Tomato / Pepper / Eggplant

Tuesday morning 9:00 am

Where: Grand Gallery (main level) Room E & F
MI Recertification credits: 2 (1B, COMM CORE, PRIV CORE)
OH Recertification credits: 1.5 (presentations as marked)
CCA Credits: SW(0.5) PM(1.5)
Moderator: Ron Goldy, Senior Vegetable Educator, MSU Extension, Benton Harbor, MI

9:00 am Irrigation and Nitrogen Management of Vegetable Crops
- Lincoln Zotarelli, Horticultural Sciences Dept., Univ. Florida

9:30 am The Sprayer Tank's Empty, but Did You Hit It? (OH: CORE, 0.5 hr)
- Jason Deveau, Application Technology Specialist, OMAFRA, Ontario, Canada

10:00 am Screening Peppers for Bacterial Leaf Spot and Silvering (OH: 2B, 0.5 hr)
- Wes Kline, Cumberland County Extension, Millville, NJ

10:30 am Tips to Control Phytophthora Crown and Root Rot in Pepper (OH: 2B, 0.5 hr)
- Charles Krasnow, Plant, Soils and Microbial Sciences Dept., MSU
- Mary Hausbeck, Plant, Soils and Microbial Sciences Dept., MSU

11:00 am Session Ends

Irrigation and Nitrogen Management of Vegetable Crops

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Irrigation can be defined as the artificial application of water to the soil to supplement rainfall in crop growth and is considered one of the most aspects of agricultural management in dry or limited rainfall areas and during periods with no or little rainfall. An approach to conserving water is to maximize the irrigation efficiency and to minimize water loss. Irrigation efficiency is a measure of 1) the effectiveness of an irrigation system in delivering water to a crop, and/or 2) the effectiveness of irrigation in increasing crop yields. Good irrigation practices imply good irrigation efficiency and can be achieved by maintaining proper irrigation water application uniformity and improving water uptake efficiency of the irrigation water. Uniformity can be defined as the ratio of the volume of water available for use in crop production to the volume pumped or delivered for use. Crop uptake efficiency may be expressed as the ratio of crop yield or increase in yield over non-irrigated production to the volume of irrigation water used. Irrigation efficiencies thus provide a basis for the comparison of irrigation systems from the standpoint of water beneficially used and from the standpoint of yield per unit of water used (Howell, 2001). Irrigation system efficiency depends primarily on three components: 1) design, 2) installation and maintenance, and 3) management. A properly designed and maintained system can be inefficient if mismanaged. The general recommendations for irrigation management of horticultural crops include the following: using a combination of target irrigation volume; a measure of soil moisture to adjust this volume based on crop age and weather conditions; knowledge of how much the root zone can hold; and an assessment of how rainfall contributes to replenishing soil moisture.

Irrigation can be grouped into the following general categories: low volume (also known as microirrigation, trickle irrigation, or drip irrigation), sprinkler, surface (also known as gravity or flood irrigation), and seepage (a variation on subsurface irrigation or water table control in other parts of the U.S.). Microirrigation and sprinkler irrigation accounts for 6% and 50%, respectively, on a national basis (USDA, 2004a).

Sprinkler systems are designed to use overlapping patterns to provide uniform coverage over an irrigated area. These types of systems have been frequently used under row vegetable crops such as sweet corn, potato, snap beans and vegetable crops not cultivated with plastic mulch. Sprinklers are normally spaced 50-60% of their diameter of coverage to provide uniform application in low wind conditions. Studies have shown that 1.5 to 7.6% of irrigated water can be lost due to wind drift and evaporation during application (Frost and Schwalen, 1960; Kohl *et al.*, 1987). Application efficiencies of sprinkler systems are typically less than 80%. Because networks of pressurized pipelines are used to distribute water in these systems, the uniformity of water application and the irrigation efficiency is more strongly dependent on the hydraulic properties of the pipe network. Thus, application efficiencies of well-designed and well managed pressurized sprinkler systems are much less variable than application efficiencies of seepage or surface irrigation systems, which depend heavily on soil hydraulic characteristics. Therefore, during water applications, sprinkler irrigation systems lose water due to evaporation and wind drift (Haman *et al.*, 2005). More water is lost during windy conditions than calm conditions. More is also lost during high evaporative demand periods (hot, dry days) than during low demand periods (cool, cloudy, humid days). Thus, sprinkler irrigation systems usually apply water more efficiently at night (and early mornings and late evenings) than during the day. It is not possible to apply water with perfect uniformity because of friction losses, elevation changes, manufacturing variation in components, and other factors. Traveling guns typically have greater application efficiencies than portable guns because of the greater uniformity that occurs in the direction of travel (Smajstrla *et al*., 2002). Periodic move lateral systems are designed to apply water uniformly along the laterals. No uniformity and low applications efficiencies occur when the laterals are not properly positioned between settings. Non-uniformity also occurs at the ends of the laterals where sprinkler overlap is not adequate (Smajstrla *et al*., 2002).

Application efficiencies of microirrigation systems are typically high because these systems distribute water near or directly into the crop root zone, water losses due to wind drift and evaporation are typically small (Boman, 2002; Locascio, 2005). This highly efficient water system (90% to 95%) is widely used on high value vegetables and tree fruit crops. The advantages of microirrigation over sprinkler include: reduced water use, ability to apply fertilizer with the irrigation, precise water distribution, reduced foliar diseases, and the ability to electronically schedule irrigation on large areas with smaller pumps relative to sprinkler systems. If microsprinkler systems are operated under windy conditions on hot, dry days, wind drift and evaporation losses can be high. Thus management to avoid these losses is important to achieving high application efficiencies with these systems. Therefore, management to avoid these losses is important to achieve high application efficiency. Less efficiency has been found for microsprinkler system compared to drip irrigation. Application efficiencies of drip and line source systems are primarily dependent on hydraulics of design of these systems and on their maintenance and management (Boman, 2002). It is thought that drip irrigation gives the higher application efficiency for vegetables (80-90%) compared with seepage (20-50%) and overhead irrigation systems (60-80%) (Simonne, *et al*., 2007).

In seepage or flood systems water is distributed by flow through the soil profile or over the soil surface. The uniformity and efficiency of the irrigation water applied by this method depends strongly on the soil topography and hydraulic properties (Boman, 2002). In some vegetable cultivated areas, drainage is required on high water table soils, and field slope is necessary for surface drainage. But surface runoff also occurs because of field slope. Runoff reduces irrigation application efficiencies unless this water is collected in detention ponds and used for irritation at a later time (Smajstrala *et al*., 2002). Water distribution from seepage irrigation systems occurs below the soil surface. Therefore, wind and other climatic factors do not affect the uniformity of water application. Use of a well-designed and well maintained irrigation system reduce the loss of water and thereby increase application efficiency as well as uniformity (Boman, 2002). Unfortunately, this type of irrigation has very low efficiency due to the large amount of water required to constantly maintain a shallow water table throughout the crop season, which may cause nutrient leaching (Pandey *et al*., 2007). However, growers like this type of irrigation system due to its relative ease of operation (e.g. constant pumping during the season) and because the infrastructure costs are much lower than with systems such as drip irrigation. Thus, as water supplies become strained, one option to increase irrigation efficiency is conversion from seepage to drip irrigation.

Strategies to improve water and nutrient use efficiency

Irrigation Scheduling

Irrigation scheduling consists simply of applying water to crops at the “right” time and in the “right” amount. Scheduling often consists of grower judgment or a calendar based schedule of irrigation events based on previous seasons. Several factors such as plant evaporative demand, soil characteristics and root distribution are taken into account as well, in order to establish proper irrigation scheduling (Locascio, 2005). The simplest form of scheduling is the “feel” method as outlined by the USDA-NRCS (1998). A wide range of irrigation scheduling methods is used in Florida with corresponding levels of water managements. The recommended method for schedule irrigation (drip or overhead) for vegetable crops is to use together, (1) the crop water requirement method that takes into account plant stage of growth; (2) a measurement of soil water status; and (3) guidelines for splitting irrigation (Simonne *et al*., 2007).

Soils hold different amounts of water depending on their pore size distribution and their structure. The upper limit of water holding capacity is often called “field capacity” (FC) while the lower limit is called the “permanent wilting point” (PWP). The total amount of water available for plant uptake is the “available water” (AW) which is the difference between FC and PWP (Fig. 1) and is often expressed a percent by volume (volume of water/volume of sample). The “plant available water” (PAW) is determined by multiplying the AW (in units of water depth) by the root zone depth where water extraction occurs. Depletion of the water content to PWP adversely impact plant health and yield. Thus for irrigation purposes, a “maximum allowable depletion” (MAD) or fraction of PAW representing the plant “readily available water” (RAW) is essentially the operating range of soil water content for irrigation management. Theoretically irrigation scheduling consists of irrigating at a low threshold corresponding to a water content at a given MAD and irrigating until the depleted water has been replaced to but not more than the FC level, otherwise drainage and or deep percolation will occur.

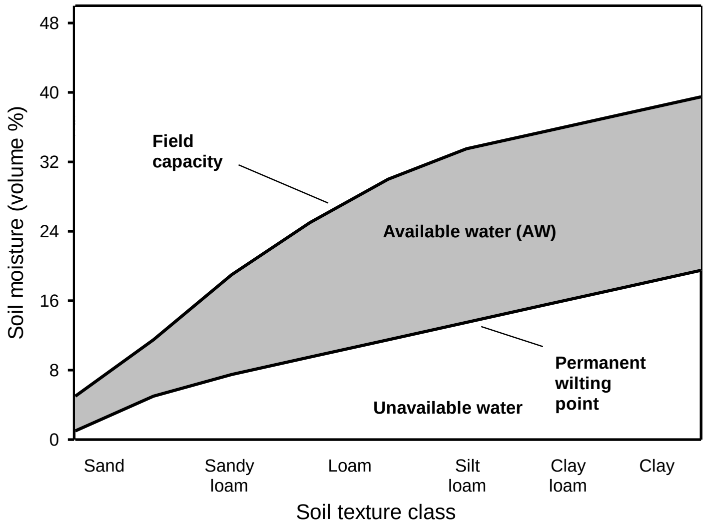

Figure 1. General relationship between readily available water, soil field capacity, permanent wilting point, soil unavailable water and soil texture class.

Vegetable production using sensor based irrigation control

Capacitance (e.g. time domain reflectometry (TDR) and frequency domain reflectometry) based soil moisture measurement devices have been shown to have relatively accurate soil moisture measurement in sandy soils common to Florida (Irmak & Irmak, 2005). Dukes & Scholberg (2005) installed an automatic irrigation control system based on research grade TDR soil moisture probes and microcontrollers for irrigation of sweet corn. Irrigation was initiated based on preset low soil moisture thresholds and terminated based on an upper threshold. This control system was coupled with a subsurface drip irrigation system with drip tube buried under each row at 23 and 33 cm in two different treatments. The 23 cm deep treatment under automatic control reduced irrigation 11% relative to sprinkler irrigation typically used by growers. Dukes *et al.* (2003) used a simple soil moisture based control system to automatically maintain a relatively constant soil moisture content in the root zone of green bell pepper through high frequency irrigation based on soil moisture measurements by the control system. Compared to manual irrigation treatments with one or two irrigation events per day with similar yield, irrigation amount was reduced by approximately 50%. Capacitance based soil moisture sensors do not require maintenance once installed in contrast to tensiometers that require weekly (Muñoz-Carpena *et al.* 2005a) or bi-weekly maintenance (Smajstrla & Locascio 1996) to maintain accuracy. Soil moisture sensor irrigation control has been used on drip irrigated zucchini squash to increase yield by 35%, irrigation water use efficiency by 274%, and nitrogen use efficiency by 40% relative to single daily timed irrigation representative of grower practices (Zotarelli *et al.* 2008a). In general, this study found that a simple and inexpensive irrigation controller coupled with commercially available soil moisture probes (Muñoz-Carpena *et al.* 2008) was effective at reducing both irrigation water application and nitrogen leaching under several drip irrigation configurations. Zotarelli *et al.* (2009) reported irrigation savings of 40% to 65% less than typical grower based time irrigation scheduling while increasing tomato yield 11% to 45%. Similar results reducing irrigation application and drainage while maintaining green bell pepper yields on sandy soils have been reported for Florida conditions (Dukes *et al.* 2006; Zotarelli *et al.,* 2011). A number of researchers have shown that excessive irrigation on vegetables may cause yield decreases relative to optimum irrigation amounts as determined by soil moisture sensor control on green bell pepper (Dukes *et al.* 2003), as determined by pan evaporation for a yield decrease in high irrigation rates on fresh market tomato in one of two seasons (Locascio *et al.* 1989), and as shown on fresh market tomato in south Florida (Muñoz-Carpena *et al.* 2005b).

Nitrogen leaching: fertigation vs. irrigation

Fertigation is the application of nutrients through the irrigation system. Fertigation is a widespread practice for microirrigated vegetable and fruit crops in Florida, providing growers with the opportunity to apply nutrients more frequently in quantities that closely match short-term crop nutrient requirements.

This results in higher fertilizer use efficiency by the crop as well as a reduction of nutrient leaching below the plant root zone. However, in soils with poor water retention, such as sandy soils, application of excess water may promote displacement of nutrients before complete uptake has occurred (Dukes & Scholberg, 2005; Zotarelli *et al*., 2008b; Zotarelli *et al*. 2009). Appropriate irrigation scheduling and matching irrigation amounts with the water holding capacity of the effective root zone thus may provide ways to minimize the incidence of excess N leaching associated with over-irrigation.

Since uniformity of water application also drives the uniformity of the fertilizer application, high water application uniformity is essential for proper fertigation. The drip system needs to be completely pressurized before the fertigation begins, in order to avoid uneven application rates. In addition, the fertilizer used must be completely soluble in water, and pass through the filters to ensure that any undissolved fertilizer particles are filtered out of the drip system. Injecting N fertigation towards the end of the irrigation cycle may also prevent immediate N displacement below the soil region with highest root concentration.

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The Sprayer Tank's Empty, But Did You Hit It?

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Sprayer operators recognize the importance of matching their sprayer settings to the crop to optimize efficacy. For example, spraying a protective fungicide in field tomato should require a different approach from spraying a locally systemic insecticide in staked peppers. Knowing this, many operators make *ad hoc* changes and then wait to "see if it worked". A process is required that empowers the operator to make systematic changes to their program and assess coverage immediately.

Such a process would require some fundamental understanding of how droplets behave, the location of the target, and the physical structure of the crop. This would be tempered by broader concerns such as weather (e.g. wind, rain and inversions as they affect coverage and spray drift), pest staging, and sprayer capacity (i.e. the sprayer's ability to cover the crop in the window of time available). Finally, there has to be a mechanism for the operator to make a single change, then assess the impact in a quick, convenient, and yet quantitative manner.

There are always exceptions to a rule, but an operator looking to assess spray coverage might consider the following process:

1) Understand how the pesticide works. Not only do certain tank mixes and weather conditions affect pesticide efficacy, but the mode of action plays a big role. A contact product must hit the target, while a locally systemic offers more latitude and can withstand less coverage.
2) Use IPM to determine where the pest is, whether it's at a stage of development where it is susceptible to the spray, and where the spray needs to be to affect it. For example, if the pest is deep in the canopy, or under a leaf, or in the flower, this is where spray coverage should be targeted and assessed.
3) Understand droplet behaviour.
    a. Coarser droplets move in straight lines and are prone to runoff (especially on waxy and vertical targets). They rarely provide acceptable canopy penetration in dense, broadleaf canopies and do not give under-leaf or panoramic stem coverage. The Coarser the droplet, the fewer the sprayer produces, reducing droplet density. However, they are not prone to drift and can tolerate higher winds.
    b. Finer droplets slow quickly and tend to move in random directions without some form of entrainment (e.g. air-assist). While they are not prone to runoff, they can get caught up on trichomes (leaf hairs) and may not reach the leaf surface. They provide improved canopy penetration and some under-leaf and panoramic stem coverage, but their lack of momentum leads some operators to use higher pressures to "fog them in". Higher pressures are generally not advisable because they increase the potential for drift and often result in less spray available to the crop.
    c. Consider the droplets' point of view. Look along the droplets potential path from nozzle to target. If there's something in the way, consider re-orienting the nozzle using drop-arms, or a nozzle body that can be adjusted to change the spray direction.
4) Understand the impact of water volume and travel speed. Higher volumes improve spray coverage by increasing the number of droplets. Slower speeds give more opportunity for spray to penetrate the canopy and reduce the potential for drift, leaving more spray available to cover the crop.

5) Use water-and-oil sensitive paper to assess spray coverage. The operator should pin or clip papers in the crop, in locations and orientations representing the desired target. Wire flags and flagging tape mark their locations:
    a. Spray using water to establish baseline coverage.
    b. Retrieve the papers and replace them with a new set in the same locations and orientation.
    c. Make one change to the sprayer set-up and determine whether or not coverage was improved.
    d. Continue to tweak the sprayer until coverage is improved. Sometimes, improving spray efficiency means maintaining coverage while using less spray.
6) Understand how much is enough. Knowing whether to drench the target, or be satisfied with a low droplet density depends on how the pesticide works and whether or not the pest is mobile. As a general rule for foliar insecticides and fungicides, 85 drops per square centimeter and 10-15% surface coverage should be sufficient.

Here are two case studies where we used this process:
http://sprayers101.com/drop-arms-improve-spray-coverage-on-field-peppers/
http://sprayers101.com/spray-coverage-in-field-tomato/

Now, a few caveats: Know that under-leaf coverage is VERY difficult to achieve and that improved coverage does not necessarily mean improved efficacy. Further, know that a systematic approach requires time and effort, and should only be performed in weather conditions the operator would spray in.

It may take time out of an already busy schedule, but performing this assessment is always worth it. When the spray tank is empty, you’ll know that you hit it.

Screening Peppers for Bacterial Leaf Spot and Silvering

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Bacterial Leaf Spot

Bacterial leaf spot (BLS) caused by the pathogens *Xanthomonas euvesicatoria* and *Xanthomonas campestris pv. Vesicatoria* is the second most important disease on peppers in New Jersey. Phytophthora blight caused by *Phytophthora capsici* is the number one disease. Phytophthora continues to be a concern among growers, but with proper management and tolerance varieties growers are learning to live with the disease.

BLS on the other hand has become more of a concern over the last ten years. The pathogen is favored by high humidity, hard driving rains, vigorous plant growth, infected stakes and working in the field when plants are wet. There are ten races of BLS identified in the United States. Most commercial bell pepper varieties are resistant to races 1-3 which have been the main races found in the Northern United States. Until recently growers in New Jersey have managed BLS with a combination of resistant varieties and chemical control. In 2004, growers reported that resistant varieties were being infected with BLS. A series of screening trials were carried out to determine if other races may be present in New Jersey. It was determined that race four was found in Southern New Jersey, but not in the Northern part of the state. Since 2004 varieties e.g. 'Turnpike', 'PS0994-1819' and 'Tomcat' have been released with resistance to race 4. There are no recommended cherry, sweet frying, hot or banana type peppers resistant to race 4. Growers continued to use a combination of resistant varieties and chemical control.

Some grower's heat treat their seed especially if the seed was saved from the field for heirloom varieties. In the Mid-Atlantic region the recommendations are for growers prior to transplanting, to apply streptomycin (Agri-Mycin 17, Agri-Strep) sprays (1.0 lbs per 100 gallons, 1¼ teaspoons per gallon) when first true leaves appear and continue every 4 to 5 days until transplanting. Streptomycin cannot be used on transplants after they are transplanted in field. After transplanting, fixed copper is applied at labeled rates as a preventative fungicide applications shortly after transplanting and repeat every 7 to 10 days, especially if symptoms of bacterial leaf spot are present during transplant production and/or on transplants. A Section 2ee for the use of Quintec (6.0 fl oz 2.08F/A) for the suppression of bacterial leaf spot in peppers has been granted for all states in The Mid-Atlantic region. Actigard can be used to reduce bacterial spot severity in hot peppers. Applications begin within one week of transplanting using 0.33 oz/acre in 30-50 gallons of water. It is recommended to increase the rate to 0.5 oz/acre in 60-70 gallons of water 3 to 4 weeks after transplanting. Applications of 0.75 oz/acre can be made from 5-8 weeks after transplanting in 70-100 gallons of water per acre. There is a concern with Actigard on drought-stressed plants.

In 2013, growers again noticed BLS showing up on varieties which were resistant to races 0-5. Differential studies were established to determine if additional races were present in New Jersey. Plots were setup in the Southern and Northern parts of the state with a series of varieties with resistance to different races from no resistance to resistances to all known races. The only varieties that did not express any symptoms were those resistant to all races. Races 6 and 10 could not be distinguished from one another since they are closely related and if there is resistance to race 6 there is resistance to race 10. This screening trial has been repeated twice with similar results.

We have started to screen breeding lines and varieties that have resistance to all 10 races of BLS for yield and fruit quality. Below is preliminary data from the 2016 trial where there was no BLS present thus we were looking at yield. The lines ‘9325’ and ‘0972’ had resistance to all know races; ‘Paladin’ no resistance; ‘Tomcat” resistant to 1-5 and 7-9; .’Turnpike’ resistant to 0-5 and 7-9; ‘Aristotle’ resistant to 1-3; ‘Revolution’ resistant to 1-3 and 5; ‘3964’ resistant to 1-4 and 7-9; and ‘1819’ resistant to 1-5 and 7-9. There will be trials over the next three years to identify varieties which are resistant to all known races of BLS and have acceptable yields and fruit types.

Percent Size and Marketable Yield (28 lb boxes) per Acre - 2016

Variety	% X large	% Large	% Medium	% commercial	% marketable	Marketable Boxes/A
9325	**10.9**	**42.6**	**16.5**	**2.2**	**72.2**	**1305**
Paladin	16.9	53.6	13.5	1.3	85.3	2041
Tomcat	16.6	47.0	15.0	0.4	79.0	1501
Turnpike	21.3	53.7	5.3	0.7	81.2	1978
Aristotle	10.3	57.8	10.2	0.7	79.1	1632
0972	**13.6**	**36.3**	**10.2**	**1.9**	**62.0**	**1245**
Revolution	21.9	42.4	11.3	2.2	77.9	1908
3964	21.3	44.0	9.0	0.9	75.2	1617
1819	11.4	51.5	9.3	1.3	73.5	1536

Cultural practices are also a concern when dealing with BLS e.g. disinfecting stakes, not working in the field when plants are wet, cleaning up fields when done harvesting, starting with clean seed, etc. Stake disinfection is a major concern for our growers and how to properly carry out the process. We are evaluating different methods and disinfectants to use that will help growers manage BLS in the future.

Fruit Silvering or Skin Separation

Silvering or skin separation is a genetic/physiological disorder. The interior and outer cuticle cells on the fruit separate from one another giving it a three dimensional (cracking in ice) appearance. Silvering can appear on any fruit, but it is more prevalent on varieties with resistance or tolerance to Phytophthora Blight. Why this is occurring is a concern among growers. There has been loads rejected if too much slivering is present. We have looked at when the symptoms appear, the effect of environment, production system and variety on the amount of silvering present.

In greenhouse studies symptoms appeared when fruit reached about a quarter to half-dollar in diameter. Symptoms can range from very little (barely detectable) to extremely severe. Not all plants in a given planting developed silvering. With some varieties like ‘Paladin’, there is more separation at the crown set stage. While with other varieties such as ‘Aristotle’ the symptoms appear over a longer period.

Four cropping systems were evaluated in growers' fields and at a research station using the same methods and varieties. The cropping systems were with and without black plastic; double and single row planting; and different rates of fertilizer. The same five varieties (both resistant and non-resistant varieties to Phytophthora) were used at each location. The results to a three year study suggest that there was more silvering in bell peppers grown on black plastic mulch in double or single rows than the same varieties grown in bare soil.

Does fertility affect silvering? Since growers continue to try for higher and higher yields fertility may relate to how much silvering is present. A two year study was carried out to determine the effects of nitrogen fertility on the development of silvering in fruit on a resistant and susceptible variety. Six nitrogen fertility programs (two granular and four liquid programs at 135, 180 and 300 lbs/A nitrogen) and two varieties ('Aristotle' and 'Camelot') were evaluated. The nitrogen fertility programs had no effect on the amount of silvering in bell pepper fruit. However, 'Camelot', Phytophthora susceptible variety had significantly less silvering than the resistant variety 'Aristotle'.

Why silvering is showing up more in recent years (last 10-15) is probably related to changing cultural practices, possible changing climate, but the main factor seems to be tolerance to Phytophthora. In the 2016 Phytophthora tolerance study the only variety which did not have silvering was 'Camelot' which has no resistance to Phytophthora.

Tips to Control Phytophthora Crown and Root Rot in Pepper

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Phytophthora blight is a destructive disease of pepper that causes significant annual losses in Michigan. The primary symptom observed on *Phytophthora*-infected plants is wilt and plant death. Infected plants may have brown and rotted roots and necrosis at the crown and lower stem can occur at advanced stages of disease. The pathogen produces an overwintering spore (oospore) that survives long term in soil and allows *Phytophthora* to persist in fields. When environmental conditions are favorable for plant growth, the oospore can germinate and infect crops. Sporangia and zoospores form on infected plants and are responsible for pathogen spread, especially during warm and rainy conditions. Raised plant beds with or without black plastic have improved pepper yields and helped to limit Phytophthora root rot and black plastic reduces soil splash onto plants. Tractors and farm implements should be power-washed after use in infested fields, as *Phytophthora* can move from infested fields to clean fields via soil particles.

***Phytophthora* cultural management strategies**

- Plant into well-drained, tiled fields
- Use raised beds with plastic mulch and drip irrigation
- Avoid using surface water for irrigation
- Irrigate sparingly from a well
- Rotate with non-susceptible crops
- Scout fields regularly for Phytophthora
- Remove any diseased plants and adjacent healthy plants
- Powerwash equipment after it has been in infested fields
- Do not dump diseased culls in production fields

Plant Resistance. Growing pepper cultivars with resistance to Phytophthora root rot is considered an optimal management strategy to increase yields and reduce fungicide usage. A recent MSU study evaluated eight cultivars and breeding lines from Seminis Seeds Inc. for resistance to root rot. ‘Turnpike’ pepper was released as a result of the trial and was notable for its resistance and large fruit size compared to the other resistant cultivars. ‘Archimedes’ and ‘Paladin’ also performed well in the trial (Table 1). Growing *Phytophthora*-resistant peppers can reduce the number of fungicide applications necessary per season, but depending on the level of *Phytophthora* in the field, the resistance may not be effective enough to protect the plant for the entire season.

Table 1. Incidence of Phytophthora root rot in 2015 pepper trial at SWMREC.

Cultivar	Seed Source	Phytophthora resistance level	Disease incidence (%)
Camelot X3R	Seminis	Low	91.6
Aristotle	Seminis	Moderate	29.4
AP4835	Seminis	Moderate	21.1
AP4841	Seminis	Moderate-high	12.8
Turnpike	Seminis	Moderate-high	11.1
AP4839	Seminis	Moderate-high	8.5
Archimedes	Seminis	High	4.3
Paladin	Syngenta	High	1.4

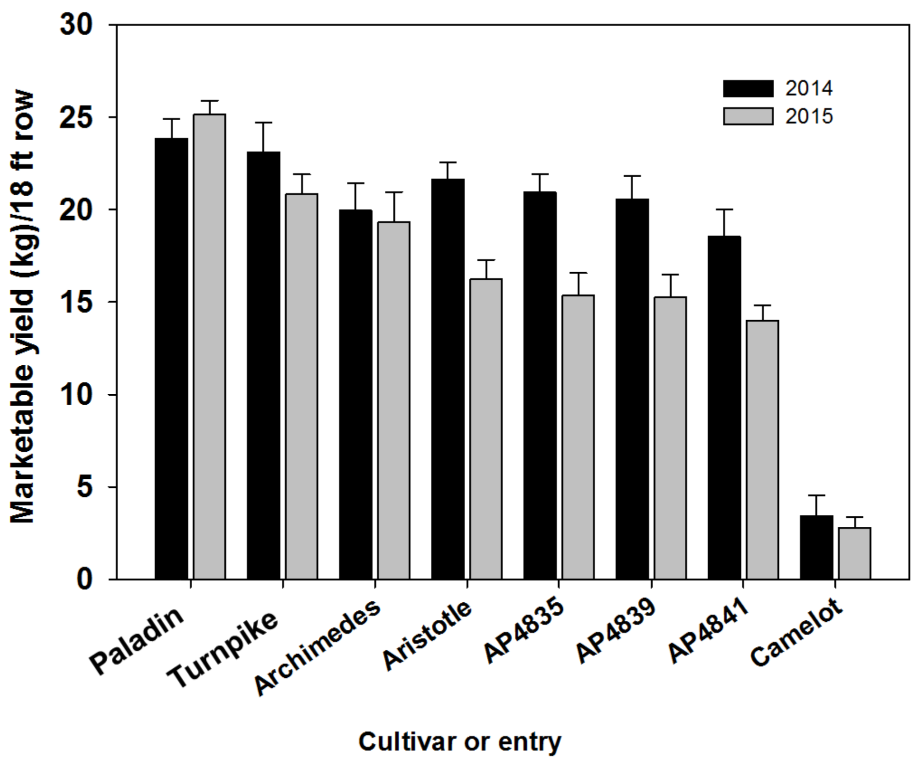

Figure 1. Marketable peppers harvested (kg/18 ft row) in Phytophthora pepper trial, 2014/15.

Table 2. Fungicides labeled for soil application or transplant water (foliar rates not listed) to control pepper *Phytophthora* blight.

Trade name	Common name	FRAC	Rate/acre	Application method	Comments
Orondis Gold	Oxathiapiprolin Mefenoxam*	U15 4	2.4-19 fl oz 1 pt	Soil-drench, Drip, Banded	30 day drip-interval (max. 3 applications)
Presidio	Fluopicolide	43	3-4 fl oz	Soil-drench Drip	Tank mix required, 10 day application interval
Zampro	Ametoctradin Dimethomorph	45 40	14 fl oz	Soil-drench Drip	Max. 2 consecutive applications
Ranman	Cyazofamid	21	2.75 fl oz	Soil-drench, Transplant water	7-10 day application interval
Ridomil Gold	Mefenoxam*	4	1 pt	Soil-drench Drip	30 day interval (max. 3 applications)
Bio-Tam	*Trichoderma* spp.	-	2.5-5 lb	Soil-drench, Drip, Banded	Apply up to 1 week prior to plant, 14 day interval
Phostrol	Phosphorous acid salts	33	2-4 pt	Drip	2-3 week application interval
Serenade Soil	*Bacillus subtilus*	-	2-6 qt	Soil-drench Drip	Apply at any growth stage

*Mefenoxam (Ridomil Gold) resistant *Phytophthora* may be present in infested fields.

Fungicides. Fungicide applications through the drip lines and as soil-directed sprays and drenches can effectively reduce Phytophthora root rot while foliar sprays provide limited control. **Orondis (**oxathiapiprolin) is a new fungicide from Syngenta that was first available in 2016 (Table 2). Orondis is systemic in the plant, moving from the roots to the foliage and from older to younger leaves. Orondis has preventive, residual, and curative activity, and is rainfast in about 30 minutes. Orondis effectively controlled root and crown rot when applied as a soil drench or via drip irrigation at transplanting in MSU research trials. This product is not readily mobile in soil, and drip lines must be positioned close to the plants for maximum uptake. Although the fungicide mefenoxam (Ridomil Gold) may not be effective in all regions of the state due to pathogen resistance, other systemic fungicides including Orondis Gold, Presidio SC, and Zampro SC are effective. Revus SC can be applied as a foliar spray directed to the base of the plant; however, MSU research demonstrates that even frequent foliar applications to a susceptible cultivar may not fully protect against root and crown rot. The FRAC code separates fungicides by their mode of action and the risk for resistance development. Fungicides with different FRAC codes should be alternated to delay the onset of pathogen resistance. Orondis Gold is expected to be available as a pre-mix containing Orondis and Ridomil in 2017.

2015 Pepper Phytophthora fungicide trial. A study was conducted in Benton Harbor, MI on a sandy soil to evaluate fungicide programs to control Phytophthora root rot. Six-week-old 'King Arthur' pepper plants were transplanted in single rows into raised plant beds covered with black LDPE plastic. The plants were inoculated with *P. capsici*-infested millet to increase disease pressure in the plot. The fungicide programs included: Orondis Gold applied as a transplant drench at a high rate (6.8 fl oz) or low rate (4.8 fl oz) followed by foliar sprays of Revus SC (8 fl oz) *alt* Kocide 3000 (1 lb) or as a stand-alone treatment. Ranman (2.75 fl oz) *alt* Kocide 3000 *foliar* was used as the industry standard. Drenches were applied using a backpack sprayer with a handwand and a single XR8010 nozzle operated at 13 psi, delivering 80 ml/plant. Foliar sprays were applied using a CO_2 backpack sprayer with a three nozzle spray boom operated at 50 psi, 50 GPA. The Orondis Gold treatments yielded significantly higher than the Ranman (2.75 fl oz) treatment and the untreated control (Figure 2).

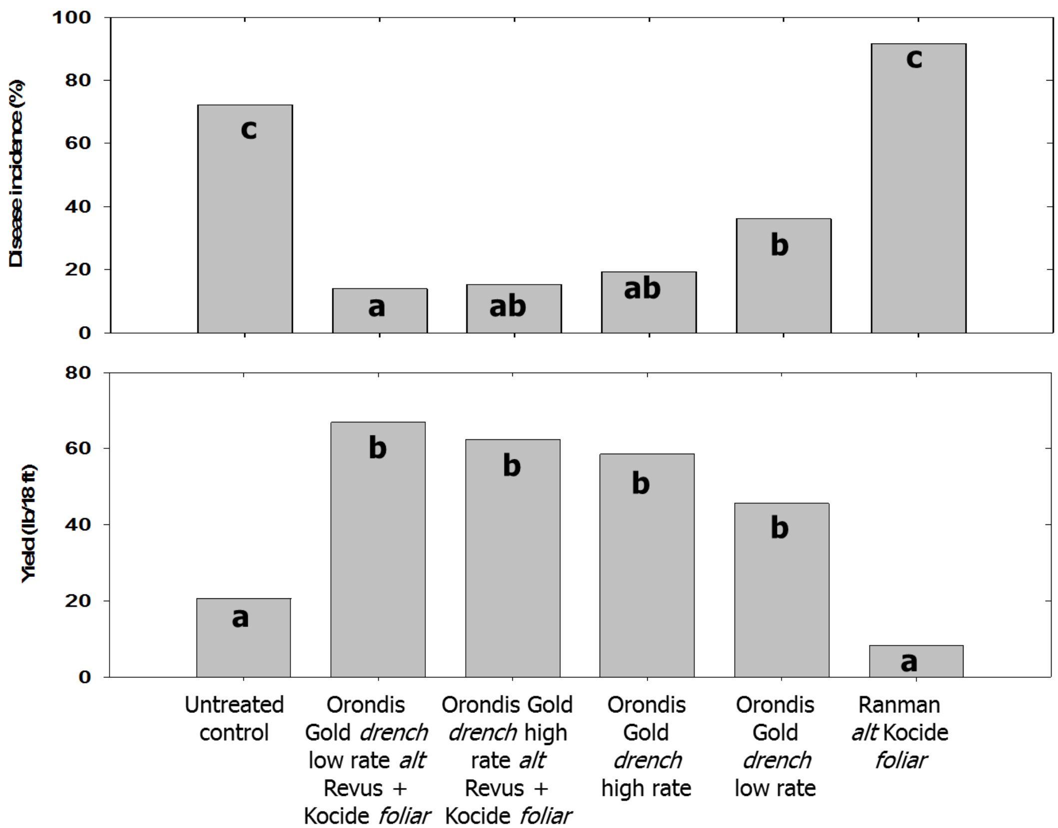

Figure 2. Effect of fungicide programs on ‘King Arthur’ pepper root rot and yield (lb/18 ft).

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