Pickling Cucumber

Tuesday morning 9:00 am

Where: Gallery Overlook (upper level) Room E & F
MI Recertification credits: 2 (1B, COMM CORE, PRIV CORE)
OH Recertification credits: 1 (presentations as marked)
CCA Credits: NM(0.5) PM(1.5)
Moderator: Bernard Zandstra, Horticulture Dept., MSU

9:00 am	Pickling Cucumber Weed Control Options, and Why Are There No New Registrations? (OH: 2C or 3p, 0.5 hr) • Mark VanGessel, Plant and Soil Sciences, Univ. of Delaware
9:30 am	Downy Mildew Prevention and Control (OH: 2B, 0.5 hr) • Mary Hausbeck, Plant, Soils and Microbial Sciences Dept., MSU
10:00 am	Nutrition and Population Research with Parthenocarpic and Gynoecious Cucumbers • Gordon Johnson, Carvel Research and Education Center Univ. of Delaware
10:30 am	Scouting Cucumbers with UAS (Drones) • Ian MacRae, Northwest Research and Outreach Center, Univ. of Minnesota
11:00 am	Session Ends

Pickling Cucumber Weed Control Options, and Why Are There No New Registrations?

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Weed competition in pickling cucumbers can reduce yield and interfere with harvest. Growers in the Delmarva region rely on herbicides for weed control. Soil-applied application of Command and Curbit is the most common treatment. About half of the fields will also receive a postemergence application of Sandea.

Curbit is a group 3 (microtubule inhibiting) herbicide used primarily for control of annual grasses and pigweed and purslane. Curbit can cause some root injury if the soil has not warmed, so Curbit is often not used for early-season plantings. Command is a group 13 (pigment inhibitor) and controls lambsquarters, common ragweed, velvetleaf in addition to annual grasses. Sandea is a group 2 herbicide (acetolactate synthase inhibitors) that provides excellent control of pigweed, common ragweed, velvetleaf, cocklebur, galinsoga, and yellow nutsedge. Herbicide are used in combination with cultivation and since pickling cucumbers are only in the field 40 to 50 days, farmers have been able to achieve a high level of weed control.

Herbicide resistance, primarily to group 2 and 9 herbicides, is spreading in our region and impacting weed control in vegetables. Group 2 resistance in pigweed (smooth or redroot) and Palmer amaranth is fairly wide-spread, and we have recently confirmed resistance in common ragweed. Complicating this issue is that most of the Palmer amaranth and some of the common ragweed are resistant to both Group 2 and glyphosate (Group 9). These multiple resistant biotypes are difficult to control in rotational grain crops that rely upon these herbicide groups for weed control. Once these resistant biotypes become established in a field they require more intensive management, often relying on non-chemical options.

Palmer amaranth is a unique weed species. It is very aggressive, growing very rapidly, attaining heights well over 5 feet, and produces over 500,000 seeds per plant. As a result, preventing seed production is one of the best strategies when it is found in a field. Farmers will often not follow up with weed control after harvest and allow those weeds remaining in the field to mature and produce seeds. But since Palmer amaranth is capable of emerging and becoming establish in August and September, these fields may need to be managed up until the first frost.

There are no new herbicides being developed for pickling cucumbers. Major herbicide manufacturers are searching for a new site of action herbicide that will help manage resistance, but once something is discovered it will be years before it is commercialized and even longer until it might be registered for minor crops. Herbicides (and all pesticides) need to meet very high industry and regulatory standards for registration. Issues such as performance, crop safety, storage and handling, low application rates, and environmental safety all must be satisfactory to warrant development and commercialization.

Famers need to use integrated management strategies that rely upon non-chemical approaches, focus on eliminating weed seed production, maintain excellent weed control in rotational grain crops, and take steps to prevent the introduction of herbicide-resistant seeds into your fields.

Downy Mildew Prevention and Control

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Cucurbit Downy Mildew

Downy mildew causes severe leaf blight on cucurbit crops, including cucumber, melon, squash, and pumpkin. Incited by the fungal-like pathogen *Pseudoperonospora cubensis*, downy mildew has occurred every growing season for Michigan cucumber growers since 2005. Michigan remains the top producer of pickling cucumbers in the United States, with 30,000 acres planted in 2015 (USDA, 2016). Although downy mildew can be especially damaging to cucumber and melons, squash and pumpkins may also become infected. The downy mildew pathogen cannot overwinter in Michigan fields but can overwinter in greenhouses or production regions that do not experience a frost.

Over the last several years, some fungicides that used to be effective are no longer working well in Michigan. If downy mildew is not effectively controlled, especially early in the cropping cycle, yield loss and misshapen fruit usually occur. Fungicides must be used preventively but it is difficult to know when the downy mildew pathogen is threatening the crop and spraying must begin. Spore trapping has been used in Michigan for nearly ten years to detect an influx of downy mildew sporangia into our production areas and alert the industry that disease is likely. An important reminder from the 2015 season is that when the weather conditions are especially favorable for downy mildew, fungicide selection and timing of applications becomes crucial.

Spore Trapping 2016

The 2016 growing season included weather conditions that were hotter and drier than normal. Downy mildew was confirmed in the state on 9 July and reached our campus research plots on 9 August. In 2015, downy mildew became established in our research plots on 27 July.

As part of our statewide early monitoring system, nine spore traps (Fig. 1) were operated from May to September 2016 in fields in cucurbit-producing areas in the lower peninsula of Michigan. The spore trapping sites included counties in the eastern part of the state (Arenac, Bay, Saginaw, Monroe), central counties (Ingham, Gratiot), and west counties (Allegan, Berrien, Muskegon).

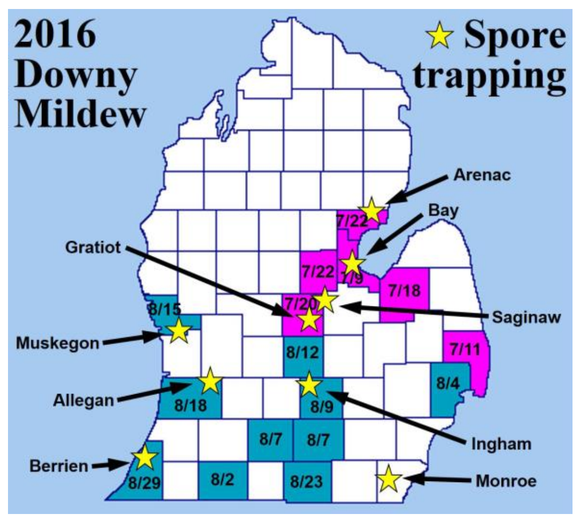

Figure 1. Map showing spore trap sites (stars) and counties with confirmed downy mildew.

The first downy mildew sporangium was detected via the spore trap in late May-early June across the state. On the east side of the state the first sporangium was observed between 1 to 3 June and a week later (from 3 to 10 June) sporangia were observed in the central part of the state. The western side of the state saw the earliest occurrence from 29 May to 2 June. Spore numbers peaked in the various production regions from late July into early to mid August. Specifically, from 4 to 9 August, the spore numbers peaked in the state's eastern production areas. In the central region of the state, the spore peak began earlier and extended over a longer period of time (13 July to 19 August). In the western regions, the peak numbers were recorded to begin later than the other regions (6 to 18 August). Peak spore numbers were highest in the western region (882) but still much lower than in previous years. The especially hot and dry conditions that prevailed for much of the growing season certainly played a key role especially since many of the pickling cucumber fields are not irrigated. Downy mildew developed in Michigan fields even though the spore counts were quite low and this is a pattern that has been observed in previous years. Our laboratory, in conjunction with other laboratories across the U.S., are working to develop and test a molecular tool that is specific to the cucurbit downy mildew pathogen and would provide a quick turnaround time as a complement to this spore trapping.

Fungicide Trials

Replicated, controlled fungicide trials were conducted at the MSU Plant Pathology Farm to compare fungicides for their ability to limit downy mildew. In 2016, downy mildew was first observed on the MSU Plant Pathology Farm on 9 August on cucumber 'Straight Eight' in a sentinel plot. Several trials were conducted that included testing the following fungicides (Table 1) for control of downy mildew on pickling cucumbers.

Table 1. List of fungicides tested in Michigan in 2016.

Product name	Active ingredient	FRAC[1]	Labeled
Bravo WeatherStik............	chlorothalonil	M5	yes
Cueva	copper	M1	yes
Curzate	cymoxanil	27	yes
Forum...............................	dimethomorph	40	yes
Gavel	zoxamide/mancozeb	22/M3	yes
Koverall............................	mancozeb	M3	yes
Omega	fluazinam	29	no
Orondis Opti......................	oxathiapiprolin(A)/chlorothalonil(B)	U15/M5	yes
Orondis Ultra	oxathiapiprolin/mandipropamid	U15/40	yes
Presidio	fluopicolide	43	yes
Previcur Flex.....................	propamocarb	28	yes
Priaxor..............................	fluxapyroxad/pyraclostrobin	7/11	no
Ranman	cyazofamid	21	yes
Revus................................	mandipropamid	40	yes
Tanos................................	famoxadone/cymoxanil	11/27	yes
Topguard...........................	azoxystrobin/flutriafol	3/11	yes
Zampro	dimethomorph/amectoctradin	40/45	yes
Zing..................................	zoxamide/chlorothalonil	22/M5	yes
V-10208	ethaboxam	-	no

[1]Numbers and letters are used to define the fungicide groups by their cross resistance potential. Numbers are primarily based on when the product enters the market. P = host plant defense inducers, M = multi-site inhibitors, and U = unknown mode of action and unknown resistance risk. Visit www.frac.info for more information about FRAC codes.

For all trials, raised plant beds were established with drip tape and covered with black plastic. Single rows spaced 5.5 feet at center were seeded with 'Vlaspik' cucumber (except where noted). Each treatment replicate was a 20-foot bed for each of four replicates with a 2-foot buffer between beds within a planting row. Treatments were arranged in a randomized complete block design. Foliar sprays were applied with a CO_2 backpack boom sprayer equipped with two then three (as the season progressed and the canopy got larger) XR8003 flat-fan nozzles, operating at 40-50 psi, delivering 50 gal/A.

MSU Single Product Fungicide Trial (Preventive Applications):

The objective of this trial was to test the efficacy of single fungicide products to verify which fungicides are working and to identify those that may no longer be effective. Although fungicides must be used in alternation in a commercial program to delay development of downy mildew resistance, testing products alone is needed to identify which products are effective enough to be included in a program.

Seeds were planted on 19 July. Fungicide treatments were applied ***preventively*** prior to disease development at 7-day intervals on 10, 17, 24, 31 August; and 7, 14 September. Priaxor SC was applied on 10, 17, 24, 31 August. Cucumber leaves were evaluated for downy mildew severity using the Horsfall-Barratt scale on 6, 9, 14, 19, 22 September (*only data from 6 and 22 September are shown*). Yields were not taken due to an uneven plant stand.

On 6 September, the untreated plants had a disease rating of 6.0 (6=25 to 50% disease). Five treatments protected plants effectively (rating <3.0: 3=3 to 6% disease) and included the following: Ranman SC, Zampro SC, V-10208 SC, Omega SC, Orondis Opti SC, and Orondis Ultra SC. The Orondis treatments resulted in healthy plants with no downy mildew evident at this early rating.

By the end of the trial, the untreated plants were severely diseased (rating = 9.3; 9=87 to 94% disease). Three fungicide treatments were especially effective with ratings ≤3.5 (4=6 to 12% disease) and included Omega SC, Orondis Opti, and Orondis Ultra SC. In addition to the Orondis SC fungicides and Omega SC, other fungicides were proven to be helpful against downy mildew and included Ranman SC, Zampro SC, Gavel DF, V-10208 SC, and Bravo WeatherStik SC. Previcur Flex SL, Tanos DF, Revus SC, Priaxor SC, Cueva SC, Presidio SC, and Forum SC treatments resulted in high disease ratings (≥7.8). The last disease rating was one week after the final fungicide application with the exception of Priaxor SC that had been discontinued three weeks before the last rating.

Table 2. Foliar downy mildew severity of pickling cucumbers treated preventively with fungicides.

Treatment and rate/acre, applied at 7-day intervals	Disease severity* 9/6		Disease severity* 9/22	
Untreated control	6.0	a**	9.3	a
Bravo WeatherStik SC 2 pt	3.3	de	6.0	de
Koverall DG 2 lb	5.3	a-c	7.5	c
Cueva SC 2 qt	5.5	ab	8.0	bc
Presidio SC 0.25 pt	4.5	bc	8.0	bc
Previcur Flex SL 1.2 pt	5.0	a-c	8.8	ab
Ranman SC 0.17 pt	2.3	e	4.3	fg
Zampro SC 0.88 pt	2.8	e	5.5	de
Gavel DF 2 lb	4.3	cd	5.0	ef
Tanos DF 0.5 lb	4.8	bc	7.8	bc
Curzate DG 5 oz	4.8	bc	8.3	a-c
Omega SC 1 pt	2.3	e	3.5	gh
Revus SC 8 fl oz	6.0	a	8.8	ab
Forum SC 6 fl oz	5.3	a-c	8.8	ab
Orondis Opti SC 34.2 fl oz	1.0	f	2.0	i
Orondis Ultra SC 9.64 fl oz	1.0	f	2.8	hi
V-10208 SC 8 fl oz	2.5	e	6.3	d
Priaxor SC 8 fl oz	5.3	a-c	8.0	bc

*Rated on the Horsfall-Barratt scale of 1 to 12, where 1=0% plant area diseased, 2=>0 to 3%, 3=>3 to 6%, 4=>6 to 12%, 5=>12 to 25%, 6=>25 to 50%, 7=>50 to 75%, 8=>75 to 87%, 9=>87 to 94%, 10=>94 to 97%, 11=>97 to <100%, 12=100% plant area diseased.
**Column means with a letter in common are not statistically different (LSD t Test; *P*=0.05).

Although the fungicides including Tanos DF, Presidio SC and Previcur Flex SL have provided good downy mildew protection in the past, they did not protect the pickle crop from the disease in the 2016 campus trial. Results from 2016 are similar to results from the 2015 fungicide trial. However, Presidio SC is an effective fungicide for control of *Phytophthora* fruit rot, so its use in cucurbits is still recommended. Tanos DF can protect the crop from Alternaria leaf spot that can be a problem in hand-harvested pickle crops due to the extended time of harvesting.

MSU Single Product Fungicide Trial (Rescue Applications):

This trial was established using the same products included in the previous trial to determine which fungicides should be used when downy mildew develops in a field prior to any fungicide application. While ‘rescue applications’ are not optimal, there are instances when recommendations are needed for these situations. Seeds were planted on 25 July. Foliar fungicide sprays were applied to cucumber foliage ***after downy mildew symptom development***. Treatments were applied at 4-day intervals on 2, 7, 11, 15, 19, 23, 27 September. Cucumber leaves were evaluated for disease severity using the Horsfall-Barratt scale on 6, 19, 22, 26, 30 September and 4, 7, 11, 14 October (*data from selected dates are presented*). Yields were taken from the entire 20-foot row on 9, 16, 22 September (*sum of all harvests are shown*).

Disease was allowed to develop prior to the first fungicide application. On 6 September, all treatments including the untreated were uniformly diseased with a rating of 6.0-6.3 (6=25 to 50% disease). By 26 September, the untreated plants were rated at 9.8 (9=87 to 94% disease). Cueva SC, Previcur Flex SL, Presidio SC, and Forum SC were similar to the untreated plot. The Orondis treatments did not show any disease progression from the time that the sprays had begun and received a rating of 6.0 which was unchanged from the beginning of the spray program. While all other treatments were better than the untreated plots, most of the fungicides allowed significant disease development. On 7 October (10 days after last fungicide application), the Orondis treatments showed only limited disease progression with ratings of 6.3-6.5 and were the most effective fungicides. Plants treated with Ranman SC received a rating of 7.8 (7=50 to 75% disease). On 14 October (17 days after the last fungicide application), plots treated with either Orondis Opti SC or Orondis Ultra SC were similar to the V-10208 SC plot treatment and were the most effective treatments in limiting downy mildew disease. The untreated plot was almost entirely diseased (11.8; 12=100% disease) and treatments of Cueva SC, Presidio SC, Previcur Flex SC, Revus SC, and Forum SC were similar to the untreated. All other treatments included in this study were better than the untreated control but still allowed unacceptable levels of disease to develop.

The untreated plot along with those treated with Cueva SC, Koverall DG, Bravo WS SC, Presidio SC, Previcur Flex SL, Gavel DF, Tanos DF, Curzate DF, Omega SC, Revus SC, and Forum SC treatments had the lowest total yields. The highest yields (>30 lb/plot) were harvested from plots treated with Ranman SC, Zampro SC, Orondis Opti SC, or Orondis Ultra SC. Although this trial provides helpful information to growers facing established downy mildew, fungicides are best applied preventively for maximum control and to delay the development of fungicide resistance to the downy mildew isolates.

Table 3. Foliar downy mildew severity and yield of pickling cucumbers treated with fungicides after disease was established.

Treatment and rate/acre, applied at 4-day intervals	Disease severity*			Total yield (lb)
	9/26	10/7	10/14	
Untreated control	9.8 a**	10.8 a	11.8 a	17.7 f
Bravo WeatherStik SC 2 pt	7.8 e-h	8.8 d-g	9.0 c-e	23.2 b-f
Koverall DG 2 lb	8.5 c-e	8.8 d-g	9.3 cd	28.2 a-f
Cueva SC 1 qt	9.8 a	10.5 ab	11.5 a	19.0 ef
Presidio SC 0.25 pt	9.0 a-c	9.8 a-d	11.0 ab	25.1 b-f
Previcur Flex SL 1.2 pt	9.8 a	10.8 a	11.0 ab	22.2 c-f
Ranman SC 0.17 pt	7.3 gh	7.8 g	9.3 cd	38.4 a
Zampro SC 0.88 pt	7.5 f-h	8.8 d-g	9.5 cd	31.3 a-d
Gavel DF 2 lb	8.8 b-d	9.3 c-f	10.0 bc	22.9 b-f
Tanos DF 0.5 lb	8.3 c-f	8.5 e-g	10.0 bc	26.9 b-f
Curzate DG 5 oz	8.0 d-g	9.0 d-f	10.0 bc	25.5 b-f
Omega SC 1 pt	8.3 c-f	9.0 d-f	9.3 cd	21.9 c-f
Revus SC 8 fl oz	8.3 c-f	9.5 b-e	10.8 ab	24.4 b-f
Forum SC 6 fl oz	9.5 ab	10.3 a-c	11.3 a	20.4 def
Orondis Opti SC 34.2 fl oz	6.0 i	6.3 h	8.0 ef	33.8 ab
Orondis Ultra SC 9.64 fl oz	6.0 i	6.5 h	7.8 f	32.5 a-c
V-10208 SC 8 fl oz	7.0 h	8.3 fg	8.5 d-f	29.6 a-e

*Rated on the Horsfall-Barratt scale of 1 to 12, where 1=0% plant area diseased, 2=>0 to 3%, 3=>3 to 6%, 4=>6 to 12%, 5=>12 to 25%, 6=>25 to 50%, 7=>50 to 75%, 8=>75 to 87%, 9=>87 to 94%, 10=>94 to 97%, 11=>97 to <100%, 12=100% plant area diseased.
**Column means with a letter in common are not statistically different (LSD t Test; *P*=0.05).

MSU Fungicide Program Trial:

This trial tested programs of fungicides on their ability to control downy mildew in order to integrate different chemistry rotations into an effective disease management plan. Seeds were sown on 21 July. Foliar spray treatments were applied prior to disease symptoms on 5, 12, 18, and 25 August; 2, 9, 16, and 22 September. Foliar disease severity was evaluated using the Horsfall-Barratt scale on 11, 19, 26 and 30 September (*data from select rating dates are presented*). Fruit were harvested on 2, 7, 13 and 22 September and weighed (*sum of all harvests are shown*).

All fungicide programs were significantly better than the untreated on each rating date. Programs 6 and 7 were the least effective treatments on 11 September; the remaining programs received a rating ≤2.3 (2= 0 to 3% disease) and were not different from each other. The final rating on 30 September showed that programs 2, 3, 4, and 5 were most effective with a rating ≤3.8 (3=>3 to 6%). Programs 6 and 7 received a rating of ~6 (6=25 to 50% disease), and the untreated plot received a rating of 10.0 (10=94 to 97% disease). Yield was significantly impacted in the untreated plot. All treatments significantly increased yields when compared to the untreated, except for plots treated with programs 6 and 7.

Table 4. Foliar downy mildew severity and yield of pickling cucumbers untreated or treated preventively with fungicide programs.

Treatment and rate/A, applied at 7-day intervals, *application schedule*	Disease severity*		Total yield (lbs)
	9/11	9/30	
1 Untreated control	6.0 a**	10.0 a	49.0 c
2 Zing! SC 36 fl oz, *apps A-H*	2.3 c	3.5 cd	74.6 ab
3 Ranman SC 2.75 fl oz + Bravo WS (WeatherStik) SC 1.5 pt, *apps A,F* -*alt*- Orondis Opti A SC 4.8 fl oz + Orondis Opti B 2 pt, *apps B,G* -*alt*- Zing! SC 36 fl oz, *apps C,E,H,J* -*alt*- Zampro SC 14 fl oz + Bravo WS SC 1.5 pt, *apps D,I*	2.0 c	3.3 d	78.5 a
4 Ranman SC 2.75 fl oz + Bravo WS SC 24 fl oz, *apps A,D,G* -*alt*- Presidio SC 4.0 fl oz + Bravo WS SC 1.5 fl oz, *apps B,E,H* -*alt*- Zampro SC 14.0 fl oz + Bravo WS SC 1.5 fl oz, *apps C,F*	2.0 c	3.8 cd	79.6 a
5 Ranman SC 2.75 fl oz + Bravo WS SC 24 fl oz, *apps A,C,E,G* -*alt*- Zampro SC 14 fl oz, *apps B,D,F,H*	2.3 c	3.8 cd	83.2 a
6 Koverall WG 1.5 lb, *apps A,C,D,F,G* -*alt*- Topguard EQ SC 8.0 fl oz, *apps B,E,H*	3.8 b	6.0 b	63.0 bc
7 Koverall WG 1.5 lb, *apps A,C,D* -*alt*- Topguard EQ SC 8 fl oz, *app B* -*alt*- Topguard EQ SC 8 fl oz, *app E* -*alt*- Koverall WG 1.5 lb + Ranman SC 2.8 fl oz, *apps F,G* -*alt*- Ranman SC 2.8 fl oz + Topguard EQ 8 fl oz, *app H*	3.8 b	5.8 b	62.2 bc
8 Ranman SC 2.75 fl oz + Silwett SL 2 fl oz, *apps A,C,E,G* -*alt*- Zampro SC 14 fl oz, *apps B,D,F,H*	2.0 c	4.0 c	78.3 a
9 Ranman SC 2.75 fl oz + Silwett SL 2.0 fl oz, *apps A-H*	2.0 c	4.0 c	76.6 ab

*Rated on the Horsfall-Barratt scale of 1 to 12, where 1=0% plant area diseased, 2=>0 to 3%, 3=>3 to 6%, 4=>6 to 12%, 5=>12 to 25%, 6=>25 to 50%, 7=>50 to 75%, 8=>75 to 87%, 9=>87 to 94%, 10=>94 to 97%, 11=>97 to <100%, 12=100% plant area diseased.
**Column means with a letter in common are not statistically different (LSD t Test; *P*=0.05).

MSU Trial to Investigate Combining Fungicide Programs and Downy Mildew Resistant Cultivars:

This trial incorporated pickling cucumber cultivars and fungicide treatment programs to demonstrate the newest options for controlling downy mildew and increasing yields. Single plant rows were seeded on 22 July with four cucumber cultivars developed by Seminis Vegetable Seeds, Inc., 'Vlaspik,' 'Expedition,' 'Citadel' and 'Peacemaker.' 'Vlaspik' and 'Expedition' are industry standard cultivars that are susceptible to downy mildew. 'Citadel' and 'Peacemaker' became commercially available in 2016 and show an intermediate level of resistance to Michigan's downy mildew isolates. Each treatment plot consisted of two 20-foot beds for each of three replicates with a 2-foot buffer between beds within a planting row. Treatments were arranged in a split plot block design, with fungicide treatment program being the main plot and cultivar being the subplot. Fungicide treatments were applied at 7-day intervals on 10, 17, 24, 31 August and 7, 14 September. Disease was evaluated using the Horsfall-Barratt scale on 2, 6, 9, 14, 19 and 22 September. Yields were taken from both 20-foot rows on 2 and 9 September (*data shown only from 9 September*), and the harvest from 9 September was stored in a cooler and graded on 12 September.

The area under the disease progress curve (AUDPC) was calculated using the Horsfall-Barratt disease rating scale. This type of analysis takes into account each rating of several ratings to provide a total and season long assessment. The table below shows the cultivars evaluated across fungicide treatment. For 'Vlaspik,' 'Expedition' and 'Citadel,' the program of Bravo WeatherStik SC (BWS) alone was better than the untreated. When applied to 'Peacemaker,' the Bravo WeatherStik SC alone program was not significantly better than the untreated. Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) alternated with Zampro SC (+BWS) displayed better downy mildew control than the Bravo WS SC alone program in both the downy mildew susceptible cultivars, but not in the resistant cultivars. The Orondis Opti SC alternated with Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) program was better than all of the other programs for the susceptible cultivars and 'Citadel' and provided control similar to Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) alternated with Zampro SC (+BWS) program.

Table 5. Area under the disease progress curve (AUDPC) for foliar severity of downy mildew on four pickling cucumber cultivars untreated or sprayed preventively with fungicide programs.

Treatment and rate/acre, applied at 7-day intervals	AUDPC for foliar severity by cultivar			
	Vlaspik	Expedition	Citadel	Peacemaker
Untreated control	155.2 a*	154.7 a	133.8 a	115.0 a
Bravo WeatherStik (BWS) SC 2 pt	121.8 b	125.3 b	105.5 b	91.2 ab
Ranman SC 2.7 fl oz +BWS -*alt*- Previcur Flex SL 1.2 pt +BWS -*alt*- Zampro SC 14 fl oz +BWS	107.8 c	116.0 c	96.2 b	85.7 bc
Orondis Opti SC 2.14 pt -*alt*- Ranman SC +BWS -*alt*- Previcur Flex SL +BWS	90.5 d	89.0 d	76.2 c	68.5 c

*Column means with no letters or share a letter in common are not statistically different (LSD t Test; P=0.05).

Untreated 'Vlaspik' and 'Expedition' pickles had the lowest total yield when compared with their respective fungicide programs. While 'Vlaspik' pickles were similar in yield regardless of the fungicide program, 'Expedition' pickles responded differently according to the fungicide program. The highest total yield was observed for 'Expedition' pickles treated with Orondis Opti SC alternated with Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS). The fungicide program that included Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) alternated with Zampro SC (+BWS) resulted in an intermediate yield level. While treatment with Bravo WeatherStik SC alone resulted in yields better than the untreated, the yields were less than that observed from the other fungicide treatments. 'Citadel' showed the highest total yield when treated with Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) alternated with Zampro SC (+BWS). The treatment program that included Orondis Opti SC alternated with Ranman SC (+BWS) alternated with Previcur Flex SL (+BWS) resulted in an intermediate yield level for 'Citadel.' While the Bravo WeatherStik SC alone program resulted in 'Citadel' yields that were significantly better than the untreated this treatment was not as effective as the other programs when comparing yields. 'Peacemaker' yields did not differ significantly in total yield among the untreated and fungicide treatments.

Table 6. Total marketable yield of four pickling cucumber cultivars untreated or sprayed preventively with fungicide programs against downy mildew.

Program and rate/acre, applied at 7-day intervals	Total marketable yield by cultivar* (bu/acre)			
	Vlaspik	Expedition	Citadel	Peacemaker
Untreated Control	115.0 b**	114.9 d	217.1 c	297.0
Bravo WeatherStik (BWS) SC 2 pt	246.2 a	205.3 c	252.7 bc	284.5
Ranman SC 2.7 fl oz +BWS -*alt*- Previcur Flex SL 1.2 pt +BWS -*alt*- Zampro SC 14 fl oz +BWS	260.3 a	255.4 b	341.2 a	333.4
Orondis Opti SC 2.14 pt -*alt*- Ranman SC +BWS -*alt*- Previcur Flex SL +BWS	303.7 a	339.3 a	293.2 ab	309.9

*Marketable yield calculated as the difference of total yield from culls.
**Column means with no letters or share a letter in common are not statistically different (LSD t Test; *P*=0.05).

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Nutrition and Population Research with Parthenocarpic and Gynoecious Cucumbers

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Pickle processors have expressed a number of concerns with the exterior quality of pickling cucumbers grown in the Eastern US region. Of greatest concern is the lighter skin color that Eastern grown pickling cucumbers often have when compared to pickles grown in other areas of the country, even when using the same varieties. Another concern has been with inconsistency in length and length/diameter ratio in some varieties. In particular, excess length that leads to wastage at the plant (having to cut off ends) is an issue.

Interest has also been expressed by growers and industry on evaluating mineral nutrient fertility programs for pickling cucumber with an emphasis on nitrogen sources and secondary nutrients.

Field Research on the Effects of Fertililty Practices on Cucumber Yield, Color, and Length

Small plot research was conducted in 2011 and 2012 to study the effect of nitrogen (N), sulfur (S), and magnesium (Mg) on yield, fruit color, and fruit length. In 2013 the focus was on nitrogen rates and sources (nitrogen with or without sulfur). All three of these nutrients affect chlorophyll production and thus have the potential for affecting pickle color. Nitrogen application rates vary across growers and use of sulfur is common with nitrogen in sandy soils.

Nitrogen Rate and Source Trials

2011 Results for Nitrogen Rates

Chlorophyll meter (CM) readings measuring the greenness of peels from cucumber fruits were impacted by N rate in this study and differed by variety. In Expedition, there was no difference in color at the 80 and 120 lbs N/a rates. The 160 lbs N/a rate gave significantly greener fruit. In Vlaspik, there was a linear response with increase in greeness with increase in N rate. Again, the highest colored fruit were with the 160 lbs N/a rate.

N rate (lbs/a)	CM Expedition	CM Vlaspik
80	36 b	33 c
120	31 b	36 b
160	40 a	40 a

Visual ratings showed similar results with increased greeness ratings as N increased to 160 lbs N/a.

N rate (lbs/a)	Visual rating (1-5, 5 full green)
80	4.1 b
120	4.1 b
160	4.6 a

There was no difference in pickle fruit length or L:D ratios with varying N rates.

N rate (lbs/a)	L:D (length to diameter ratio)
80	2.97 a
120	2.91 a
160	3.00 a

In 2011 Color values obtained from pixel maps of pickle digital photos showed that the variety expedition had significantly more medium green areas on pickles with increasing nitrogen and significantly less light colored areas (light green, yellow, and white) with increasing nitrogen. The Vlaspik variety had significantly more dark green colored areas with an increase in nitrogen.

Color	**Variety/N Rate** (lbs/a)					
	Expedition			**Vlaspik**		
	80	**120**	**160**	**80**	**120**	**160**
	Mean number of pixels					
Dark	9934 a	10411 a	10373 a	8566 a	10708 b	11320 c
Medium	5623 a	5042 ab	4647 b	5231 b	6841 a	4852 b
Light	4514 a	4069 b	3689 c	3821 b	5708 a	4005 b

Overall, increasing nitrogen increased the intensity of green coloration on pickles.

2012 Results for Nitrogen Rates and Sources

Average chlorophyll meter readings for cucumber peels, measuring how green the fruits were, differed by nitrogen treatment and variety in 2012. In the first planting, there was an increase in chlorophyll content with an increase in nitrogen in the variety Expedition but not in Vlaspik. This was particularly evident in 3A grade pickles. Use of ammonium sulfate as a nitrogen source improved pickle color compared to Urea-Ammonium-Nitrate (UAN) solutions.

Trial 1.

VARIETY	GRADE	NITROGEN TREATMENTS (lbs/a N)					
		80	**120**	**160**	**200**	**80+40 AS**	**80+80 AS**
		Chlorophyll Meter Values					
EXPEDITION	**3A**	27.9 c	31.0 b	31.0 b	33.8 ab	38.1 a	34.3 ab
	3B	31.6	33.2	32.1	30.8	34.3	29.9
	Total	29.8 b	32.1 ab	31.6 ab	32.3 ab	36.2 a	32.1 ab
VLASPIK	**3A**	31.5	30.6	27.5	29.9	26.6	28.7
	3B	24.7	27.1	22.8	26.9	26.9	28.7
	Total	28.3	28.8	25.3	28.4	26.7	28.7
Total		29.1	30.5	28.5	30.4	31.4	30.4

There were significantly more dark color readings with an increase in nitrogen and a decrease in light colo measurements in Expedition. Use of ammonium sulfate as a nitrogen source increased dark colored areas and decreased light colored areas in this variety. In Vlaspik, there were no significant differences by nitrogen treatment.

Length to diameter ratios differed by treatment in Vlaspik with longer pickles found where a portion of the fertilizer N came from ammonium sulfate.

Trial 1.

Variety	Nitrogen Treatment					
	80	**120**	**160**	**200**	**80+40**	**80+80**
	L:D					
Expedition	2.94	2.96	3.12	2.93	3.16	2.97
Vlaspik	3.25 ab	2.99 b	2.89 b	3.01 b	3.60 a	3.00 b
Total	3.11	2.98	3.01	2.97	3.38	2.99

In the late trial, the addition of ammonium sulfate for a portion of the nitrogen (40 lbs of N equivalent) increased green color in fruits. There were no other differences between treatments.

Yields of cucumbers did not vary with treatment and there was no increase in yield over 80 lbs of N per acre.

Effect of fertilizer treatment on pickling cucumber yields. Trial 1, 2012.

Fertilizer Treatment (total N)	**Variety**	
	Expedition	Vlaspic
	Marketable Yield (bu/a)	
80	216.03	173.94
120	223.70	128.56
160	220.11	115.92
200	202.51	117.13
80+40 AS	170.52	146.41
80+80 AS	186.81	150.10
	NS	NS

Trial 2.

Variety	Nitrogen Treatment Trial 2 (lbs/a N)				
	80	120	80+40 AS	160	80+80 AS
	Chlorophyll Meter Reading				
Expedition	51.48 b	50.97 b	55.71 a	50.75 b	51.02 b
Vlaspik	56.07	52.70	53.73	54.40	53.50
Total	53.93	51.84	54.72	52.57	52.26

2013

There were no differences in plant density or color as measured by Normalized Digital Vegetative Index (NDVI) for any rate or treatment. There were no differences in yield for any of the sidedressing treaments from 0 to 80 lbs of N/a with no sidedressing yielding 301 bu/a. The highest yield was with 60 lbs of N/a applied as ammonium sulfate (385 bu/a). There was a significant decrease in yield with the high rate N applications (100 lbs N sidedressed as UAN of NSul) which yielded 214 and 230 bu/a respectively.

Length to diameter ratio was not affected by sidedress fertilizer treatment and there was no difference in grades statistically by sidedress fertilizer treatment. However, it is evident that fruiting was delayed with the high N rate treatments (100 NSUL or 100 UAN).

Pickle color was influenced by nitrogen rate but not by nitrogen source. The high rate controls (100 lbs N sidedressed) had darker green fruit than lower application treatments; however, fertilizer sources did not show any difference in fruit color.

Secondary Nutrients Sulfur and Magnesium and Pickle Quality

There were no differences in color between sulfur (S) or magnesium (Mg) treatments by visual ratings or chlorophyll meter readings. However, there was a trend for ammonium sulfate preplant treaments to be greener.

Treatment	CM reading	Visual rating
3	45.7	4.6
7	45.5	4.4
8	44.0	4.2
4	44.0	4.3
2	43.2	4.3
1	42.7	4.4
5	42.5	4.2
6	41.3	4.2
10	41.2	4.2
9	40.2	4.2

1) Control – no added S or Mg
2) S provided by gypsum 500 lbs/A preplant
3) S provided by ammonium sulfate 200 lbs/A preplant
4) Sidedressed S as ammonium sulfate 200 lbs/A
5) Foliar S, 2 lbs S per acre equivalent
6) Mg provided by 1000 lbs/A dolomitic limestone preplant
7) Mg and S provided by K-mag 500 lbs/A preplant
8) Mg provided by MgSO4 sidedress
9) Mg provided by MgSO4 foliar
10) Mg and S provided by K-mag foliar

There was a significant increase in pickle length with treatments applied. The ammonium sulfate treament preplant applied had the longest pickle fruit lengths. Shortest fruits were with the K Mag foliar treatment.

With three years of results, it has been shown that increasing nitrogen beyond 80 lbs. of nitrogen/acre does not improve yield and high N rates may decrease yield or delay maturity. Higher nitrogen can improve pickle color; however, this effect is variety dependent. There may be critical N rates for varieties to achieve highest color. However, this needs to be balanced with potential for delaying flowering and fruit set, producing too much foliage, and increasing the potential for disease incidence. Nitrogen sources did not vary in their effect on yield but they did vary in their effect on fruit color. The addition of ammonium sulfate as part of the nitrogen source was shown to increase the amount of dark colored areas in pickle fruits in some trials but not in others. By including a portion of the nitrogen source as ammonium sulfate, the same color improvement may be obtained without using higher total nitrogen rates but this effect is not consistent enough to be a general recommendation.

The use of sulfur sources with nitrogen or nitrogen fertilizers that contained sulfur did not improve yield when compared to straight nitrogen sources. There was an indication that ammonium sulfate produced more highly colored pickles in two studies but not in four others. Use of ammonium sulfate preplant did not have the same effect as when used as a sidedressing. Pickle length was influenced by nitrogen source in two trials where ammonium sulfate treatments had longer pickles. This effect may be from the sulfur content and the specific balance between sulfur and nitrogen in some soils and the sulfur:nitrogen balance may be important for pickle color and may be an issue on our light textured (sandy) soils. Trials showed that adding additional sulfur or magnesium as foliar applications had no effect on yield or quality of pickles.

In 2013, trials were expanded to include lower N rates and different at-plant and sidedress N applications. It is clear that modest amounts of nitrogen are needed to grow a pickle crop in Delaware loamy sand soils. Depending on the nitrogen release in the soil from previous crop residue, as little as 60 lbs of N may be needed to grow a high yielding crop when the majority is applied as a sidedressing at 3 weeks after planting. While adding a sulfur containing nitrogen fertilizer such as ammonium sulfate may be beneficial from a quality standpoint, there was no effect on yield in our trials.

Use of NDVI to predict N needs was not successful in pickling cucumbers and therefore variable rate N application to pickles is not recommended at this time. Because the crop is quick growing and has low relative N needs any variation in application that could be imposed would be minimal and of limited cost savings.

2016 Parthenocarpic Pickle Nitrogen Trials and Population Studies

Nitrogen Rate Trials

Six parthenocarpic cultivars were grown under different nitrogen fertilizer regimes in 2 trials at the University of Delaware Thurman G. Adams Agricultural Research Farm near Georgetown, Delaware. The first trial was planted on July 12, 2016 with 4 varieties and the second trial was planted on July 24 with 2 varieties. All plots were replicated 4 times in a Randomized Complete Block Design. Initial nitrogen fertilizer consisted of 40 lbs. of N/acre at UAN solution sprayed with herbicides right after planting. Each variety strip was divided into 5 fertilizer treatments with an additional 20, 40, 60, 80, or 120 lbs of N/acre sidedressed 3 weeks after emergence as ammonium sulfate and cultivated in. This gave final N rates of 60, 80, 100, 120 and 160 lbs/a N. .

Results

The yield of the variety Gershwin was optimized at 80 lbs of nitrogen per acre and this was also the case for NUN53028. The varieties NQ5543 and NUN53025 had optimal yields at 100 lbs of N per acre. The variety V5016 was less responsive to nitrogen with optimal yield at 60 lbs of N per acre. Rates of nitrogen above 100 lbs of N per acre did not prove to offer any advantage over lower rates and could reduce yields in some cases. This is consistant with our current recommendations for once over pickle harvest of 80-120 lbs of N per acre.

Population Trial

Four parthenocarpic cultivars were grown in a population study at University of Delaware Thurman G. The trial was planted with a Monosem planter at a population of 60,000 seeds per acre and then hand thinned 2 weeks after planting to one of four populations 23,000, 29,000, 34,000, or 40,000 plants per acre. Parthenocarpic hybrids were planted in randomized 4-row plots, 200' long and then subdivided in to subplots 20' in length. All row widths were 2.5 feet between rows. All plots were replicated 4 times in a Randomized Complete Block Design. Plots received 100 lbs of N per acre. Inner rows of all plots were harvested on August 15 and then weighed and graded.

Results

The variety NQ5007 yielded equally well at all populations testing suggesting that it would be advantageous to plant the variety at a lower population than is currently being used (23,000). Similarly, the variety NQ5543 showed equivalent yields from 23,000 to 40,000 plants per acre showing that the plants compensated by producing more fruit at lower populations. The variety Bowie was optimized at 29,000 plants per acre. Higher populations showed much more variability and lower yields. The variety Gershwin was optimized at 29,000 plants per acre with reduced yields above that level. However, the lower population of 23,000 plants per acre did not differ statistically from 29,000 plants per acre suggesting that Gershwin could be planted at a lower population with good yields