by *Colletotrichum acutatum* (Pollock et al., 2012) which is very similar to celery anthracnose and another disease described in Japan as celery stunt anthracnose. Some of the confusion with the disease name is underpinned by the changing taxonomy of the causal pathogen *Colletotrichum*. In PA, we typically refer to this disease as celery leaf curl (CLCD) caused by *Colletotrichum acutatum* while in Michigan, the disease is more commonly referred to as anthracnose (Rodriguez-Salamanca et al., 2012). Celery stunt anthracnose is caused by a different species of *Colletotrichum*.

Figure 1. Curled leaves and stem lesions (top) and crown lesions (bottom) characteristic of celery leaf curl disease.

Since the first sample in 2010, CLCD has been observed in PA every year and has been most frequently associated with the cv. Tango. It has also been reported in Ontario, Canada, New York, Massachusetts, Maine, Nova Scotia, Virginia, Connecticut, and New Jersey. Isolates of the pathogen are currently being collected to gain a better understanding of the population genetics (how similar or dissimilar are the isolates causing disease) and whether or not the pathogen could potentially be seedborne. Recent research in Japan on celery stunt anthracnose demonstrated that *C. nymphaeae* is seed associated and recommends that growers hot water treat seed at 122°F for 30 min prior to planting (Yamagishi et al. 2015). *C. acutatum* has a wide host range and it has been shown to be seedborne on a range of hosts including ornamentals such as lupin and zinnia and commercial crops like cowpea and safflower. Our initial seed screening efforts has been unsuccessful to-date, however, we are continuing to work on detection methods.

Aside from efforts to better understand the pathogen population causing disease and potential sources of inoculum, growers are interested in specific disease management recommendations. Host resistance is an important tool for disease management. Previous research conducted in Australia (Wright and Heaton, 1993) as well as research conducted by Raid et al. (2014) evaluated ten cultivars and breeding lines for susceptibility and found that although all showed some level of susceptibility, disease severity ranged between 1.0 and 5.0 (severe) with cv. Tango receiving a moderate disease severity rating of 2.5. An

artificially inoculated and replicated greenhouse trial is currently underway to evaluate the susceptibility of 20 commercially available cultivars and breeding lines some of the commercially available cultivars being evaluated include Tall Utah, Tango, Samba, Congo and Redventure. Preliminary results will be presented.

A fungicide trial was conducted in 2015 at the Russell E. Larson Research and Extension Center in Centre Co., PA to evaluate the efficacy of products for the management of CLCD under PA environmental conditions. The products include the broad spectrum protectants chlorothalonil (Bravo WeatherStik 2.0 pt/A and Equus 2.0 pt/A) and mancozeb (Manzate Pro-Stik 3.0 lb/A); FRAC code 11 fungicides Quadris (12.0 fl oz/A) and Cabrio (16.0 oz/A); microbial and biochemical biofungicides Regalia (4.0 qt/A), Actinovate (12 oz/200 gal), Double Nickel 55 (3.0 lb/A) as well as Champ (2.0 lb/A) and Oxidate 2.0 (32.0 fl oz/100 gal). The trial was arranged in a randomized complete block design with four replications and fungicide applications were made using a tractor mounted R&D sprayer on 6, 21, 27 Aug and 3, 9, 16 and 23 Sep. Despite inoculating with the pathogen twice with a conidial suspension on 17 Aug and 1 Sep and using overhead misters to create favorable conditions for disease development, disease pressure was low and disease incidence only reached approx. 25% in the inoculated row of the untreated plots by the end of the trial on 6 Oct. Even under low disease pressure, differences in disease incidence between the treatments were observed with the broad spectrum protectants (chlorothalonil, mancozeb and copper hydroxide) as well as the FRAC code 11 fungicides reducing disease incidence to below 0.5% while disease incidence in the biofungicide treated plots ranged between 13.3% for Regalia and 28.3% for Actinovate. Symptoms of CLCD did not develop in the uninoculated and untreated plots indicating that there was little to no *Colletotrichum* associated with the transplants imported from out-of-state. Plans are underway to repeat this trial again in 2016.

References:

Pollok, J.R., Mansfield, M.A., Gugino, B.K., and May, S.R. 2012. First report of leaf curl on celery caused by *Colletotrichum acutatum* in the United States. Plant Dis. 96:1692.

Raid, R. N., Klamer, D., and Klamer, J. 2014. Poster abstract. Fungicidal management of celery anthracnose caused by *Colletotrichum acutatum*. Available at: http://www.apsnet.org/meetings/Documents/2014_meeting_abstracts/aps2014abP181.htm.

Rodriguez-Salamanca, L.M., Enzenbacher, T. B., Byrne, J.M., Feng, C., Correll, J.C., and Hausbeck, M.K. 2012. First report of *Colletotrichum acutatum sensu lato* causing leaf curling and petiole anthracnose on celery (*Apium graveolens*) in Michigan. Plant Dis. 96:1383.

Yamagishi, N., Fujinaga, M., Ishiyama, Y., Ogiso, H., Sato, T. and Tosa, Y. 2015. Life cycle and control of *Colletotrichum nymphaeae*, the causal agent of celery stunt anthracnose. J. Gen. Plant Pathol. 81:279-286.

Wright, D.G., and Heaton, J.B. 1991. Susceptibility of celery cultivars to leaf curl caused by *Colletotrichum acutatum*. Australas. Plant Pathol. 20:155-156.

Managing Pythium Root Rot on Celery Seedlings

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Pythium species are commonly found in soil and water. Some species can cause serious diseases on greenhouse crops and vegetable seedlings resulting in severe losses. The pathogen can be introduced into greenhouse facilities through infected plug transplants, contaminated equipment, reused containers, and benches or through contaminated surface water used for irrigation. *Pythium* species have the ability to survive in infected plant debris or soil and wait for favorable conditions to initiate the infection process.

The root rot disease can be a sporadic or chronic problem depending on the adoption of management practices. Sanitation is an effective option to reduce the opportunity of *Pythium* to cause infection, eliminating the potential source of inoculum. Cultural practices aimed at limiting the opportunities of the pathogen to spread (i.e. elimination of surface water), may contribute to reducing the disease.

Chemical applications for Pythium root rot control are a reliable practice when used preventively. Growers of vegetable seedlings are interested in fungicides for celery seedling production. Fungicide drenches at the appropriate rate and time of application have proven effective in reducing root rot problems, but few are registered. Mefenoxam has been widely used for controlling *Pythium* spp. associated with root rot, pre- and post-emergence damping off of seedlings in floriculture greenhouse crops; however, reports of *Pythium* resistance to mefenoxam have also been documented in numerous crops. Thus, determining the sensitivity of *Pythium* spp. from celery seedlings to mefenoxam and identifying effective fungicide treatments for controlling Pythium root rot may contribute to improved current management recommendations for greenhouse-grown celery transplants.

Disease sampling 2015. Celery seedlings were scouted in May of 2015 at three Michigan greenhouses. Symptoms included stunting, chlorotic leaves or seedling wilting. A total of 175 celery samples including healthy and diseased plants were collected for diagnosis of root rot symptoms. Samples included celery cultivars CR-1 (100) and WA-7 (75). The celery samples were processed in our laboratory; the roots were rinsed with tap water without further surface-disinfestation. Four root portions were randomly selected from each plant, excised, and placed onto water agar. The isolates with morphological structures distinctive of the Oomycetes group were selected using single hyphal tip transfer. The internal transcribed spacer (ITS) was sequenced and compared to GeneBank and a curated *Pythium* database to confirm their identity.

Mefenoxam sensitivity test. A stock solution of mefenoxam (Subdue MAXX; Syngenta, Greensboro, NC) was added to corn meal agar (CMA) to final concentrations of 0, 1 and 100 µg of active ingredient (a.i.)/ml. A total of 35 *P. mastophorum* isolates were tested including the isolates collected during 2014 (9) and 2015 (26). The isolates were grown on CMA plates at room temperature for 8-10 days under constant light. A 4-mm agar plug from an actively growing *Pythium* culture was placed in the center of 6-cm plates of CMA amended with mefenoxam. The experiment was arranged as a completely randomized design with two replicate plates per isolate at each concentration and was repeated twice.

The proportion of isolates of *P. mastophorum* that was sensitive, intermediately resistant and highly resistant was calculated for each year.

Results. In total, 26 isolates of *P. mastophorum* were isolated and identified from the celery cv. WA-7. All celery seedling samples had symptomatic roots with evident tissue discoloration and reduction of secondary roots. No *Pythium* species were isolated from cv. CR-1.

The mefenoxam sensitivity test included a total of 35 isolates of *P. mastophorum* collected in 2014 and 2015 (Figure 1). In 2014, 56% of the isolates evaluated were highly resistant to mefenoxam at 100 µg a.i./ml whereas 22% were sensitive at 1 µg a.i./ml and 22% were intermediately resistant. In contrast, all the isolates of *P. mastophorum* recovered were 100% resistant at 100 µg a.i./ml in 2015 (Figure 1).

Mefenoxam resistance has been previously documented in other *Pythium* spp. However, there are no reports associated with *P. mastophorum* which is an important root pathogen in the *Apiaceae* (celery, carrot) family.

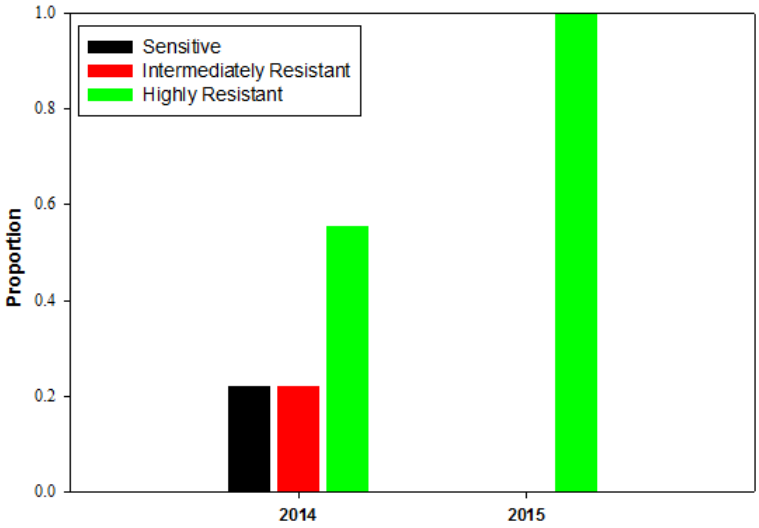

Figure 1. Proportion of *Pythium mastophorum* isolates from Michigan greenhouses, showing sensitivity, intermediate resistance and high resistance to mefenoxam at 1 µg a.i./ml and 100 µg a.i./ml based on percentage of growth inhibition on amended CMA.

Fungicide trial. A trial was conducted including products that are registered and unregistered for greenhouse used (Table 1). Healthy 5-6 week old celery seedlings cv. CR-1 were inoculated immediately prior to transplanting. The inoculum was prepared by growing *P. mastophorum*, *P. sylvaticum* and *P. ultimum* on CMA for 5-8 days. A mixture of 500 g of the *Pythium* spp. inoculum was prepared and approximately 35 g from this mix was used to inoculate seedling roots. Treatments were applied as soil-drenches at the recommended rates and reapplied at intervals listed in Table 1. Biological control agents were applied 48 hours before inoculation, and fungicide treatments were applied the same day of inoculation. Controls consisted of untreated uninoculated (healthy) plants and untreated inoculated plants. The experiment was arranged as completely randomized design with eight replicate plants for each treatment.

Disease assessment. Disease severity was assessed at 3-day intervals from 5 to 31 days post inoculation. The plants were visually assessed using a 1-5 scale where 1=no evident symptoms; 2=lower leaves with chlorosis; 3=25-50% of leaves with chlorosis and slight wilting or evident stunting; 4=>50% of leaves with chlorosis, severe stunting and wilting; 5=plant death.

Root rot severity was also visually assessed using a scale from 1-5 where 1=normal, healthy appearance of the root system; 1.5=occasional lesions or slight discoloration of the roots; 2=≤25% of the primary and lateral roots with lesions or discolored; 2.5=26-50% of the primary or lateral roots with lesions or discolored plus lateral roots pruned; 3=51-75% of the roots with lesions or discolored plus many lateral roots pruned; 3.5=76-90% of the lateral roots missing or completely rotted and primary roots extensively discolored; 4=>90% lateral roots missing and primary roots completely discolored; 5=root system completely disintegrated and detached from the stem. Total plant fresh weight was measured at the end of the experiment.

Table 1. List of products evaluated for Pythium root rot control of celery seedlings cv. CR-1.

Product	Active Ingredient	FRAC code	Rates/100 gal	Total no. applications[1]	Labeled for greenhouse use[2]
Phostrol	phosphorous acid salts	33	24 fl oz	2	Yes
Alude	phosphorous acid salts	33	12.75 fl oz	2	Yes
Rootshield WP	*Trichoderma harzianum* T-22	-	5 oz	3	Yes
Actinovate SP	*Streptomyces lydicus* WYEC108	-	6 oz	3	Yes
Terrazole L	etridiazole	14	7 fl oz	2	No
Micora	mandipropamid	40	8 fl oz	5	**
Reason 500SC	fenamidone	11	8.2 fl oz	3	No
Previcur Flex	propamocarb HCl	28	12.8 fl oz	3	No
Subdue MAXX EC	mefenoxam	4	1 fl oz	3	No
V-10208	ethaboxam	22	8 fl oz	3	No
Presidio 4SC	fluopicolide	43	4 fl oz	3	No

[1] Total number of soil drenches.
[2] If greenhouse use is NOT prohibited on the label and is allowed on celery, the product can be used.
**Labeled for control of downy mildew on celery as a foliar spray.

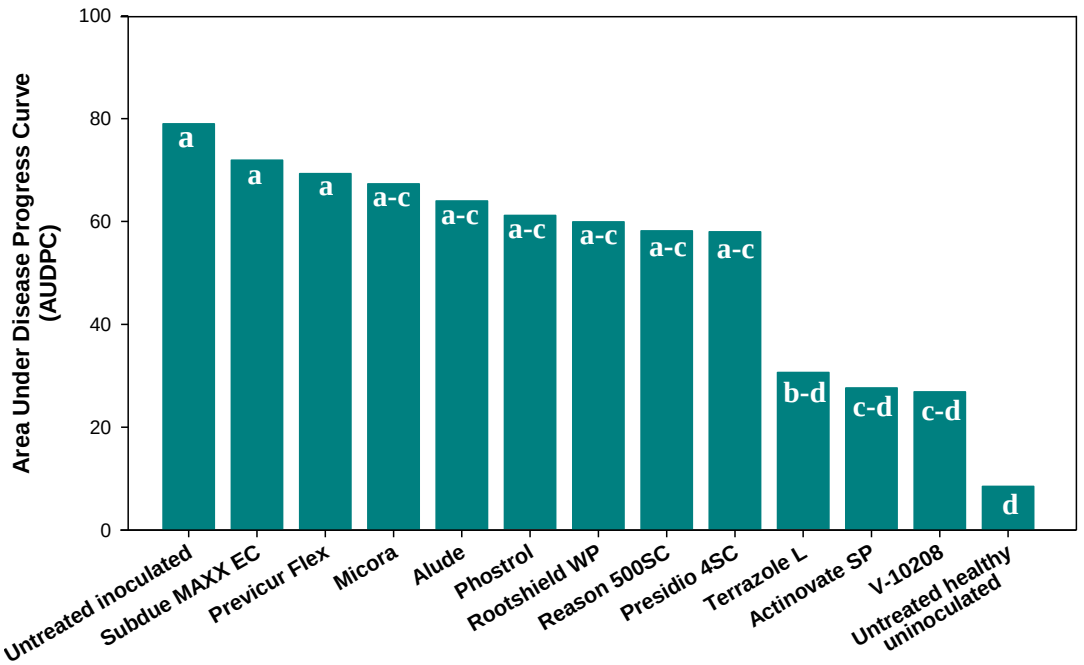

Figure 2. Area under disease progress curve of celery seedlings cv. CR-1 evaluated for *Pythium* root rot after fungicides drenches under greenhouse conditions. The higher the AUDPC number, the greater the amount of disease. Disease was visually assessed using a 1-5 scale where 1= no evident symptoms; 2= lower leaves with chlorosis; 3=25-50% of leaves with chlorosis and slightly wilting; 4=>50% of leaves with chlorosis, stunting and wilting; 5=plant death. Bars with a letter in common are not significantly different (Tukey HSD; $P = 0.05$).

Results. Drench applications of Terrazole, Actinovate and V-10208 effectively limited the progress of the disease when compared with the untreated inoculated control and Subdue MAXX (Figure 2, Figure 3). Severity of root rot was significantly reduced with the applications of V-10208, Terrazole, and Phostrol whereas all other treatments were similar to the untreated inoculated control. Treatments of

V-10208 and Terrazole resulted in plant biomass statistically similar to the untreated healthy uninoculated control (Table 2). Neither V-10208 nor Terrazole are registered for use on celery.

Table 2. Effect of drench applications of fungicide treatments on root rot severity and fresh weight of celery seedlings cv. CR-1.

Treatment	Plant fresh weight (g)[x]	Treatment	Plant fresh weight (g)[x]
Untreated healthy uninoculated .	65.51 a[y]	Rootshield WP	35.55 a-c
Terrazole L.....	53.13 ab	Presidio 4SC	31.81 bc
V-10208	55.97 ab	Subdue MAXX EC.....	29.55 bc
Phostrol	40.88 a-c	Reason 500SC.....	29.98 bc
Actinovate SP	48.68 a-c	Previcur Flex.....	17.53 c
Micora.....	35.95 a-c	Untreated inoculated...	29.61 bc
Alude.....	36.85 a-c		

[x]Fresh weight was taken at the end of the experiment, 45 days after *Pythium* spp. inoculation.
[y]Column means with the same letter are not significantly different (Tukey HSD; $P = 0.05$)

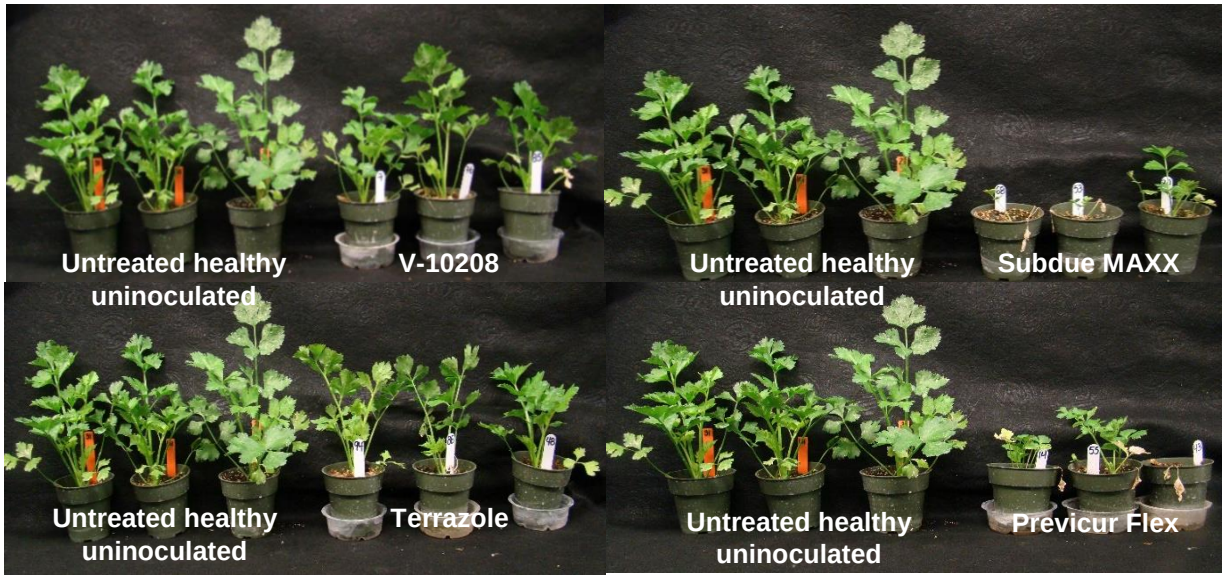

Figure 3. Results of the fungicide trial (2015), comparing the overall effectiveness of treatments evaluated. Panel A: (left) treatments with levels of control similar to the untreated healthy uninoculated control. Panel B: (right) treatments with limited effect on disease progress compared to the healthy control.

Overall, V-10208, Actinovate or Terrazole applied as a drench were more effective than some products in limiting *Pythium* root rot of celery seedlings under greenhouse. However, since no fungicide was able to completely protect plants from *Pythium* other measures are recommended including greenhouse sanitation.

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Postharvest Handling for Celery

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HARVEST, HANDLING AND COOLING GUIDELINES

Celery is a hardy, cool-season crop; however at harvest it needs to be handled more like a fresh-cut crop, since trimming creates fresh cuts on the stalk, increasing perishability and susceptibility to postharvest diseases.

1) Harvest
- Hand-cut vs. machine
- Field pack: individual cartons vs. mule train
- Bulk containers
- Sanitation

2) Packing
- Rinse
- Trim
- Sanitation
- Packing - sleeved vs. unsleeved (naked)

3) Cooling and storage
- Hydrocooling, vacuum cooling, efficiency
- Sanitation
- Storage at 32 to 34ºF; 95% relative humidity

4) For further reference (copies available at MSU Extension Booth)

- Handling, Cooling and Sanitation Techniques for Maintaining Postharvest Quality
- Chlorine Use In Produce Packing Lines.
  https://edis.ifas.ufl.edu/ch160
- Food Safety on the Farm: An Overview of Good Agricultural Practices.
  https://edis.ifas.ufl.edu/fs135