Great Lakes Fruit, Vegetable & Farm Market EXPO
December 4-6, 2007
DeVo Place Convention Center, Grand Rapids, MI

Tomato

Tuesday morning 9:00 am

Where: Grand Gallery (lower level) Room E-F
Recertification credits: 1 (1B, PRIV CORE)
CCA Credits: SW(0.5) PM(0.5) CM(1.0)
Moderator: Ron Goldy, District (Vegetables Educator, MSU Extension

9:00 a.m. Tomato Disease Update

- Mary Hausbeck, Plant Pathology Dept., MSU

9:30 a.m. Irrigation of Fresh Market Tomatoes

- Jeff Andresen, Geography Dept., MSU

10:00 a.m. High-Tunnel Tomato Production

- Ron Goldy, District (Vegetables Educator, MSU Extension

10:30 a.m. Growing and Marketing Heirloom Tomatoes

- Jeanine Davis, Horticultural Science Dept., North Carolina State Univ.

Tomato Disease Update

Dr. Mary K. Hausbeck (517-355-4534), and Chandra Howard
Michigan State University, Department of Plant Pathology

Bacterial Canker

Bacterial canker is diagnosed yearly in Michigan tomato fields. Bacterial canker is caused by the bacterium, *Clavibacter michiganensis* subsp. *michiganensis* (*Cmm*), and causes plant stunting, wilting and fruit spotting. Although yield losses vary among years, bacterial canker has the potential to be devastating. Young plants are more susceptible than older plants. Bacterial canker can be introduced into a clean field via transplants, machinery and wooden stakes or other equipment that has been previously used in an infested field.

Once a greenhouse or field is contaminated with bacterial canker, steps must be taken to assure that future crops remain disease free. If a greenhouse is contaminated, remove all plant material from the greenhouse (including weeds and dead plant tissue on the floor), wash and disinfect floor surfaces, hoses, equipment, etc. with a 10% solution of bleach or a commercial disinfestant (GreenShield is an example). Wooden structures such as benches or trays should be soaked in a disinfestant such as bleach (10%) or GreenShield for a minimum of an hour and preferably overnight. A simple washing of wooden surfaces is inadequate because of the cracks and crevices that may allow the bacteria to escape a surface wash. Bacteria that overwinter on a wooden surface may be carried to the plants in water droplets next season during the splashing of overhead irrigation.

A contaminated field should be rotated out of tomatoes for at least three years. At one time it was believed that a rotation of at least five years was necessary, however, it is now known that the level of bacteria in a contaminated field drops dramatically after the first year of rotation. Any equipment used in the problem field should be washed and disinfected prior to entering a clean field. Equipment and workers should begin work in the cleanest field and finish with the contaminated field.

Copper sprays every five to seven days may help reduce the spread of bacterial canker. However, if the environment is favorable for bacterial canker (75-90ºF with rain) coppers may be limited because the bacteria has a decided advantage in a wet environment.

Avoid working in a diseased field when it is wet to avoid spreading the disease. Bacteria may enter the plant through natural openings, or wounds created by wind, pesticide spraying or insects. A film of water on the leaf surface allows the bacteria to remain viable and move. If workers are moving within a wet field and creating new wounds on the plants, new infections are likely. If plants have been staked, all stakes should be treated as discussed previously for wooden trays and benches.

New Product Test for Bacterial Canker

Bacterial canker is a seedborne disease that has caused great economic losses for the Michigan tomato industry. On 30 May, tomato ‘Mountain Spring’ transplants were hand-transplanted 18-inches apart into raised beds covered with black plastic. The plot was located at the Michigan State University Muck Soils Research Farm in Laingsburg, MI. The plot followed a fresh market planting design and drip irrigation was provided. The beds were 2 ft wide, 6 in. high and 50 ft long with rows spaced at 5.5 ft apart. Each row comprised of two treatments, 22.5 ft long with a 5-ft section in the middle that was reserved for inoculated plants. Treatments were arranged in a complete randomized block design.

Treatments consisted of Kocide 2000 (copper hydroxide) at 2 lb/A alternated with Kocide 2000 at 1.5 lb/A; OxiDate (hydrogen dioxide) at 4 pt/A; Tanos (famoxadone and cymoxanil) at 0.5 lb/A alternated with Kocide 2000 at 1.5 lb/A; Actigard (acibenzolar-S-methyl) at rates of 0.02, 0.03, and 0.05 lb/A with remaining applications at 0.05 lb/A alternated with Kocide 2000 at 1.5 lb/A; untreated control. On 6 June, treatments were applied preventively and then reapplied every 5 days through 2 September. All treatments received alternating Bravo Weather Stik (chlorothalonil) at 1.5 pt/A and Manzate (mancozeb) at 2 lb/A applications to prevent fungal infections and were applied at the same time as the bactericidal treatments. All treatments were sprayed from the center of the row outward to encourage natural spread of *Cmm* from the inoculum source.

On 7 June, transplants were inoculated with *Cmm* and incubated in a greenhouse. On 9 June, three inoculated transplants were hand placed adjacent to the first plant in each treatment to serve as a source of inoculum. On 30 June, 21 July, 11 August, and 2 September, ten asymptomatic leaflets of approximately the same age and size were randomly selected from the tomato plant at each of the three sample sites that were located 0, 9 and 18 ft from the inoculum source.

In our study, *Cmm* spread 18 ft in 3 weeks (data not shown). *Cmm* populations for the Actigard-, Kocide 2000- and Tanos-treated plants were generally lower compared to plants treated with OxiDate or the untreated control, but numbers may not be statistically different. Foliar disease symptoms of OxiDate-treated plants were statistically similar to the untreated control. Actigard and Kocide 2000 offered statistically superior control of bacterial canker foliar symptoms compared with either OxiDate or the untreated control. Tanos alternated with Kocide 2000 effectively suppressed disease symptoms and was shown to be helpful in managing bacterial canker.

Table 1. Evaluation of bactericides for *Cmm* symptoms.

Treatments	**Leaf incidence**[z]	**Unilateral wilting**[y]	**Plant vigor**[x]
Untreated control	30.00 a[w]	69.75 a	5.00 a
OxiDate	40.00 a	72.75 a	4.00 a
Kocide 2000..................................	10.00 bc	40.25 b	7.25 bc
Tanos alternate Kocide 2000.......	21.25 b	18.25 ab	6.00 b
Actigard alternate Kocide 2000 ..	7.50 c	18.25 b	8.00 c

[z]Percent of leaf exhibiting marginal leaf necrosis.
[y]The number of strikes exhibiting unilateral wilting over a 22.5 ft treatment row.
[x]Overall plant vigor was rated on a 1 to 10 scale with 10 being a completely disease free plant, 8: showing <10% marginal necrosis and/or minor unilateral wilting; 6: increased marginal leaf necrosis but <30% and/ or moderate unilateral wilting; 4: increased marginal leaf necrosis but less than <50% and/or severe unilateral wilting; 2: increased marginal leaf necrosis but less than <70% and/or entire plant showing unilateral wilting symptoms; and 1: dead plant.
[w]Different lower case letters within the same column denote statistical difference ($p < 0.05$).

Late Blight

Late blight is a fungal disease that most commonly affects potatoes, but can affect tomatoes in some years. When the weather is favorable, late blight can be a very serious disease. Although this disease was not a reported problem in Michigan this year, it occurred in several eastern states. Late blight symptoms include blighting on all aboveground parts of the tomato plant. Lesions on leaves often appear dark and oily with production of spores occurring on the undersides of the leaves resulting in a purplish appearance

especially when conditions are wet and humid. Blackened lesions on the stems also occur and are unique to late blight disease. Late blight affects green and ripened tomato fruit. The blighting on fruit appears as dark, greasy areas that enlarge rapidly encompassing the entire fruit. During wet and humid conditions, white threads (mycelium) can be seen on the fruit.
Between cropping seasons, the fungus survives on volunteer and abandoned potato and tomato plants in fields, cull piles, and homeowner gardens. Cool nights and warm days are ideal for late blight development. The spores can be carried from diseased plants to nearby healthy plants via wind.

Control measures include eliminating all potato cull piles in the vicinity of tomato plantings and destroying volunteer potato plants that grow from overwintered tubers. All tomato varieties are susceptible to late blight. When late blight on potatoes has been reported in the state, fungicides that control late blight are recommended for tomatoes.

Fungal Leaf and Fruit Rots

Anthracnose is caused by the fungus *Colletotrichum coccodes* and causes a rotting of ripe fruit which reduces yield and fruit quality. Disease symptoms do not appear on the foliage. Early symptoms include slightly depressed, water-soaked circular spots that increase in size (up to 1/2"), become further sunken and may contain a pattern of concentric rings. As the fungus spreads within the fruit, a semi-soft decay occurs. Lesion development is most rapid at 80ºF and disease development is greatest during wet, rainy weather. To control the disease, a 2- or 3-year crop rotation is suggested. Also, avoidance of sandy soil sites to minimize injury from blowing sand particles will reduce anthracnose.

Early Blight is caused by the fungus *Alternaria solani* and infects foliage and ripening fruit. Infection can occur at the point of attachment to the stem and through growth cracks and wounds on the fruit. The early blight fungus causes dark brown, leathery sunken spots with concentric rings. When young fruits become infected, they may drop off prematurely. Infection is greatest in warm weather (75-85ºF). Heavy dews, extremely humid weather and abundant rainfall are essential for heavy disease pressure. To control the disease, a 3- or 4-year rotation will reduce the levels of the fungus in the soil.

Soil rot is caused by the fungus *Rhizoctonia solani* and causes slightly sunken brown spots about 1 inch in diameter on fruit that are in contact with the ground. Dark concentric markings are distinct within new spots and eventually the center of the spot may crack. Disease usually appears on ripe fruit in contact with soil. Disease is promoted by wet conditions. The pathogen is present in all field soil and affects tomato fruit whenever conditions are favorable.

Irrigation of Fresh Market Tomatoes

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To comply with the Michigan Right to Farm Act through the Generally-Accepted Agricultural and Management Practices (GAAMP) for Irrigation Water Use guide (MDA, 2003), agricultural irrigators in Michigan are required to incorporate sound, scientifically-based scheduling in their management strategies. Use of irrigation scheduling ultimately leads to more consistent crop yields and quality, and more efficient use of a valuable natural resource.

The most comprehensive and effective approach to managing water use and demand in a crop of interest is referred to as the mass balance approach, in which all the major sources and sinks of water in the system are monitored and operationally balanced. This is sometimes more commonly referred to as a 'checkbook' strategy following that system in which a user must balance all incoming funds with all outgoing checks or expenditures. In the irrigated crop system, there are two possible sources of water, precipitation and irrigation, while there are three major sinks or losses of water: evapotranspiration (the combined loss of water from crop transpiration and soil evaporation), runoff, and drainage of water out of the soil profile or at least out of the crop rooting zone. Mathematically, this results in the balance:

$$PPT + IRR = ET + RO + DR$$

Where PPT is precipitation, IRR is irrigation, ET is evapotranspiration, RO is runoff, and DR is drainage. ***Ideally, the objective of the grower is to monitor and balance all of these variables (i.e. adding water to meet crop needs if the precipitation is insufficient) while optimizing the growing conditions for the crop being managed***.

Of these variables, PPT and IRR are relatively easy to monitor with precipitation gages. The RO term varies with soil texture and slope. For most irrigated acreage in the state, soils are coarse-textured and relatively level, so the term can be assumed to be near zero or very small at best. The drainage term (DR) is more complicated. Here, one must take the plant available water holding capacity of the soil into account, typically described as the difference between the amount of water at field capacity and that at the soil's wilting point. Drainage is assumed to occur whenever the actual soil moisture value exceeds field capacity (e.g. such as when a heavy rainfall event occurs on a wet soil already near or exceeding field capacity). Much of this paper considers the last term, ET, which is a function of both atmospheric conditions and physical characteristics of the crop system itself. From the atmospheric side, there are four major factors involved in ET: 1) Solar radiation. There must be a source of energy to evaporate water and sunlight is the predominant source. There must be a source of energy to evaporate water and sunlight is the predominant source. The greater the rate of solar radiative flux, the greater the ET; 2) Air temperature. The warmer the air, the more water vapor it can hold and thus the greater the potential for ET; 3) Humidity. Air can hold a finite amount of water vapor at a given temperature. The drier the air (the less water vapor it is already holding), the greater the potential for ET; 4) Wind. In general, the greater the wind, the greater the ET. In a humid climate such as Michigan's, the solar radiation and air temperature terms dominate ET on a daily basis, although low humidity and strong winds can occasionally play a larger role (these terms are more important in arid and semi-arid climates).

In terms of the crop, the larger the plants and the more the leaf area, the greater the potential for ET. Similarly, the wetter the soil surface, the greater the potential addition of soil evaporation to ET. As antecedent soil and plant available water decrease, the ET rate decreases quickly. This is the rationale for the term ***Potential Evapotranspiration (PET)***, which describes the rate of ET when water is not limiting. To make things more complicated, the rate of PET also depends greatly on the phenological stage of development. For most annual crops including tomatoes it follows the physical development of leaf area, with relatively small PET early in the season growing to a maximum somewhere in mid-season as the crop reaches its maximum size, then a dropoff at the end of the season as the crop senesces. This seasonal PET cycle is different for almost every crop type, and even for the same crop type with differing production systems. To help simplify for operational irrigation management, it is advantageous to consider the PET for a specific type of 'crop' canopy, defined by international convention as a well-watered 4 inch grass-covered surface. This is the definition of ***Reference Potential Evapotranspiration (ET0)***. An estimate of daily ET for a given crop of interest can then be estimated by simply multiplying ET0 by a ***crop coefficient (Kc)***, which collectively describes that crop's size and leaf area (and thus PET) on a given day. Daily and seasonal Kc values for many crops have been derived from research studies and are commonly available (see the end of this paper for www-based reference). An excellent overall reference on determining ET0 and other aspects of irrigation management for a wide variety of crops and production systems is, 'FAO Irrigation and Drainage Paper No. 56' by Allen et al. (1998), which is also available on the www at: http://www.fao.org/docrep/x0490e/x0490e00.htm. Note that this technique for estimating ET works only when the crop is well-watered. Once plant available water drops below a certain level, the actual crop ET begins to decrease below its potential rate (i.e. PET) and is much more difficult to estimate. The threshold at when to begin irrigating a crop varies somewhat, but a general 'trigger' for the addition of irrigation water is when the plant available soil moisture levels in the rooting zone drop to 50% of the maximum value.

Crop coefficients (Kc) for a staked tomato production system representative of Michigan conditions as a function of the growing season are given in Table 1. The Kc values increase rapidly during the first couple of weeks following transplanting as the canopy develops (and leaf area increases). Peak Kc rates of 1.05 continue from late vegetative through reproductive crop stages. Finally, Kc drops off sharply to 0.60 in the week or so prior to harvest during the ripening stage. An estimate of daily ET for tomatoes would be obtained by multiplying the daily ET0 value by the respective crop coefficient. For example, with an ET0 value of 0.20" 50 days into a 100 day crop season, the Kc value would be 1.05 and the daily ET estimate would be (1.05)(0.20) = 0.21".

Given changing crop stages and atmospheric conditions, there are very pronounced seasonal patterns of ET in any given year. In an effort to illustrate and understand these seasonal patterns, hourly weather data (air temperature and relative humidity, solar radiation, and wind speed) were obtained from four sites across Lower Michigan and northern Indiana and Ohio: Muskegon, MI, Flint, MI, South Bend, IN, and Toledo, OH. Daily reference evapotranspiration (ET0) was estimated for each site with the modified Penman-Monteith methodology for the period 1971-2000.

Percent of Growing Season	Crop Coefficient
0	0.37
10	0.60
20	0.89
30	1.05
40	1.05
50	1.05
60	1.05
70	1.05
80	1.05
90	1.05
100	0.60

Table 1. Crop coefficients (Kc) for staked tomatoes as a function of growing season.

A representative mean annual pattern of reference evapotranspiration and rainfall frequency (from South Bend, IN) for the Great Lakes region is given in Figure 1. ET0 can be seen to increase from mid-winter values of less than 0.05" per day to a peak of around 0.20" per day near calendar day 180 (June 29th). As noted previously, this cycle is strongly correlated with incoming solar radiation values (annual maximum in late June, early July) and air temperatures (maximum in late July, early August). Given crop water needs, the daily frequency of precipitation was also considered (gray line on graph). The average fraction of wet days can be seen to seasonally vary out of phase with the ET0 values, with lowest annual values on the order of 0.3 (rain on 30% of the days) coinciding with relatively high ET0 values. Fortunately, daily rainfall totals must also be taken into account, and these happen to be greatest during summer and fall months when crop needs are greatest (data not shown).

Next, we consider the seasonal pattern of water by staked tomatoes with the crop coefficients listed in Table 1. Mean daily estimates of ET, the product of daily average ET0 and Kc, are given by calendar day in Figure 2 for Muskegon, MI. In all cases, the tomatoes are assumed to be transplanted on May 30th and harvested on September 15th for a 108 day growing season. Similar to the Kc seasonal curve in Figure 1, the ET values increase rapidly following transplanting during the month of June and reach a peak during the later half of July continuing through August. Due to the relatively late start during the growing season, it can be seen that the tomato crop just lags behind the period of greatest ET0 in late June and early July, which reduces the potential seasonal water needs slightly. Adding up all of the mean ET values for the entire season results in seasonal ET totals between 17.0 and 18.0 inches across the four sites considered. Normal precipitation for the same period in southern Lower Michigan varies from about 10.0-13.0 inches, which translates to an expected seasonal deficit on the order of 4.0-8.0 inches. This water must be supplied either by irrigation or from stored soil moisture (especially if the crop is rainfed). For reference, the amount of plant available soil moisture in the top 5 feet of the profile in Michigan at field capacity varies from less than 3.0 inches in coarse-textured, sand-based soils (some of the most commonly irrigated soils) to almost 8.0 inches on fine-textured, heavy clay soils.

A great deal of helpful irrigation management information can be found on the worldwide web. Some examples from MSU Extension include:

- http://www.ipm.msu.edu/cat07field/pdf/5-17IrrigationSchedulingTools.pdf.
- A www-based irrigation scheduling system that utilizes weather data from the Michigan Automated Weather Network can be found at: http://www.weather-icm.geo.msu.edu/is4/
- A more basic, excel spreadsheet-based version of the irrigation scheduler is available at: http://www.agweather.geo.msu.edu/mawn/irrigation/. At this site, the excel spreadsheet can be accessed by clicking on the link marked, 'Irrigation Checkbook (final rev)' while PET estimates can be obtained for the more than 50 MAWN sites around the state under the header marked, 'Irrigation Data - Individual Data Files'.

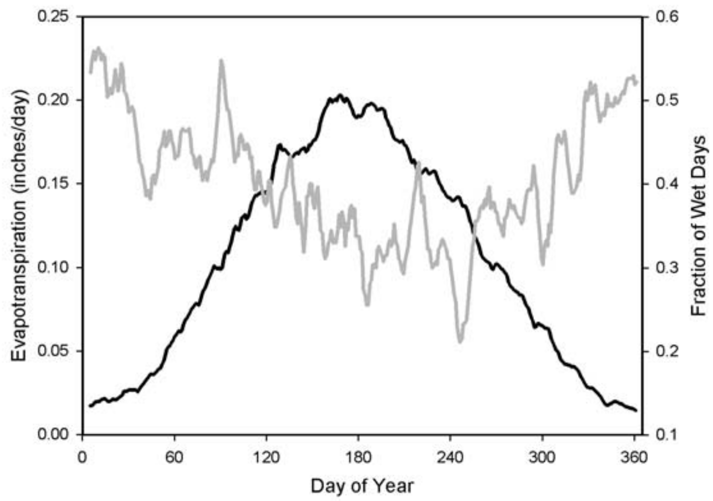

Figure 1. Average estimated daily reference evapotranspiration (black) and the fraction of wet days (0.01" or greater, in gray) by calendar day (1 = January 1st) at South Bend, IN 1971-2000. Data were smoothed with a 9-day moving average filter. A wet day fraction of value of 0.30 indicates that 30% of the total days on the date of interest were wet.

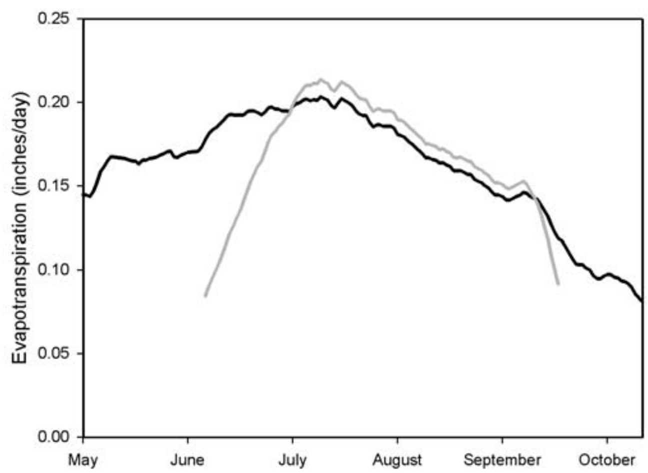

Figure 2. Average estimated daily evapotranspiration for tomatoes (gray) and reference evapotranspiration (black) by calendar day at Muskegon, MI 1971-2000. Data were smoothed with a 9-day moving average filter. Tick marks on the x-axis denote the beginning of months.

High Tunnel Tomato Production In Michigan

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Production of tomatoes under high tunnels has been investigated at SWMREC since 2005. The 2005 and 2006 trials evaluated nutrients (primarily nitrogen) needed for production and the 2007 trial was planted to 14 fresh market and six Roma-type tomatoes to evaluate potential genetic differences in fruit yield and quality in a high tunnel system. This presentation will report findings from all three years.

2005 and 2006 Trials: Early experience with tunnel tomato production found field nutrient rates too high for tunnel grown tomatoes. Vegetative growth was excessive making harvesting and other cultural practices difficult. A higher level of physiological gray wall was also experienced compared to tomatoes produced in the open. The 2005 and 2006 trials investigated three levels of nitrogen and several levels of potassium for their affect on yield. These two trials will be discussed together.

Nitrogen levels in 2005 were a preplant application of 40#/acre along with 250#/acre 0-0-60 and either 1# or 0.5#/acre/day nitrogen through the drip system as 4-0-8-2(Ca) plus 28-0-0. Potassium ratios in 2005 were 1:1 to 1:4 – N:K plus a calcium nitrate foliar application at the 1 : 3 level. Little differences in yield were found at these rates (data not shown) and growth seemed excessive even at the lower rate.

Nitrogen rates in 2006 were 0.5 and 0.25#/acre/day through the drip system supplied again as 4-0-8-2(Ca) and 28-0-0. Ratings on gray wall and green core were taken by randomly selecting 10 number one large fruit and counting the number of fruit exhibiting symptoms. To make green core evaluations fruit were sliced open horizontally slightly above midway to the stem. Few differences were noted at the 0.25# rate. However, differences were observed in total yield, yield of number one large and gray wall and green core at 0.5# (Table 1). The N : K ratio of 1 : 2 had the highest total yield but it did not differ from ratios of 1 : 1, 1 : 3 and 1 : 4. The 1 : 2 ratio also had the highest yield of number one large fruit, again 1 : 1, 1 : 3 and 1 : 4 were similar. Only 1 : 5 and no drip applied fertilizer had lower yields in both categories. However, the 1 : 2 ratio had elevated gray wall and green core (Table 1).

Table 1. Affect of five N : K ratios at **0.50# N/acre/day** on yield of 'Mt. Spring' tomato in 25 lb cartons/acre. Plants were set 5.5 feet between rows and 1.5 feet in the row (5280 plants per acre). 2006

N:K Drip applied	Total Yield	Yield No. 1 Large	Fruit Weight	Yield No. 2	Yield No. 1 Small	Yield Cull	Gray Wall	Green Core
1 : 2	2875	1771	316	330	427	347	6.17	6.69
1 : 3	2672	1684	309	248	381	359	5.42	4.62
1 : 1	2661	1619	311	298	460	284	6.62	5.87
1 : 4	2523	1422	310	325	372	404	6.50	5.87
1 : 5	2178	1268	291	212	416	283	5.20	5.62
none	2158	1154	289	255	417	333	6.12	5.75
Lsd .05	**677**	**477**	**21**	**ns**	**ns**	**ns**	**1.37**	**1.50**

Considering all factors the best overall treatment for ‘Mt Spring’ in 2006 was the 1 : 3 N : K ratio. This treatment was among the leaders in yield and lowest in green core and tended toward the bottom in gray wall.

Incidence of gray wall was greater in the 2006 trial then in the 2005 trial. Previous research has indicated gray wall (yellow areas along the sides of the fruit that never ripen) is a poorly understood problem. Factors contributing to expression include; genetics, light level, temperature, general nutrition and nutrient ratios. The growing conditions during the fruit ripening stage varied significantly between 2005 and 2006 (Table 2). Average daily maximum temperature was 4.3^{o}F higher in 2005 than in 2006 and average minimum was 1.2^{o}F higher. The biggest contributing factor, however, probably was light (radiation) level. Light levels in 2005 were significantly lower (125.7 units) than in 2006. The light filtering and reduction effect of the plastic may have contributed further to the light effect on gray wall.

Table 2. Daily temperature and solar radiation comparisons from 1 August to 16 September 2005, 2006 and 2007 at the Southwest Michigan Research and Extension Center.

	Year		
	2005	**2006**	**2007**
Avg. Maximum T	82.1	77.8	79.4
Avg. Minimum T	60.8	59.6	60.0
Mean T	71.4	68.7	69.7
Avg. Radiation/day	515.4	389.7	409.4

The 2007 trial was designed to determine possible genetic differences in fruit yield and quality in tunnel production, with particular emphasis on gray wall symptoms. The trial consisted of 14 fresh market and six Roma tomatoes. Results are presented in Tables 3 and 4.

Indy was the highest yielding fresh market tomato at 2629 cartons/acre (Table 3). Nine other fresh market tomatoes had similar yields, including Mt Spring, the industry standard for this area. Paragon had the highest yield of number one large fruit at 642 cartons/acre. Eight other entries had similar number one yield. Soraya had the highest yield of cull fruit at 1828 cartons/acre. Seven other varieties had similar cull yields.

Plum Crimson was the highest yielding Roma-type at 2782 cartons/acre only Plum Dandy at 2054 cartons/acre had a significantly lower yield then other entries. Plum Crimson and Mariana had similar number one fruit yield (2787 and 2388 cartons/acre, respectively). Mireina and Miroma had similar cull yields at 1333 and 1250 cartons/acre, respectively.

The high amount of culls in this trial was a result of the heavy emphasis placed on culling gray wall symptoms. There was little tolerance for any sign of the condition. A fair amount of blossom end rot was also present in early yields. Roma-type tomatoes did not seem to suffer as much from gray wall symptoms as the fresh market tomatoes. This is reflected in their higher number one yields.

Plant vigor of both types was not adequate. Few plants reached the top of the three-foot stakes. Tissue analysis at fruit harvest revealed less than ideal levels of nitrogen, phosphorous and potassium. The trial received no preplant nitrogen or phosphorous, 250#/acre potassium, 1 ton/acre lime and 100#/acre Cal Fortified. Nitrogen was applied through the drip at a rate of 1/3# nitrogen/acre/day as 4 – 0 – 8 – 2(Ca). Low tissue nutrient levels were most likely due to inadequate nitrogen combined with the warm, sunny conditions experienced during June and July. The plants needed more nitrogen for enough growth to occur to pick up nutrients. This probably also contributed to the high level of blossom end rot even though tissue analysis indicated adequate calcium levels.

During the ripening stage of the 2007 trial (1 August to 16 September) the growing conditions were more like 2006 than 2005, especially when considering light levels (Table 2). Also, as the plastic ages it becomes more opaque decreasing light levels further. It was the third season for the plastic on our tunnels in 2007 and the incidence of gray wall seemed to get worse with each year.

Table 3. Yield in 25#catons/acre of 14 fresh market tomato cultivars grown under tunnels at the Southwest Michigan Research and Extension Center in 2007. Selections were heavily graded on gray wall symptoms, with gray wall fruit being culled. Plant spacing provided 5280 plants/acre.

Variety	**Seed Source**	**Total Yield**	**Yield No. 1 Large**	**Avg. Fruit Weight**	**Yield No.1 Small**	**Yield No. 2**	**Yield Cull**
Indy	SY/RG	2629	600	262	277	218	1533
Paragon	JS	2602	642	250	251	128	1581
ACR 2012	AC	2478	583	246	444	75	1376
Mt. Spring	SY/RG	2473	611	277	222	234	1405
Mt. Crest	NU	2427	618	256	230	217	1362
Linda	SK	2417	616	280	93	110	1598
Soraya	SY/RG	2237	304	270	69	36	1828
Crista	RI	2168	613	278	104	99	1352
NRT 6785	NU	2144	357	279	115	86	1587
Red Delight	SK	2125	217	278	78	149	1682
Big Shot	RI	1997	328	255	102	93	1474
Sebring	SY/RG	1966	234	232	60	42	1630
Florida 47	RI	1857	304	247	137	82	1333
FL 7514	RU	1806	421	226	281	68	1037
	Lsd = .05	**569**	**256**	**26**	**83**	**93**	**404**

Table 4. Yield in 25#catons/acre of six Roma tomato cultivars grown under tunnels at the Southwest Michigan Research and Extension Center in 2007. Selections were heavily graded on gray wall symptoms, with gray wall fruit being culled. Plant spacing provided 5280 plants/acre.

Variety	**SS**	**Total Yield**	**Yield No. 1**	**No. 1 Fruit Wt.**	**Yield No. 2**	**Yield Cull**
Plum Crimson	RI	2787	2096	103	0	691
ACR 8625	AC	2388	1319	122	0	1069
Marianna	SK	2383	1751	125	0	632
Mireina	SY/RG	2325	986	142	6	1333
Miroma	SY/RG	2234	977	125	7	1250
Plum Dandy	HM	2054	1216	84	6	832
	Lsd=.05	**575**	**458**	**9**	**ns**	**229**

Sites at risk for gray wall can be identified using the Hartz Ratio calculator developed by Dr. Timothy Hartz, University of California at Davis. The calculator takes into account soil phosphorous, potassium, magnesium, calcium and cation exchange capacity (CEC). At risk sites are identified by putting soil test numbers into the calculator. The calculator can be found at Ohio State University's web site: http://oardc.osu.edu/tomato/HartzRatioCalculator.htm. Using 2007 soil test numbers the calculator indicated our tunnel site was at risk for gray wall from a potassium and calcium/magnesium ratio standpoint and was close to at risk from the Hartz Ratio (Figure 1).

At the third harvest, some fruit showing the worst gray wall symptoms were saved and placed in a 65 °F room for ripening. Surprisingly, fruit continued to ripen and color well. This was not expected since fruit with severe gray wall symptoms generally do not fully ripen. Why these continued to ripen is unclear.

It appears proper tomato fertilization may be dependant on growing conditions and a standard recipe approach may not be best; especially under tunnels. Fertilizing according to weather conditions adds another level of management to tomato production since fertilizer rates would change as conditions change. At this time it is not known how far ahead growers would have to predict conditions and adjust fertilizer rates based on those conditions.

		Units	
P	170		
K	130		
Mg	88	ppm ◉	Calculate
Ca	334	lb/acre ○	
CEC	3.5	Kg/ha ○	

The results are presented below. You can compare your results with the most desirable values

Your results			Soil at low risk of YSD in the Midwest & Mid Atlantic	Soil at low risk of YSD in California
Extractable K	0.332	cmol/kg	>0.4	>0.7
Hartz ratio	0.391		>0.35	>0.25
K	9.5	% of the CEC	> 4%	>2%
Ca/Mg Ratio	2.302		> 3.0	> 2.0
Available P	170	ppm	> 30	

Figure 1. Hartz Ratio calculations for the site of the tunnel trials. Calculations were made using numbers from the 2007 soil test

Growing and Marketing Heirloom Tomatoes

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Heirloom tomatoes are varieties that have been available for 50 years or more, are open pollinated, and grow "true to type" from seed saved from fruit each year. They usually have an indeterminate growth habit which means they require trellising and constant pruning. Most heirloom varieties have little disease resistance. The fruit are usually thin-skinned, soft, and tend to crack. But, consumers are attracted to heirloom tomatoes because the most popular ones are very flavorful, colorful, come in many unusual sizes and shapes, and have interesting names. For growers, however, heirloom tomatoes are challenging to produce and difficult to ship, but they can bring high prices on the local market.

Because most heirloom tomatoes are indeterminate, they must be grown on a tall, strong trellis; in a high-stake system; or in some other way that will provide strong support for very long vines. A trellis can be constructed of three inch or larger diameter posts set 10 to 15 feet apart within the row. We use 7 to 8 foot long posts, leaving 6 to 7 feet above ground. Run a stout wire (12 gauge) across the tops of the posts and secure it with staples. Pieces of twine, long enough to reach the ground, should be tied to the top wire above each plant. The twine can be anchored with a loop to each plant or to a bottom line of twine that is strung about six inches off the ground and secured to the posts. Some growers use the standard string and weave staked culture system for heirloom tomatoes, as described for the determinate tomatoes, but they use six foot long stakes instead of the normal four foot long stakes. Other growers establish the field with the standard four foot long stakes; then later in the season, they set a six foot long post right next to the four foot long post, at every other post.

In a trellis system, plants are usually spaced 8 to 10 inches apart within the row and pruned to a single stem system. A two stem system may also be used, in which the plants should be spaced 18 to 30 inches apart within the row. If using a standard staking system, plants should be spaced 18 to 24 inches apart. Once the plants are established, suckers must be removed several times a week. If the main growing point is broken off, a sucker can be trained to take its place.

Because most heirloom tomatoes have little disease resistance, it is important to plant them in an area where they will get good airflow and where tomatoes, peppers, or potatoes have not been grown for at least four years. If being produced in a conventional system, maintain a good fungicide spray schedule. For organic production, organic fungicides such as Serenade, copper, and/or Sporatec may be used. Many organic growers produce heirloom tomatoes under high tunnels to reduce disease incidence.

Dr. Randy Gardner, tomato breeder at N.C. State University, has been working to improve on heirloom tomatoes. His goal has been to produce an heirloom type hybrid with disease resistance, less cracking, and better shipping qualities than most heirlooms while retaining all the wonderful characteristics that consumers love. He has developed several promising lines that have performed well in our trials.

In our recent trials we compared production of several of Randy Gardner's new lines with heirloom varieties and grew them in two organic systems, a conventional system, and a non-treated control. Some of the results from those studies will be presented and also will be made available on http://ncspecialtycrops.org.

Most heirloom tomatoes are marketed locally at tailgate markets, farmers' markets, and roadside stands. Chefs in upscale restaurants often develop relationships with farmers to deliver these tomatoes directly to the restaurant. There are also a few heirloom tomatoes being sold on the wholesale market, but the selection is limited. Farmers selling direct to the consumer report that they receive very high prices (often over $3 per pound) from very loyal customers who return week after week throughout the season.

There are hundreds of varieties of heirloom tomatoes available. Some of the most popular ones that have performed well in our field trials and in consumer taste tests include:

- Amish Paste
- Arkansas Traveler
- Brandywine, Pink
- Brandywine, Red
- Cherokee Purple
- German Johnson
- German Red Strawberry
- Green Zebra
- Hugh's
- Jersey Devil
- Mortgage Lifter, Radiator Charlie's
- Mr. Stripey
- Noir de Crimee
- Persimmon
- Stupice

For general information on heirloom tomatoes:

- Vegetables and Fruits: A Guide to Heirloom Varieties and Community-Based Stewardship: http://www.nal.usda.gov/afsic/AFSIC_pubs/heirloom/heirloom.htm#heirbk2 –
- Definition of heirloom vegetables: http://attra.ncat.org/attra-pub/PDF/specialtyveg.pdf

For production information:

- Growing Heirloom Tomato Varieties in Southwest Florida: http://edis.ifas.ufl.edu/HS174
- Growing Heirloom Tomatoes: http://www.hort.cornell.edu/extension/commercial/vegetables/online/2002veg/PDFs/Growing%20Heirloom%20Tomatoes.pdf

For research results:

- 2002 NC Specialty Crops Program Heirloom Tomato and Vegetable Project http://www.cals.ncsu.edu/specialty_crops/publications/reports/DavisHeirloom.html
- 2003 NC Specialty Crops Program Heirloom Tomato Marketing Project http://www.cals.ncsu.edu/specialty_crops/publications/reports/heirloomtomato.html
- 2005 Heirloom Tomato Project at NC State http://www.cals.ncsu.edu/specialty_crops/projects.htm

- Ohio State University, "SPECIALTY AND HEIRLOOM TOMATO TRIAL - 1999 http://www.ag.ohio-state.edu/~vegnet/reports/res99/heirlm99.htm
- Marketable Yield Evaluation of Eleven Heirloom Tomato Varieties (research poster) http://www.uvm.edu/~pass/tignor/pdf/TomatoPosterASHS02.pdf-
- UC Master Gardeners, Heirloom Tomato Project (has yield info) http://www.mastergardeners.org/projects/tomato.html

For related articles and books:

- A pretty amazing website by a North Carolina home gardener with a passion for heirloom tomatoes: http://nctomatoman.topcities.com
- Weaver, W.W. 1999. Heirloom Vegetable Gardening: A Master Gardener's Guide to Planting, Seed Saving, and Cultural History. Owl Publishing. (available through Amazon.com)