ORGANIC PRODUCTION OF FRUIT CROPS UNDER HIGH TUNNELS

Final Report to The CERES Trust Organic Research Initiative

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BACKGROUND

This project was initiated in 2009 to develop organic production practices for raspberries and sweet cherries in the Midwest. These crops are seldom grown organically in the Midwest due to challenges associated with rainy humid summers and diverse complexes of insects and diseases. In fact, nearly all of the fresh raspberries and sweet cherries now sold in the region (organic and conventional) are produced in the Pacific coast states. These locations offer moderated temperatures in the summer and winter and relatively little rain during the summer when fruit are present. Many key diseases that are challenges to organic production in the Midwest (gray mold and cane diseases of raspberries, leaf spot and bacterial canker of cherry) are of little consequence in these regions.

A potential solution to the Midwest climate is the use of high tunnels to modify the environment around cherries and raspberries. High tunnels are un-heated, temporary greenhouse-like structures that are large enough for small trees and farm equipment. They vary from small stand-alone structures to larger, multi-bay systems. Stand-alone structures are usually designed to withstand snow and can be covered with plastic all year (4-season tunnels), whereas multi-bay tunnels are not as strong and need to be uncovered in the winter. Multi-bay tunnels are less expensive per area covered than stand-alone tunnels. For hardy perennial crops like sweet cherries and raspberries that can acclimate to winter temperatures (and require some exposure to cold temperatures to complete the dormancy phase of their life cycle), multi-bay systems are the least expensive way to obtain climatic protection during flowering and fruiting periods.

The purpose of this project was to develop organic raspberry and cherry production methods under high tunnels. Our specific objectives are to:

1. Develop soil management strategies for establishing and sustaining organic production of sweet cherries and red raspberries under 3-season high tunnels.

2. Develop plant and pest management systems suitable for organic high tunnel production of fresh market bramble and cherry crops in the North Central region.

FACILITY AND PLANTING DESIGN

The High Tunnel Facility is located at the Horticulture Teaching and Research Center (HTRC) on the MSU campus in East Lansing. It consists of a 1.1 acre range of nine 26 ft by 200 ft interconnected tunnels (Haygrove Tunnels Ltd.) constructed in 2009 on a Spinks sandy loam soil that had been fallow for many years. Organic certification was accomplished in collaboration with Jeremy Moghtader of the MSU Student Organic Farm (SOF) using the Ohio Ecological Food & Farm Association (OEFFA). Three contiguous bays were planted to raspberries in 2010. Each bay contains a row each of the varieties Himbo Top, Joan J, and Polka. Three contiguous bays were cover-cropped in 2010 and planted in 2011 to sweet cherries (varieties and experimental design described below). The two outside bays and the middle bay were planted in 2011 to mixed raspberry and cherry plantings in which the middle rows contain a range of replicated experimental cherry varieties for organic production evaluation and the two outside rows contain 'Polka' raspberries. Raspberry rows are irrigated with single trickle irrigation lines with 0.6 gallon per minute emitters at 24 inch spacing. Cherry rows are irrigated with two lines. Raspberry tunnels are covered each year with Luminence THB poly from May through October. Cherry and intercropped tunnels are covered from April through September.

The three intercropped tunnels and the three cherry tunnels were cultivated until June 2010 to reduce the native weed population and seed bank. The intercropped tunnels were then seeded to buckwheat in July. The buckwheat was tilled under in mid-August. A winter cover of cereal rye plus hairy vetch was seeded in late August. A portion of each cherry tunnel was divided into subplots for three cover crop seeding treatments, yielding six replications: 1) buckwheat seeded in July, tilled under in mid-August, and followed with a late August seeding of a winter cover of cereal rye plus hairy vetch; 2) crimson clover seeded in late July; 3) crimson clover plus oats seeded in late July.

After observing drainage patterns following rain in June and July, tile was installed in two leg rows of the raspberry tunnels to prevent water from flowing across the treatment plots. In late fall, drainage tiles were also installed in the cherry tunnels, to reduce the potential for excessive rainwater shed from the tunnel covers to collect in the root zone when cherries are susceptible to fruit cracking (which can occur from direct contact of fruit with rainwater or from internal uptake of water through the tree root system). Thermostatically controlled motorized roll up curtains were installed on the ends of all tunnels for the 2012 growing season.

RASPBERRIES

Fertility

Each 200 ft-long tunnel was partitioned into eight 25 ft-long plots and four treatments were applied to two plots in each tunnel. These include 1) Compost 10,000 lb per acre, 2) Compost 20,000 lb per acre, 3) Fertilizer 1,250 lb per acre, and 4) Fertilizer 2,500 lb per acre.

The compost was dairy based and supplied by Morgan's Compost, Evart, MI. The 2010 material was incorporated before planting and was amended with feather meal. The 2011 and 2012 composts were not amended and surface applied. The fertilizer was 8:1:1 organic from McGeary (Lancaster, PA) that was primarily based on soybean meal.

Table 1. Chemical characteristics, including pH, electrical conductivity, carbon to nitrogen ratio, and nutrient levels in compost applied to high tunnels in 2010, 2011, 2012 East Lansing, Michigan.

		EC	C:N	% of dry weight						
Year	pH	($dS \cdot m^{-1}$)	ratio	N	P	K	Ca	Mg	Na	S
2010	6.9	14.1	8:1	2.9	2.4	1.8	7.5	0.7	0.4	1.4
2011	8.2	2.7	13:1	1.3	1.1	1.0	6.5	0.7	0.1	0.3
2012	7.7	5.4	11:1	1.7	0.5	1.5	2.8	0.9	0.2	0.4

High tunnel soil conditions are unlike field soils because precipitation is excluded. Soil was sampled through each season for nitrate- and ammonium-N analyses to better understand N mineralization and retention. Total soil inorganic N (NH_4^+-N + NO_3^-- N) was extremely high early in the 2010 season soon after materials were incorporated into the soil (Fig. 1). This was due in part to the high N content of the compost used that season (Table 1) and the fact that materials were incorporated into the soil. Soil N levels declined substantially as the season progressed. The high fertilizer and compost treatments supplied more N early in the season, but late season levels were similar to those in the low N treatments. Materials were top dressed in April of 2011 and 2012. Soil N levels in these seasons were much lower than in 2010.

Soil N dynamics indicate that fertilizer and compost can supply adequate N through most of a growing season if materials are incorporated into the soil as in 2010, but perhaps are inadequate if top dressed. Incorporated materials are exposed to moisture and microbial activity so that N is released and available to plants. Surface applied materials were exposed to rain between application and tunnel covering. Rain amounts during this time totaled 3 inches in 2011 and 1 inch in 2012. Once tunnels were covered, irrigation supplied needed water, but only the soil surface immediately beneath emitters was wetted. Most of the surface residues remained dry during the season, and the N they contained likely was not available to the plants.

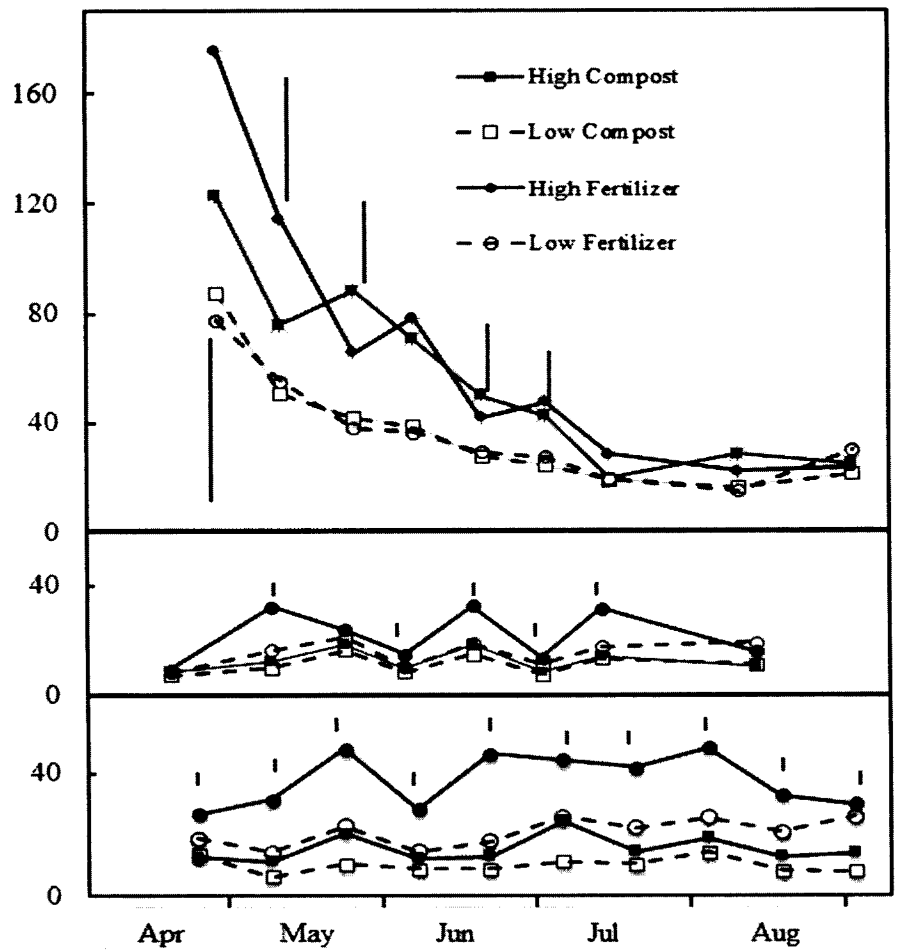


Figure 1. Total inorganic-N (NH_4^+-N + NO_3^- -N) in mg per kg dry soil in the top 20 cm of soil in high tunnels in 2010 (top), 2011 (middle) and 2012 (bottom) in East Lansing, Michigan. Bars indicate tukey-kramer's least significant difference (P≤.05).

Soil Salts. A concern in high tunnels is the buildup of soluble nutrient salts due to the lack of leaching from precipitation. The compost incorporated before planting in 2010 was high in salts and resulted in excessive soil salt levels at the end of the 2010 season (Fig. 2). However, leaching by rain and snow over the following winter when the tunnels were not covered reduced salts to acceptable levels by April 2011. Salts had again increased by the end of the 2011 season, but levels were still moderate. These observations illustrate first that the use of amendments that are high in total salts can be problematic under high tunnels that exclude precipitation and minimize leaching potential. However, precipitation during the off season, when multi-bay tunnels are not covered, appears to remove salts so that there is no long term accumulation. This might be considered an advantage of three-season tunnels over four-season tunnels that are covered continuously. However, leaching can be an advantage or disadvantage depending on the situation. With proper fertility management four season tunnels at the Student Organic Farm have been managed successfully for 10 years without leaching and are effectively providing a high level of fertility to vegetable crops.

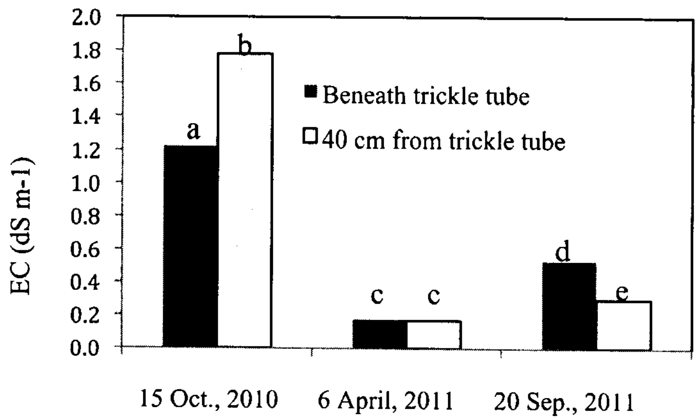


Figure 2. Change in soil salts measured as electrical conductivity (mmhos/cm) in high tunnels, East Lansing, Michigan. Tunnels were covered with plastic from May to October and uncovered during the winter. (Measured by saturated media extract or 1:2 soil water dilution??)

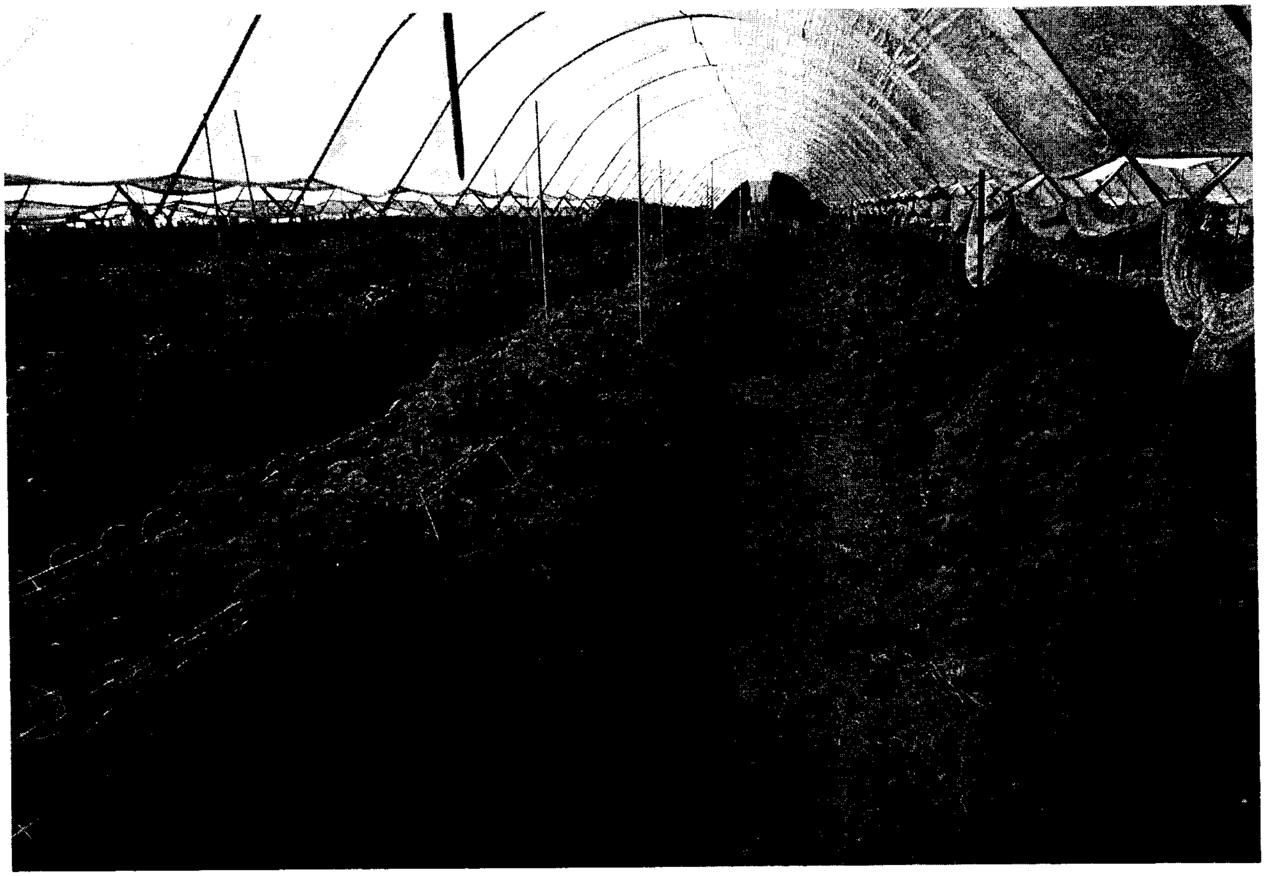
Leaf nutrient levels. Leaf nutrient levels are used in fruit culture as a measure of plant nutrient status. Treatments affected leaf phosphorus (P), potassium (K), and boron (B) in 2010, and N, sulfur (S), manganese (Mn) and B in 2012 (Table 2). All nutrient levels were sufficient in 2010, except S (deficient) and P (marginally deficient). High rates of compost resulted in slightly higher leaf P levels in 2010.

In 2012, treatments affected leaf N, S, Mn, K and B. The high fertilizer rate resulted in the highest leaf N levels, although N in all treatments was marginally deficient. Phosphorus concentrations were higher than in 2010 and nearly sufficient across treatments. Leaf K and S levels were deficient across all treatments. Boron concentrations were below the deficiency level of 25 mg kg^{-1} in the fertilizer plots, but were adequate in both compost treatments.

Table 2. Leaf nutrient element concentration in raspberry primocane leaves in 2010 and 2012 in multi-bay high tunnels.

	N	P	K	S	Mn	B
		%			mg kg^{-1}	
			2010			
High compost	2.98	0.22a	1.80a	0.17	307	63a
Low compost	2.97	0.20b	1.66ab	0.16	317	49b
High fertilizer	3.07	0.20ab	1.60b	0.16	651	29c
Low fertilizer	2.93	0.19b	1.54b	0.16	573	30c
			2012			
High Compost	2.13a	0.26	1.41	0.12a	157a	35a
Low compost	2.06a	0.24	1.37	0.11a	112ab	29b
High Fertilizer	2.41b	0.22	1.23	0.13b	114ab	23c
Low Fertilizer	2.27a	0.23	1.13	0.13b	87b	21c

Raspberry Growth and Fruiting



Berry yields in 2011 and 2012 were unaffected by fertilization treatments, but varieties differed each year (Fig. 3). 'Joan J' was the highest yielding in 2011, and 'Himbo Top' was the most productive in 2012. Expressed on a per acre basis, yields ranged from about 7,000 to 13,000 lb, with the highest levels observed in 2011. This is lower than conventional production trials in tunnels, which can exceed 20,000 lb per acre. Several factors likely limited yields. Nutrient deficiencies and insect pest pressures likely reduced yields to some degree. High temperatures may have been responsible for the lower yields in 2012. The daily high temperature met or exceeded 35°C on 42 dates in 2012, compared to just two dates in 2011. Optimum temperatures for raspberry photosynthesis are believed to be 20 to 25°C, and rates may be reduced by 50% at 35°C. Considering this, the plants may have been heat stressed often during the 2012 summer.

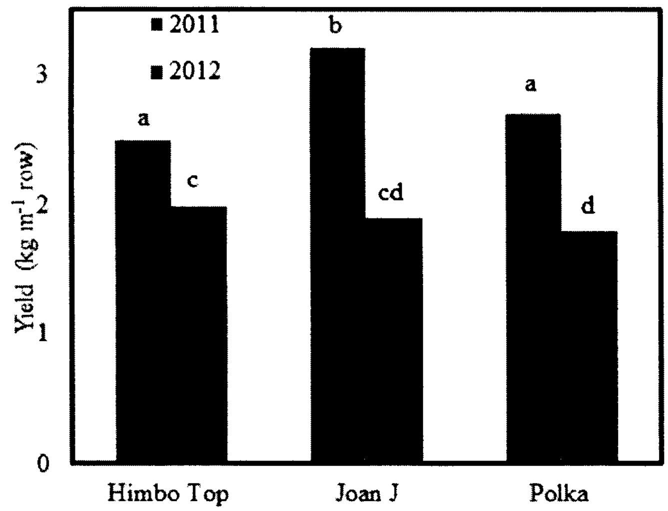


Figure 3. Yield of three primocane raspberry varieties grown in multi-bay high tunnels in 2011 and 2012 in East Lansing, Michigan. Means with a different letter are significantly different ($P \leq .05$)

The hot, dry conditions in 2012 also promoted spider mite populations to increase to epidemic levels. Mite levels were low to moderate during the cooler 2011 season, but there was a significant interaction between variety and year ($P \leq .0001$). The highest yields were obtained from 'Joan J' in 2011 with a mean of 3.2 kg m^{-1} row, which was significantly more than 'Himbo Top' and 'Polka', with respective yields of 2.5 and 2.7 kg m^{-1} row. In 2012, 'Himbo Top' yielded significantly more than 'Polka' but was not different from 'Joan J'.

Varieties differed in average berry weight and visual appearance after a short storage period, but fertility treatments had no effect. 'Himbo Top' berries were the heaviest (3.0 g), followed by 'Polka' (2.8) and 'Joan J' (2.7). Visual appearance after storage, on a scale of 1 = non-salable to 5 = perfect, was lower for 'Joan J' (3.6) than 'Himbo Top' (4.0) and 'Polka' (4.1).

We encountered severe infestation problems from spotted winged drosophila (SWD) in 2011 and 2012. This fruit fly was recently introduced to North America from Asia and first appeared in Michigan after the initiation of this project. The adults lay eggs in ripening fruit. The resulting maggots infest the berries, causing fruit flesh breakdown. Rufus Isaacs (MSU Entomology Department) installed vinegar baited traps in the tunnels in 2011. Flies were caught on 9 Sep., infested fruit were present 3-5 days later, and we ceased fruit sales for about 10 days. We were eventually able to manage the pest by alternating sprays of Entrust and Pyganic at 3-7 day intervals when fruit were present. This suppressed infestation levels, but timely harvest was also critical. All fruit need to be harvested as they ripen. Overripe or dropped fruit serve as breeding sites for the flies. This fly is expected to be a regular pest in this planting and many areas of the Midwest for years to come. The most pressing challenge is that only two effective organic pesticides are available. Repeated use of these products can exceed the maximum seasonal tolerances and potentially result in insect resistance.

Spider mites were a severe problem in 2012, due in part to our SWD spray program. We introduced predatory mites in 2011, which appeared to control spider mites populations that year. The severity in 2012 resulted from a perfect storm of events, including an unusually warm summer which promoted spider mites, and the frequent spraying for SWD, which may have reduced predatory mite populations. One future approach might be the use of insect- netting to exclude SWD and reduce pesticide use. Netting, however, will obstruct air flow and may promote spider mites by elevating tunnel temperatures. We also would like to investigate Pyganic resistant predator mites that might perform better when spraying is necessary.

Raspberry Trellis Systems

One row in each tunnel was trellised with one of three systems. Trellis consisted of 1) pairs of conduit 1.5 ft apart spaced every 20 ft down the row, 2) pairs of conduit 2.0 ft apart every 20 ft down the row with cut flower netting suspended 2-3 ft above the ground, and 3) a V-trellis composed of 1 x 2 inch wood boards tied to a 7 foot metal fence post (Fig. 4). Monofilament plastic wire was strung down each side of the rows at several heights and secured to the conduit to contain the canes. Wire for the V-trellis ran through holes in the boards. We saw no difference in yields between the three trellis types. However, the V-trellis was more expensive to install and required some additional labor since the boards needed to be adjusted and removed in the winter. This system makes sense where raspberries are double cropped (retaining 2-year-old canes for summer berries). Here, floricanes can be tied to the outside wires to separate them from the first year primocanes. The flower netting trellis worked well to position canes, but pruned canes were difficult to remove from the netting. Overall, the pairs of conduit worked best for fall production.

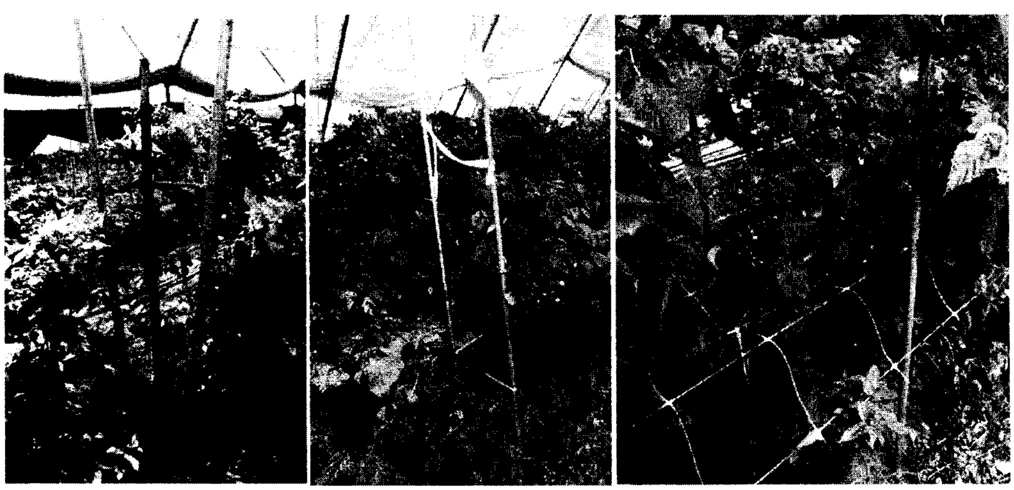


Figure 4. Raspberry trellis system components in the organic high tunnels at East Lansing, Michigan, from L to R: wooden V, steel conduit, and nylon netting.

SWEET CHERRIES

Cherry Experiments

The focus in 2011 was planting, establishment, and training of the various sweet cherry experiments in the three sweet cherry tunnels. Baseline soil samples were taken from the 2010 cover crop treatments prior to planting of the nursery trees in spring 2011. Initially, four separate experiments (cover crops, compost, fertilizer, and training systems) were planned for the cherry tunnels, but these were consolidated to create larger plots of fewer experiments for better treatment imposition and statistical sampling. The cherry variety/rootstock combinations planted in each experiment are described below.

Orchard Floor Management/Cover Cropping Treatments

The east row in each tunnel is planted to 'BurgundyPearl'/Gisela5 (Gi5) as the data trees, with plot guard trees of two experimental mildew-resistant genotypes (WG7 and WL12, both on dwarfing Gi5 rootstock) plus a breeding selection from Cornell, NY9116 on very dwarfing Gi3 rootstock. To study potential orchard floor management and cover cropping strategies during the seasonal cherry cropping cycle to continue to build soil and manage rootzone competition (weeds and cover crops) following establishment of these perennial plantings in 2011, six experimental treatments were imposed in

2012. These included: 1) mowing of natural weed vegetation, 2) year-long application of a woven polypropylene weed barrier fabric, 3) annual seeding of a cover crop mix (sorghum sudangrass+crotolaria+clover), 4) seasonal application of weed barrier fabric plus annual seeding of a winter cover crop (rye+hairy vetch), annual seeding of a winter cover crop (rye+hairy vetch), and seeding of a perennial cover crop (orchard mix). Several seasons will be needed for complete results and subsequent soil quality analyses, but initial impacts on tree growth revealed tunnel-to- tunnel variability (Fig. 5). Overall, the mowed weedy plot (Tunnel 6 and 7) tended to negatively

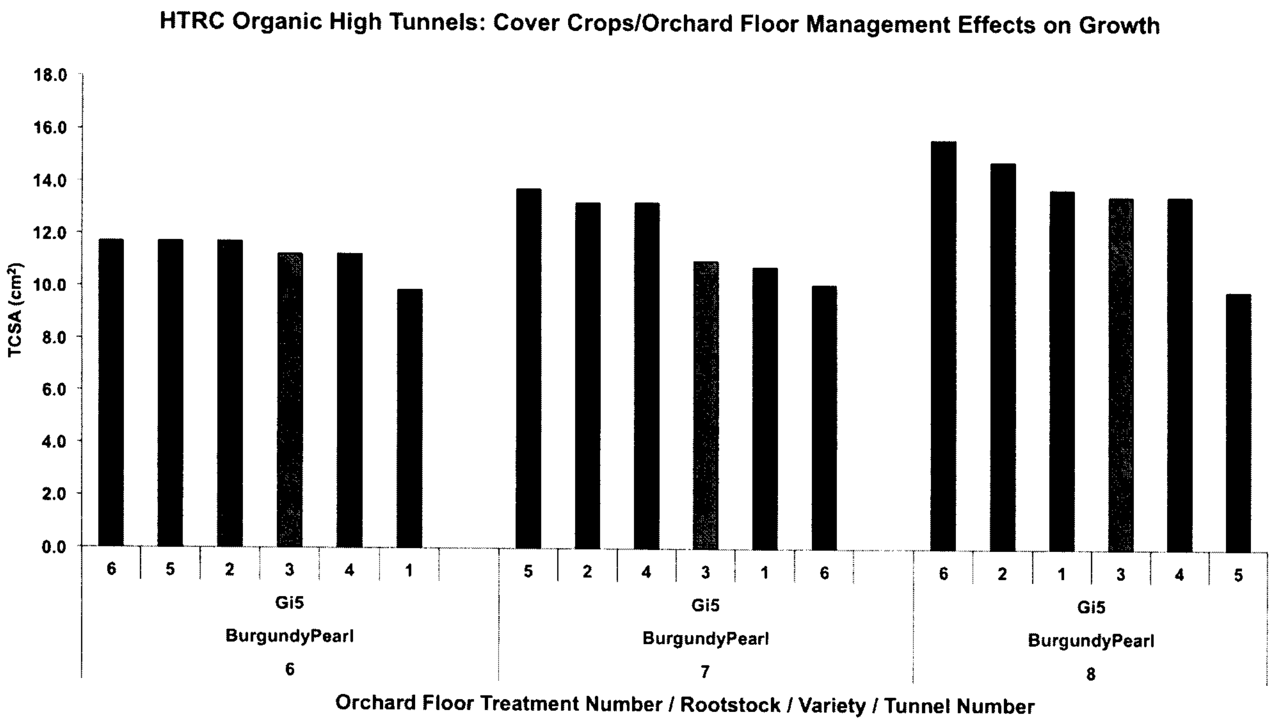


Figure 5. 'BurgundyPearl/Gisela 5 tree growth, as determined by trunk cross-sectional area (TCSA), at the end of the establishment year (2012) for six annual orchard floor management/cover cropping treatments in the organic high tunnels at East Lansing, Michigan.

impact tree growth, presumably due to strong root competition, but this impact was not apparent in Tunnel 8. The weed barrier fabric tended to promote good growth, presumably due to elimination of root competition as well as moisture retention, though eventual impacts on soil organic matter are expected to be negative.

With respect to cover crop establishment results, the mixture of sorghum-sudangrass, Crotolaria (sunhemp) and red clover was sown in mid-July. The Crotolaria germinated well, but suffered severe rodent damage shortly after emergence. Sorghum sudangrass grew vigorously until the onset of cool temperatures in September, reaching a mean height of 71" and accumulating over 5 T/a of biomass. *Portulaca oleracea* (Purslane) was the dominant weed species in the summer cover crop treatment, and produced substantial quantities of seeds prior to winter-kill. Rye-vetch (treatments 4 and 5) and the perennial mixture (treatment 6) were sown following weed barrier removal in mid-September and hence are likely to compete only minimally with the tree root systems until spring 2013. Cherries in the weedy (mowed) treatment (treatment 1) appeared notably stunted and chlorotic relative to all other treatments. The long-term impacts on organic soil health may require several growing seasons to be manifested, so that hybrid strategies such as the seasonal application of weed barrier fabric during tree growth, while alternating with winter cover-cropping to add organic matter, can be best compared to either individual strategy applied continuously.

Space-efficient Canopy Training System Experiments

Since high tunnel plastic covers reduce the quantity of light available to plants, and since fruit tree canopies are 6-10 ft tall and therefore have the potential for significant shading of lower wood, fruit tree production under high tunnels is likely to be improved by training trees to narrow, space-efficient canopy architectures. Narrow canopies may also assist in pest management strategies due to greater penetration of light, air movement, and organic spray materials for control of problematic diseases and insects. 'RadiancePearl'/Gi5 and 'EbonyPearl'/Gi5, with plot guard trees of experimental genotypes WH8 and WJ10, both on Gi3, were planted in 2011. The 'EbonyPearl' trees had apparently been damaged in the commercial nursery during fall 2010 before shipment to MSU, as a majority of these collapsed and died in June during establishment in the tunnels. Therefore, all 'EbonyPearl' trees in Tunnels 6 and 7 were replaced in spring 2012 with 'RadiancePearl/Gi6 trees, which will allow a comparison of the interaction between the three training systems and the same variety on a dwarfing (Gi5) and vigorous (Gi6) rootstock, albeit with trees planted one year apart. The three canopy architectural systems are 1) the Tall Spindle Axe (TSA), a central leader tree developed with temporary fruiting lateral branches that are renewed at about 20% per year and are maintained in a overall conical canopy shape; 2) the Super Slender Axe (SSA), a central leader tree developed with permanent fruiting lateral branches that are renewed at nearly 100% per year through a specialized short-pruning technique to create a very narrow canopy; and 3) the Upright Fruiting Offshoots (UFO), a grape-like cordon-based tree with multiple upright temporary fruiting shoots that are renewed at about 20% per year, which also creates a very narrow canopy. Again, there is significant tunnel-to-tunnel variability with respect to the apparent influence of training system on tree growth (TCSA, Fig. 6) thus far, with the UFO 'RadiancePearl'/Gi5 trees exhibiting the most growth in Tunnels 7 and 8, followed by the SSA, and least vigorous, the TSA. Differences should become more apparent as the trees begin fruiting in 2013 and finish filling their space.

Sweet Cherry Trellis Systems

The middle row in each sweet cherry tunnel was used to demonstrate different components of tree trellising systems. Trellising of sweet cherry trees can be problematic in regions like the Midwest due to the potential for bacterial canker infections from tree rubbing against steel trellis wires. The fivewire trellis was constructed in 2011 with three post types (steel fence posts, carbon-fiber I-beams, or untreated wood posts) and three wire types (plastic-coated steel, high tensile polypropylene, or high tensile extruded carbon fiber). The most expensive components were the carbon fiber, but thus far no significant differences have been seen for incidence of bacterial canker infection due to trellis rubbing. Canker infection incidence tends to be cumulative, so this trial merits continued observation for several more years before clear conclusions can be drawn.

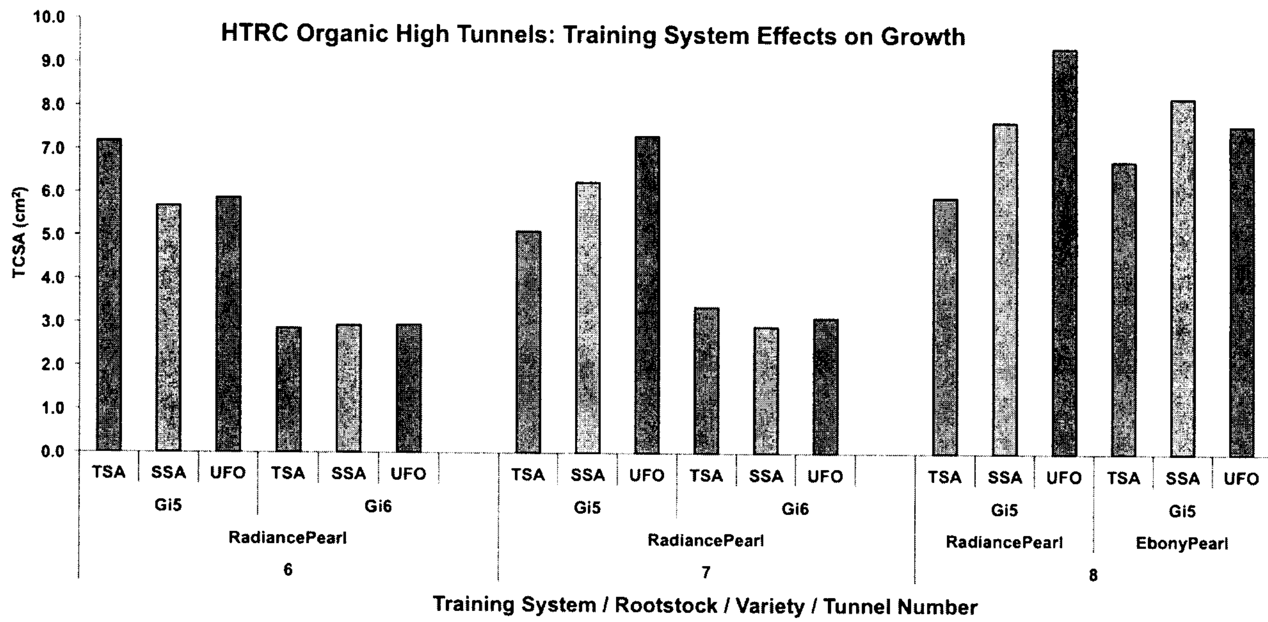


Figure 6. 'RadiancePearl/Gisela 5 (two-years-old), 'RadiancePearl'/Gi6 (one-year-old), and 'EbonyPearl'/Gi5 (two-years-old) tree growth, as determined by trunk cross-sectional area (TCSA), at the end of the establishment year (2012) for six annual orchard floor management/cover cropping treatments in the organic high tunnels at East Lansing, Michigan.

Cherry Pest Incidence and Management

Insect pests observed in the cherries after planting included tent caterpillars and Japanese beetles, which began skeletonizing new leaves in June-July and July-August 2011, respectively. Trees were scouted for caterpillars and beetles two to three times a week for manual removal when found. The caterpillars were found sporadically throughout the tunnels, but the beetles were found primarily in the two outside guard tunnels (nos. 1 and 9) or at the ends of each tunnel bay with cherries. Beetle incidence and damage were rare on the interior trees or the interior tunnel bays (nos. 5-8). In 2012, black cherry aphid populations increased quickly during new shoot elongation in the spring. Beneficial predators, primarily lady beetle adults and larvae, quickly followed, bringing infestations under control (Fig. 7). No caterpillars were observed in 2012. Late season insect pests were primarily leafhoppers from mid-June to Mid-August and Japanese beetles from early July to late August.

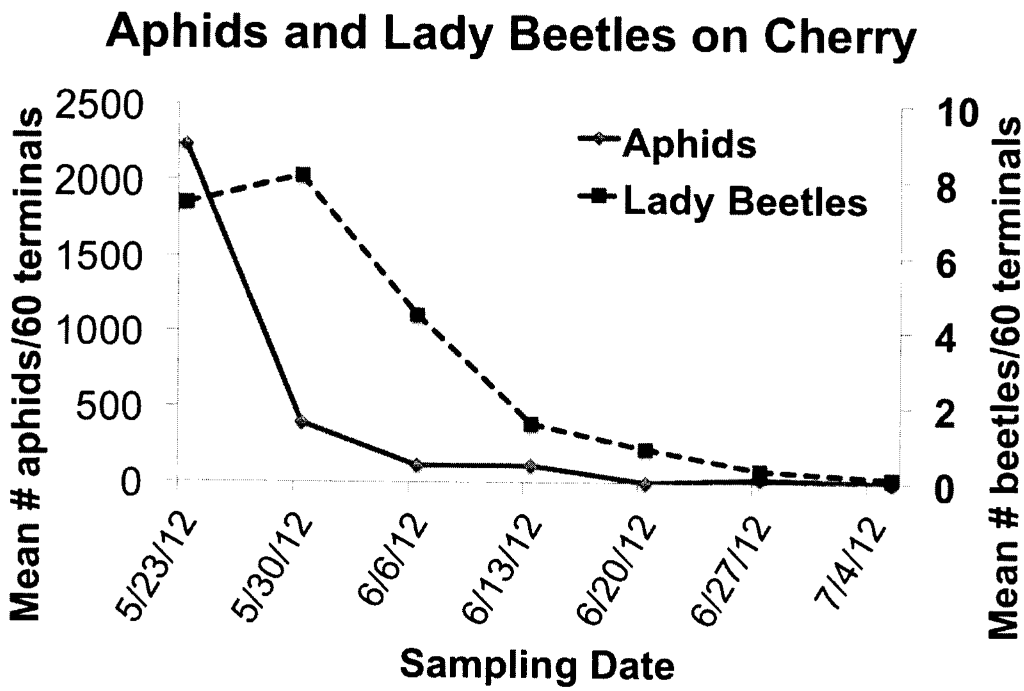


Figure 7. Black cherry aphid and lady beetle populations from mid-May to mid-July in the organic sweet cherry high tunnels at East Lansing, Michigan, 2012.

Disease incidences observed by MSU plant pathologist Annemiek Schilder in the high tunnel cherries has included powdery mildew on most of the varieties that are not genetically resistant to mildew, and some trunk gummosis, which may be an indication of bacterial canker infection; most of the gummosis appeared to be present on the nursery trees at planting, and did not spread during the period in which the tunnels were covered to exclude rain. While three-season high tunnel cherry trees are susceptible to infection by bacterial canker (*Pseudomonas syringae*) during the uncovered periods in late fall and winter, it appears that the incidence of canker may be reduced by covers in the spring (compared to uncovered trees in the spring) due to reduced exposure to frosts and/or rain-dissemination of bacteria. Incidence of cherry leaf spot was negligible in the tunnels, eliminating one of the major diseases that requires multiple fungicide applications in conventional cherry production. The testing of organic pest management materials, such as Oxidate and Zerotol for brown rot and powdery mildew, will commence with the first fruiting season in 2013.

INTERPLANTINGS IN BORDER TUNNELS

Three tunnels (no. 1, 5, and 9) were interplanted with cherries and raspberries in May 2011. Each tunnel contains a middle row of cherries and two outer rows of raspberries. These tunnels are being used to study pest and disease incidence and control measures, including control of weeds with weed barrier fabrics and other strategies. The outer mixed tunnels (nos. 1 and 9) were planted to 4 sweet cherry varieties (BigStar, GraceStar, LalaStar), each of which are grafted onto either dwarfing Gi5 or vigorous Gi6 rootstocks, to determine what level of rootstock vigor will be most successful under organic management; also included are 'BlackStar'/Gi6, 'BlazeStar'/Gi6, and 'EarlyStar'/Gi5. The middle mixed tunnel (no. 5) was planted to 12 additional cultivar/rootstock combinations ('Attika'/Gi3, 'Benton'/Krymsk6, 'BlackPearl'/Gi3, 'EbonyPearl'/Gi3, 'Glory'/Gi6, 'Kiona'/Gi5, 'Kootenay'/Gi5, 'Santina'/Krymsk6, 'Sonnet'/Gi3, 'Summit'/Gi3, 'Symphony'/Gi5, and WK11/Gi3) to evaluate organic tunnel production potential of cultivars that ripen over an extended marketing window. The first crop from these trees is expected in 2013.

OUTREACH AND INSTRUCTION ACTIVITIES

We hosted organized tours of the project and facility in July 2011 (in conjunction with MSU Ag Expo) and in August 2012 (Fig. 8). These tours were each attended by about 60 individuals. Numerous other individuals and small groups have visited the facility over the last three seasons. The facility and projects have been incorporated into the MSU Organic Farming instruction programs, and several SOF students each year have been directly involved in the work. Undergraduate students have visited and discussed the project as part of HRT 335 Berry Crop Production and HRT 332 Tree Fruit Production. A 90 minute workshop on Organic High Tunnel Fruit Production, based on this project, was developed and presented by Co-PIs Eric Hanson and Greg Lang, and project graduate student Ben Gluck, at the Midwest Organic and Sustainable Education Service (MOSES) Conference in LaCrosse, Wisconsin, in February 2012. The audience was comprised of between 150 and 200 organic fruit growers, primarily from around the Midwest.

Figure 8. The twilight tour in August 2012 at the organic fruit high tunnel research project, East Lansing, Michigan.

YouTube videos were developed to describe:

Overall project and tunnel construction: (http://www.youtube.com/watch?v=xWnI6iIZeVQ)
General raspberry culture (http://www.youtube.com/watch?v=4O90sGj8ky8)
Tunnel pest management (http://www.youtube.com/watch?v=Ex2dTcn_Ehc)

Other presentations on this project have been made at numerous regional, national and international conferences. Some of these include:

Gluck, Ben and Eric Hanson. 2011. Effect of drip irrigation and winter precipitation on distribution of soil salts in three season high tunnels. International Society for Horticultural Science (ISHS) Symposium on High Tunnel Production of Horticultural Crops. State College, PA. Oct 16-19.

Gluck, Ben. 2011. Raspberry and cherry high tunnel production research at MSU. Great Lakes Fruit, Vegetable and Farm Market Expo. Grand Rapids MI. Dec 6-8. https://glexpo.com/summaries/2011summaries/webHoopHouseTunnel.pdf

Gluck, Ben and Eric Hanson. 2011. Year two of the MSU organic high tunnel raspberry project. Great Lakes Fruit, Vegetable and Farm Market Expo. Grand Rapids MI. Dec 6-8. https://glexpo.com/summaries/2011summaries/webOrganicFruit.pdf

Hanson, Eric and Ben Gluck. 2011. Organic production of raspberries in high tunnels. Great Lakes Fruit Workers Meeting. Grand Rapids MI. Oct 30-Nov 1. http://www.hrt.msu.edu/glfw/index.htm

Lang, Gregory. 2011. Tree fruit production in high tunnels. International Society for Horticultural Science (ISHS) Symposium on High Tunnel Production of Horticultural Crops. State College, PA. Oct 16-19.

Lang, G.A. 2011. Holistic integration of organic strategies and high tunnels for Midwest/Great Lakes fruit production. USDA Organic arming Systems Research Conference, Washington D.C., Mar 16-18. (poster)

Lang, Greg. 2011. Update on MSU high tunnel sweet cherry production systems research. Great Lakes Fruit Workers Meeting. Grand Rapids MI. Oct 30-Nov 1. http://www.hrt.msu.edu/glfw/index.htm

Lang, Gregory A. 2011. High tunnel sweet cherries: optimizing production and quality for niche markets. Great Lakes Fruit, Vegetable and Farm Market Expo. Grand Rapids MI. Dec 6-8. (poster)

Lang, Greg. 2012. Research update on the MSU high tunnel organic fruit production research. Great Lakes Fruit Workers Meeting. Niagara Falls Ontario. Nov 4-7. http://www.greatlakesfruitworkers.weebly.com/2012-glfw-meeting-archive.html

Lang, Gregory A., Husnu Demirsoy, and Leyla Demirsoy. 2011. High tunnel management for early ripening of sweet cherries: bringing Hawaii to Michigan? American Society for Horticultural Science annual conference, Waikoloa HI. Sept 26-28.

PUBLICATIONS AND FUTURE EFFORTS

This project has generated seven publications to date (listed below). CERES Trust support has led to additional funding through the U.S.D.A Organic Research and Extension Initiative program. Since raspberries and cherries are long-lived perennial plants, demonstrating the efficacy and sustainability of production systems requires many years. Future efforts will likely emphasize management of spotted wing drosophila and spider mites in both crops, management of fruit brown rot in cherries, and double cropping (summer plus fall) of raspberries.

Gluck, B, and E. Hanson. 2013. Effect of drip irrigation and winter precipitation on distribution of soil salts in three season high tunnels. Acta Hort. (in press).

Demchak, K. and E. Hanson. 2012. Small fruit production in high tunnels in the U.S. Acta Hort. (in press).

Gluck, B., E. Hanson and A. Schilder. 2013. High tunnels for organic raspberry production in midwestern U.S. states. Acta Hort. (in press).

Lang, G.A. 2013. Tree fruit production in high tunnels: current status and case study of sweet cherries. Acta Hort. (in press).

Lang, G., E. Hanson, J. Biernbaum, D. Brainard, M. Grieshop, R. Isaacs, A. Schilder, D. Conner, and J. Koan. 2013. Holistic integration of organic strategies and high tunnels for Midwest/Great Lakes fruit production. Acta Hort. (in press).

Lang, G., E. Hanson, and B. Gluck. 2012. Organic production of cherries and raspberries in high tunnels. Organic Broadcaster 20(5):7, 14.

Lang, G., T. Valentino, H. Demirsoy, and L. Demirsoy. 2011. High tunnel sweet cherry studies: innovative integration of precision canopies, precocious rootstocks, and environmental physiology. Acta Hort. 903:717-723.